ENHANCING YIELD AND NITROGEN USE EFFICIENCY IN MAIZE-WHEAT SYSTEM UNDER CONSERVATION AGRICULTURE

Dissertation

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
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DOCTOR OF PHILOSOPHY
in
SOIL SCIENCE
(Minor Subject: Chemistry)

By

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(L-2012-A-39-D)

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LUDHIANA-141 004

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CERTIFICATE-I

This is to certify that the thesis entitled, **"Enhancing yield and nitrogen use efficiency in maize-wheat system under conservation agriculture"** submitted for the degree of **Ph.D** in the subject of **Soil Science** (Minor Subject: **Chemistry**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Opinder Singh (L-2012-A-39-D)** under the supervision of **Dr. H S Thind** upto 31^{st} January, 2016 and under my supervision thereafter for the completion of Ph.D degree and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigations have been fully acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled, **“Enhancing yield and nitrogen use efficiency in maize-wheat system under conservation agriculture''** submitted by **Opinder Singh (L-2012-A-39-D)** to the Punjab Agricultural University, Ludhiana, in partial fulfilment of the requirements for the degree of **Ph.D** in the subject of **Soil Science** (Minor Subject: **Chemistry**) has been approved by the Student’s Advisory Committee along with the Head of Department after an oral examination of the same.

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ABSTRACT

The present study "Enhancing yield and nitrogen use efficiency in maize-wheat system under conservation agriculture" was carried out at research farm of Borlaug Institute for South Asia (BISA), Ladowal (Ludhiana), during *Rabi* and *Kharif* seasons of 2013-14 and 2014-15 on sandy loam soil. In experiment-I, grain yield of wheat and maize was significantly higher under $DIPB_{MB}$+R as compared to DIPB-R which in turn was significantly better than FIPB-R during both the years. In maize the per cent increase in grain yield was 27.05 and 23.40 under $DIPB_{MB}$+R, and 22.13 and 19.80 per cent under DIPB+R over that of FIPB-R during the year 2014 and 2015, respectively. However in wheat there was approximately 16.09 and 15.22 per cent increase in yield with drip irrigation along with residue retention as compared to furrow irrigation without residue retention in both the years, respectively. The yield and yield attributes of wheat and maize under NE was on par with $RN_{100\%}$, but was significantly higher from $RN_{75\%}$. However, the yield and yield attributes of wheat and maize of $RN_{100\%}$ and $RN_{75\%}$ were on par with each other, thereby saving 25% of fertilizer in both the crops. In experiment-II significantly higher grain and straw yield of maize and wheat was recorded in the residue retained plots i.e. FIRB+R as compared to the residue removed plots i.e. FIRB-R during both years, respectively. Maize yield under residue retained treatments showed significant increases of 7.10 and 8.41 per cent in yield compared to residue removed treatments in 2014 and 2015, respectively. Wheat yield obtained from residue retained treatments showed significant increase of 4.41 and 4.06 per cent compared to residue removed treatments in 2014 and 2015, respectively. The top placement of fertilizer was significantly better than furrow application and broadcasting in terms of grain and straw yield, nitrogen uptake at different growth stages and nitrogen use efficiency. In experiment-III, throughout the decomposition cycle, the per cent decrease in weight was significantly higher from the subsurface placed residue as compared to surface placed residue. Type of residue and method of placement had a strong influence on releasing behavior of N, P and K. In sub-surface placed residue total N, P and K released at the end of decomposition period was more in $ML_{50\%}$ (31.66 kg N ha^{-1}, 2.91 kg P ha^{-1} and 56.12 kg K ha^{-1}) as compare to $MT_{50\%}$ (21.6 kg N ha^{-1}, 1.62 kg P $ha^{-1}$and 46.22 kg K ha^{-1}), respectively. Similarly in wheat and moongbean residues N, P and K release was higher in sub-surface placed residue as compared to surface placed residue throughout the decomposition period irrespective of type of residue.

Keywords: Maize-Wheat system, conservation agriculture, nitrogen, residue management, drip irrigation

Signature of Major Advisor **Signature of the Student**

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ਸਾਰ-ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ "ਮੱਕੀ-ਕਣਕ ਫ਼ਸਲੀ ਪ੍ਰਣਾਲੀ ਵਿੱਚ ਝਾੜ ਅਤੇ ਨਾਈਟ੍ਰੋਜਨ ਦੀ ਸੁਚੱਜੀ ਵਰਤੋਂ ਨੂੰ ਵਧਾਉਣਾ" ਸਿਰਲੇਖ ਅਧੀਨ ਬੋਰਲੌਗ ਇੰਸਟੀਚਿਊਟ ਫਾਰ ਸਾਊਥ ਏਸ਼ੀਆ (ਬੀਸਾ), ਲਾਢੋਵਾਲ (ਲੁਧਿਆਂਣਾ) ਦੇ ਖੋਜ ਫਾਰਮ ਵਿਖੇ ਸੰਨ 2013-14 ਅਤੇ 2014-15 ਦੌਰਾਨ ਮੈਰਾ ਰੇਤਲੀ ਮਿੱਟੀ ਉਪਰ ਸਾਉਣੀ ਅਤੇ ਰੱਬੀ ਰੁੱਤੇ ਕੀਤਾ ਗਿਆ। ਪਹਿਲੇ ਤਜ਼ਰਬੇ ਵਿੱਚ, ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ DIPB-R ਦੇ ਮੁਕਾਬਲੇ $DIPB_{MB}$+R ਅਧੀਨ ਕਣਕ ਅਤੇ ਮੱਕੀ ਦੇ ਦਾਣਿਆਂ ਦਾ ਝਾੜ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੇਰੇ ਸੀ, ਜੋਕਿ FIPB-R ਤੋਂ ਵੀ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੀਆ ਸੀ। ਮੱਕੀ ਵਿੱਚ ਸੰਨ 2014 ਅਤੇ 2015 ਦੌਰਾਨ FIPB-R ਦੇ ਮੁਕਾਬਲੇ $DIPB_{MB}$+R ਅਧੀਨ ਦਾਣਿਆਂ ਦੇ ਝਾੜ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 27.05 ਅਤੇ 23.40 ਪ੍ਰਤੀਸ਼ਤ ਅਤੇ DIPB+R ਅਧੀਨ 19.80 ਅਤੇ 22.13 ਪ੍ਰਤੀਸ਼ਤ ਦਾ ਵਾਧਾ ਹੋਇਆ। ਹਾਲਾਂਕਿ, ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਰਹਿੰਦ-ਖੂੰਹਦ ਤੋਂ ਬਿਨਾਂ ਖਾਲ੍ਹ ਨਾਲ ਸਿੰਚਾਈ ਦੀ ਮੁਕਾਬਲੇ ਰਹਿੰਦ-ਖੂੰਹਦ ਸਣੇ ਤੁਪਕਾ ਸਿੰਚਾਈ ਨਾਲ ਕਣਕ ਦੇ ਝਾੜ ਵਿੱਚ ਕ੍ਰਮਵਾਰ ਲਗਭਗ 16.09 ਅਤੇ 15.22 ਪ੍ਰਤੀਸ਼ਤ ਦਾ ਵਾਧਾ ਹੋਇਆ। NE ਅਤੇ $RN_{100\%}$ ਅਧੀਨ ਕਣਕ ਅਤੇ ਮੱਕੀ ਦਾ ਝਾੜ ਅਤੇ ਝਾੜ ਨਾਲ ਸਬੰਧਤ ਮਾਪਦੰਡ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੀਆ ਪਾਏ ਗਏ ਪਰ ਇਹ ਆਂਕੜੇ $RN_{75\%}$ ਦੇ ਆਂਕੜਿਆਂ ਦੇ ਸਮਾਨ ਸਨ, ਇਸ ਤਰ੍ਹਾਂ ਦੋਨਾਂ ਫ਼ਸਲਾਂ ਵਿੱਚ ਖਾਦਾਂ ਦੀ 25% ਬੱਚਤ ਹੋਈ। ਤਜ਼ਰਬਾ II ਵਿੱਚ, ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ FIRB-R ਭਾਵ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਰਹਿਤ ਪਲਾਟ ਦੇ ਮੁਕਾਬਲੇ FIRB+R ਭਾਵ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਵਾਲੇ ਪਲਾਟ ਵਿੱਚ ਮੱਕੀ ਅਤੇ ਕਣਕ ਦੇ ਦਾਣਿਆਂ ਅਤੇ ਪਰਾਲੀ ਦਾ ਝਾੜ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੇਰੇ ਸੀ। ਸੰਨ 2014 ਅਤੇ 2015 ਦੌਰਾਨ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਰਹਿਤ ਉਪਚਾਰ ਦੇ ਮੁਕਾਬਲੇ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਵਾਲੇ ਉਪਚਾਰ ਅਧੀਨ ਮੱਕੀ ਦੇ ਝਾੜ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 7.10% ਅਤੇ 8.41% ਦਾ ਅਰਥਪੂਰਨ ਵਾਧਾ ਦਰਜ ਕੀਤਾ ਗਿਆ। ਸੰਨ 2014 ਅਤੇ 2015 ਦੌਰਾਨ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਰਹਿਤ ਉਪਚਾਰ ਦੇ ਮੁਕਾਬਲੇ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਵਾਲੇ ਉਪਚਾਰ ਅਧੀਨ ਕਣਕ ਦੇ ਝਾੜ ਵਿੱਚ ਕ੍ਰਮਵਾਰ 4.41% ਅਤੇ 4.06% (4.23% ਔਸਤ ਨਾਲ) ਦਾ ਅਰਥਪੂਰਨ ਵਾਧਾ ਦਰਜ ਕੀਤਾ ਗਿਆ। ਦਾਣਿਆਂ ਅਤੇ ਪਰਾਲੀ ਦੇ ਝਾੜ, ਵਿਕਾਸ ਦੇ ਵੱਖੋ-ਵੱਖਰੇ ਪੜਾਵਾਂ ਉਪਰ ਨਾਈਟ੍ਰੋਜਨ ਦੇ ਗ੍ਰਹਿਣ ਅਤੇ ਨਾਈਟ੍ਰੋਜਨ ਦੀ ਸੁਚੱਜੀ ਵਰਤੋਂ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਖਾਲ੍ਹ ਵਾਲੀ ਸਿੰਚਾਈ ਵਾਲੇ ਉਪਚਾਰ ਲਈ ਖਾਦਾਂ ਦੀ ਵਰਤੋਂ ਸਭ ਤੋਂ ਉੱਤਮ ਪਾਈ ਗਈ। ਤਜ਼ਰਬਾ III ਵਿੱਚ, ਅਪਘਟਨ ਚੱਕਰ ਦੌਰਾਨ, ਉਪ-ਸਤ੍ਹਾ ਉਪਰਲੀ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਦੇ ਮੁਕਾਬਲੇ ਸਤ੍ਹਾ ਉਪਰਲੀ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਵਿੱਚ ਭਾਰ ਵਿੱਚ ਆਈ ਕਮੀ ਦੀ ਪ੍ਰਤੀਸ਼ਤਤਾ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੇਰੇ ਸੀ। ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਾਸਫ਼ੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ ਦੇ ਨਿਕਲਣ ਦੇ ਵਤੀਰੇ ਉਪਰ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਦੀ ਕਿਸਮ ਅਤੇ ਇਸਦੇ ਸਥਾਪਨ ਦੀ ਵਿਧੀ ਦਾ ਅਰਥਪੂਰਨ ਪ੍ਰਭਾਵ ਵੇਖਿਆ ਗਿਆ। ਜਦੋਂ ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਨੂੰ ਉਪ-ਸਤ੍ਹਾ ਉਪਰ ਰੱਖਿਆ ਗਿਆ ਤਾਂ ਅਪਘਟਨ ਅੰਤਰਾਲ ਦੇ ਅੰਤ ਵੇਲੇ $MT_{50\%}$ (21.6 kg N ha^{-1}, 1.62 kg P ha^{-1} ਅਤੇ 46.22 kg K ha^{-1}) ਮੁਕਾਬਲੇ $ML_{50\%}$ ਵਿੱਚ ਕੁੱਲ ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਾਸਫ਼ੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ ਦੇ ਨਿਕਲਣ ਦੀ ਕੁੱਲ ਮਿਕਦਾਰ ਵਧੇਰੇ ਸੀ ਜੋਕਿ ਕ੍ਰਮਵਾਰ 31.66 kg N ha^{-1}, 2.91 kg P ha^{-1} ਅਤੇ 56.12 kg K ha^{-1} ਸੀ। ਇਸੇ ਤਰ੍ਹਾਂ, ਸਾਰੇ ਦੇ ਸਾਰੇ ਅਪਘਟਨ ਅੰਤਰਾਲ ਦੌਰਾਨ ਸਤ੍ਹਾ ਦੇ ਮੁਕਾਬਲੇ ਉਪ-ਸਤ੍ਹਾ ਉਪਰ ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਦੀ ਮੌਜੂਦਗੀ ਰੱਖ ਕੇ ਕਣਕ ਅਤੇ ਮੂੰਗੀ ਦੀ ਫ਼ਸਲ ਦੀ ਰਹਿੰਦ ਖੂੰਹਦ ਵਿੱਚ ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਾਸਫ਼ੋਰਸ ਅਤੇ ਪੋਟਾਸ਼ੀਅਮ ਦੇ ਨਿਕਲਣ ਦੀ ਮਿਕਦਾਰ ਵਧੇਰੇ ਸੀ ਅਤੇ ਇਸ ਉਪਰ ਫ਼ਸਲੀ ਰਹਿੰਦ ਖੂੰਹਦ ਦੀ ਕਿਸਮ ਦਾ ਕੋਈ ਵੀ ਪ੍ਰਭਾਵ ਨਹੀਂ ਵੇਖਿਆ ਗਿਆ।

ਮੁੱਖ ਸ਼ਬਦ: ਮੱਕੀ-ਕਣਕ ਫ਼ਸਲੀ ਪ੍ਰਣਾਲੀ, ਸੰਰੱਖਿਅਕ ਖੇਤੀ, ਨਾਈਟ੍ਰੋਜਨ, ਫ਼ਸਲੀ ਰਹਿੰਦ-ਖੂੰਹਦ ਦਾ ਪ੍ਰਬੰਧਨ, ਤੁਪਕਾ ਸਿੰਚਾਈ

ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

In the the Indo-Gangetic plains (IGP) of the Indian sub-continent, continous adoption of rice and wheat cropping system results into a variety of adverse effects like degradation of soil health (Bhandari *et al* 2002), air pollution (Bijay-Singh *et al* 2008), severe ground water depletion (Hira *et al* 2004) and emergence of weed, diseases and resilient insect pests anticipating the need for crop diversification. Extraction of groundwater throughout the years to meet the rich water necessity of flooded rice has brought about serious in ground water level (Sharma *et al* 2012, Humphreys *et al* 2010) and likely reduces the availability of water in the future, which results into the socio-economic instability (Jat *et al* 2013). Rice-Wheat system is not only crucial for the nation's sustenance security but rather in the meantime likewise ensure sustainability of natural resources and crop production in dull zones, which also in the north-western IGP over-exploited groundwater. Therefore, to overcome these issues, replacement of rice with crops requiring less water crops like maize etc. is imperative. (Jat *et al* 2015, Jat *et al* 2009).

In addition, unsound management practices of the past have led to the twin challenges of depletion of resources and deceleration of productivity of cereal crops. In the times to come, the global food security will rely not only on increasing production and access to food but also on the need to manage the dangerous impacts of current agricultural production systems on ecosystem sustainability and increasing the resilience of production systems to mitigate the effects of climate change (Foresight 2011). Declining soil fertility, high input costs, erratic rainfall patterns and tricky economic situations have all influenced the profitability, sustainability and the livelihood of the small holder in the farming sector (Marongwe *et al* 2012). Nearly 94 percent (143 Mha) of the agriculturally suitable land is under cultivation and had limited scope for any further horizontal expansion. Hence, the pressure on land is bound to increase as it will have to produce more from the same area under cultivation which will call for increasing the input-use efficiencies and better agronomic practices (Jat *et al* 2016). These detrimental factors have necessitated that, there is a need to adopt alternative crops and cropping systems, which are more ecologically benefited and as well as aides utilizing natural resources (Aulakh and Grant 2008).

In north-western India alternate to rice-based systems, maize (*Zea mays* L.) based systems are recommended as an important cropping systems, to address the issues of degradation of resources, especially water table and climate change induced variability, basically in precipitation and temperature, etc (Yadav *et al* 2016). Maize has a considerable lower prerequisite of water than rice and along these lines can improve the profitability of the system and sustain health of the soil (Meelu *et al* 1979). In the later past in view of the falling water table and increasing cost of extraction of water for rice combined with high yielding cultivars of maize, the acreage under maize-wheat system has shown an increasing trend in India. Maize has a considerable lower prerequisite of water than rice and along these lines can improve the profitability of the framework and support soundness of the dirt and nature of the earth (Meelu *et al* 1979). In the later past in view of the falling water table and expanding expense of extraction of water for rice development combined with high yielding cultivars of maize, the grounds under maize-wheat framework has demonstrated an expanding pattern in India.

Maize is an important crop in the country which provides food and nutritional security. It is grown in diverse ecologies and seasons covering 9.06 m ha acreage in the country (GoI 2015). Maize, around the globe, provides for nearly 30 percent of the food calories to more than 4.5 billion people in almost 94 developing countries and it is expected that the demand of maize will double worldwide by 2050 and to meet this rising demand, there is a need of higher production of maize (Srinivasan *et al* 2004). During the last decade (2003-04 to 2012-13), the area, production and productivity under maize increased by 1.8 percent, 4.9 percent and 2.6 percent, respectively per annum which was mainly due to increase in demand of maize in India (GoI 2015). Stagnation of agricultural productivity and degradation of water and soil resources of the IGP has forced many eminent agricultural scientists and policy makers to look towards a healthier sustainable path of conservation agriculture (CA) and technologies which augment resource conservation (Erenstein and Laxmi 2008, Gupta and Sayre 2007). Conservation agriculture is progressively being looked upon as a farming system that can decrease the unfavourable impacts of some of the factors constraining the agricultural productivity and enables the sustainable intensification by enhancing and conserving the quality of the soil (Marongwe *et al* 2012, Friedrich and Kassam 2009).

Due to the rising concern over degradation of natural resources the conservation agriculture based crop management technologies for example permanent raised beds (PB) with residue retention and planned crop rotation is gaining attraction (Ladha *et al* 2009, Jat *et al* 2009, Saharawat *et al* 2012). The crop management practices based on CA are observed to be effectual in increasing crop productivity (Jat *et al* 2013, Das *et al* 2014, Parihar *et al* 2016), profitability and energy-use efficiency (Parihar *et al* 2011). Furthermore, the traditional and intensive practices of tillage led to degradation of soil properties mainly because of decrease in soil organic matter due to more oxidation and breakdown of organic carbon (Biamah *et al* 2000, Gathala *et al* 2011). The experimental results published in various scientific literature have shown increased productivity and soil quality, mainly through SOM build-up (Ladha *et al* 2009, Bhattacharyya *et al* 2013, Parihar *et al* 2016a) and higher SOC content under zero-tilled as compared to the soils which were conventionally tilled (West and Post 2002, Alvarez 2005).

In any production system, the practice of tillage is the main contributor towards the energy and labour cost, resulting in lower economic returns (Jat *et al* 2005, Saharawat *et al* 2010, Labios *et al* 1997, Kumar *et al* 2013). A way of adopting CA is PB planting (Sayre 2004) which allows the bed to be re-used for successive crop and thus has the potential to conclusively reduce the cost of cultivation. Various experimental results have shown that over the no tillage (NT) and conventional tillage (CT), PB with residue retention can have more benefits (Limon- Ortega *et al* 2000, Sayre and Hobbs 2004). Advantages under PB with residue retention are better irrigation management (Hassen *et al* 2005, Sayre and Hobbs 2004), better establishment of plants (Khalequei *et al* 2008, Gursoy *et al* 2010), and it also increases the ability to use inter-bed cultivation for weed control (Govaerts *et al* 2005, Rautaray 2005). Other than these advantages, PB have been shown to enhance the grain yield and water productivity in wheat (Gupta *et al* 2009, Wang *et al* 2004) and maize (Hassen *et al* 2005, McFarland *et al* 1991). Maize planted on PB, recorded about 11 per cent lower water use and 16 per cent higher water use efficiency compared to CT and similarly, wheat planted on PB required 24.7 per cent less irrigation water than CT, with 30 percent and 8.1 percent higher yield of maize and wheat on PB and NT, respectively. It also demonstrated higher water productivity (Jat *et al* 2013). The increase in productivity of water used for irrigation is the result of both increase in yield and saving in water used for irrigation. The higher grain yield of maize-wheat in PB than in CT suggests a greater crop responses to applied N in PB.

Efficient use of N is an essential parameter in crop production and management and it is important to maintain N optimising use of N fertilizer to ensure better yields and minimizing N surpluses which can percolate into groundwater or spread out into the air (Janzen *et al* 2003). Maize has been seen as a major feeder and utilizations bigger amount of N than some other nutrient element. Increment in the N levels prompted to noteworthy increment in leaf area index, dry matter accumulation and net absorption rate in all the development phases of the crop (Shivay *et al* 2002).

Compared to conventional systems, nitrogen use efficiency (NUE) can be improved in PB by more than 10 per cent because of improved N placement possibilities (Fahong *et al* 2004). The leaching of the nitrates which happens below the root zone is found to be affected by a multitude of factors, including application rate, method of application and the time at which the dose is applied (Siyal *et al* 2012). Higher application of fertilizer N under the continuous maize-wheat cropping system may result not only in yield losses, but also in increasing potential contamination of both underground and surface water and higher soil nitrate concentrations (Pei *et al* 2009, Yi *et al* 2010). Fertilizer placement plays vital role in the uptake of nutrients by plants and loses of nutrient through leaching below the root zone. The careful placement of fertilizer can make easy access of nutrients to roots without causing any harm to the young seedlings, particularly during the initial stages of growth of the plant

(Jones and Jacobsen 2009, Benjamin *et al*, 1998). Waddell and Weil (2006) ascertained that by putting the fertilizer near the top of the bed, the yields of the maize crop increased and decreased the risk of leaching N. Mailhol *et al* (2001) also reported that if we placed the N fertilizer near the top of the ridge, a profitable impact on the yield was observed.

Punjab soils are low in organic carbon, therefore it is not possible to achieve the coveted yield levels and maintain soil health on a long term basis by purely depending on the nitrogenous fertilizers which are generally chemical in nature. The high soil nutrients levels fulfilling the nutritional demand of cultivated plants can only be upheld through the application of inorganic and organic fertilizers (Ranjbar and Jalali, 2012, Sarkar *et al* 2000). Utilization of natural organic materials as soil additives is an essential management strategy that can enhance and elevate soil-quality traits change the nutrient cycling through mineralization or immobilization turnover of added materials (Baldi and Toselli 2014, Novara *et al* 2013, Hueso-González *et al* 2014, Campos *et al* 2013, Oliveira *et al* 2014).

Utilization of nearby local organic materials derived from livestock or plants is gaining popularity around the globe for improving the fertility and productivity potential of soils which are nutrient poor and degraded (Tejada and Benítez, 2014, Abbasi *et al* 2015). Crop residues are an important source of plant nutrients and are the viable primary source of organic matter (as C makes up for more than 40% of the entire dry biomass). These are available in sufficient quantities and are being partially utilized. The crop residues contain the nutrients whose economic value is almost equivalent to the chemical fertilizer which are applied to the crop (Rezig *et al* 2014). To maintain current soil organic carbon stocks and ensure future soil productivity and agricultural sustainability, it is important to boostthe contribution to soil organic carbon by the use of crop residue management (Stewart *et al* 2015). Among the organic sources, the limited availability of farmyard manure can be complimented by using leguminous cover crops such as mungbean. These leguminous cover crops are the natural N producers and are known to increase soil N and P availability and concurrently contribute to the conservation of soil organic matter and improve the soil physical, biological and chemical properties (Yadvinder-Singh *et al* 2010a, FAO 2010). The application of green manures to soil increases its organic matter, level of fertility (Doran and Smith 1987, Power 1990) and escalates nutrient retention (Drinkwater *et al* 1998, Dinnes *et al* 2002).

At present, annual crop water requirement for the state is estimated at 4.53 m ha-m, against the current availability of only 3.26 m ha-m, thereby indicating a deficit of about 1.27 m ha-m of water (Minhas *et al* 2010). Substitution of rice with maize in rice-wheat system which require less water and identification of effective and efficient strategies for substitute tillage systems will promote sustainable systems of cropping in the IGP. Maize grown along with wheat is the 5th most dominant cropping system in India and it occupies almost 2.0

million ha in IGP, which is the situated right in the heart of the rice–wheat production system of South Asia (Jat *et al* 2009, Yadav and Subba Rao 2001, Jat *et al* 2013). Maize has a markedly lower requirement of water than rice and thus can increase the output of the system, which in turn can preserve the quality of the environment and also the health of the soil (Hassen *et al* 2005).

The advanced methods of irrigation such as sprinkler and drip giving better water management practices are highly advocated for water saving (Zaman *et al* 2001) in crop production, particularly under conditions of water scarcity (Pereira *et al* 2002, Zeng *et al* 2009). The efficiency of water use and yield of crops which are drip irrigated can be improved under restrained water application by lessening the amount of water that leaches beneath the root zone (El-Hendawy *et al* 2008). Using the drip irrigation method, savings in water usage and yield increases as reported by Tiwari *et al* 2003, Yuan *et al* 2003 and Dhawan 2002. Drip fertigation is an exemplary technology, which saves on the fertilizer use and increases the efficiency of applied nutrients thereby leading to an increase in the yield of the crop. The drip fertigation technology apparently increased the uptake rate of nutrients when compared to surface irrigation (Sampathkumar and Pandian 2011).

Therefore, N management along with conservation tillage needs to be developed particularly for the maize-wheat system. Till now, there is hardly any substantive systematic research to increase the recourse use efficiency, water use efficiency and carbon footprints of the cropping system based on maize as per different management practices. Hence there is a pressing need to minimize losses due to indiscriminate use of groundwater under traditional system of mono-cropping or rice-wheat system with optimum use of water along with nutrients under resource conserving practices to enhance production and sustain the foundation of natural resource. The proposed research work entitled “Enhancing yield and nitrogen use efficiency in maize-wheat system under conservation agriculture” was planned with the following objectives:

1. To evaluate the effect of residue management, cover crop and rates of N application through fertigation on yield and N use efficiency in maize-wheat system under conservation agriculture.
2. To study the effect of different methods of N application, rates of N and straw management on yield and N use efficiency in maize-wheat system under conservation agriculture.
3. To determine the effect of methods of placement on decomposition rate and pattern of nutrient release from crop residues and mungbean cover crop.

CHAPTER II

REVIEW OF LITERATURE

Tillage refers to the different mechanical manipulations of the soil that are used to provide the necessary soil conditions favorable to the crop growth. A proper tillage can be alleviate the soil related constraints while improper tillage may leads to degradative processes, e.g., deterioration of soil structure, accelerated erosion, depletion of organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrients (Lal 1996). Sustaining production and productivity of any system is of paramount importance by improving the soil's physico-chemical and biological properties. Continues soil inversion lead to a degradation of soil structure and leading to a compact soil by fine particles with low levels of soil organic matter (SOM). Such soils are more prone to soil loss through water and wind erosion eventually resulting in desertification, as experienced in USA in the 1930s (Biswas, 1984). To combat soil loss and preserve soil moisture soil conservation techniques were developed in USA known as conservation agriculture or conservation tillage this involves soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity, thereby minimizing erosion and degradation, control annual weed and seed bank but also water contamination (Anonymous, 2001). The relavent research work done so far by different workers on various aspects of the present investigation entitled "**Enhancing yield and nitrogen use efficiency in maize-wheat system under conservation agriculture**" has been reviewed under the following headings:

2.1 Conservation agriculture

2.2 Effect of conservation agriculture on soil properties

- 2.2.1 Effect of conservation agriculture on soil physical properties
- 2.2.2 Effect of conservation agriculture on soil chemical properties
- 2.2.3 Effect of conservation agriculture on soil biological properties

2.3 Permanent raised beds as a part of conservation agriculture

2.4 Maize-wheat system under conservation agriculture

2.5 Nitrogen management in maize-wheat system

2.6 Effect of irrigation methods on growth, yield and yield attributes

2.7 Plant residue decomposition and nutrient release

2.1 Conservation agriculture

Conservation agriculture (CA) is a crop management system based on three key principles: minimum soil disturbance, permanent organic-matter soil cover and diversified crop rotations. Corsi *et al* (2012) define CA as a method of managing agro ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. They added that minimum mechanical soil disturbance, permanent organic soil cover and crop diversification are the three basic principles of CA. According to CTIC (2004), conservation tillage is any tillage system that leaves at least 30 percent of the soil surface covered with crop residue after planting to reduce soil erosion by water. Lal (1990) described conservation tillage as the method of seedbed preparation that includes the presence of residue mulch and an increase in surface roughness as the key criteria. Conservation tillage is an ecological approach to soil surface management and seed bed preparation. According to Busari *et al* (2015) conservation agriculture, practising agriculture in such a way so as to cause minimum damage to the environment, is being advocated at a large scale world-wide. Conservation tillage, the most important aspect of CA, is thought to take care of the soil health, plant growth and the environment.

These CA principles are applicable to a wide range of crop production systems from low-yielding, rainfed conditions to high-yielding irrigated conditions. In present scenario due to over exploitation of natural resources (soil and water) and to offset the production cost and environmental footprints, the conservation agriculture (CA) based crop production technologies are gaining attention in this region to explore maximum yield potential of these new single cross hybrid in maize (Ladha *et al* 2009, Jat *et al* 2009, Saharawat *et al* 2012). The CA based crop management practices found to be effective for increasing crop productivity (Jat *et al* 2013, Das *et al* 2014, Parihar *et al* 2016), profitability (Parihar *et al* 2016) and energy-use efficiency (Parihar *et al* 2011). Furthermore, the intensive traditional tillage practices led to reduction in soil organic matter because of more oxidation and breakdown of organic carbon and ultimately degrade soil properties (Biamah *et al* 2000, Gathala *et al* 2011). Published experimental results across the globe have shown increased productivity and soil quality, mainly through soil organic matter build-up (Ladha *et al* 2009, Bhattacharyya *et al* 2013) and higher soil organic carbon content under zero-tilled compared to conventionally tilled soils (West and Post 2002, Alvarez 2005, Parihar *et al* 2016a). In CA with crop residue retention on the soil surface reduces, unproductive losses of water through evapo-transpiration and also controls weeds. Crop residues are an important source of soil organic matter vital for the sustainability of agricultural ecosystems. About 25 percent of N and P, 50 percent of S and 75 percent of K uptake by cereal crops is retained in crop residues, making them valuable nutrient sources (Yadwinder-Singh *et al* 2004). Thus, CA is a concept for optimizing crop yields, and economic and environmental benefits (Jat *et al* 2011).

Conservation agriculture aims at increasing agricultural, increase profitability and contributing to environmental sustainability (Marongwe *et al* 2010). Conservation agriculture provides environmental services such as contributing to atmospheric carbon sequestration, preserving biodiversity, managing watersheds and preventing soil erosion (Fowler and Rockstorm2001). The techniques to apply the principles of CA will be very different in different situations, and will vary with biophysical and system management conditions and farmer circumstances (Verhulst *et al* 2010). Communities and societies can also benefit from the adoption of CA through improved food and water security, more reliable water supplies and protection of ecosystem services (Kassam *et al* 2009).

The area and productivity of rice-wheat (RW) system in the IGP increased dramatically between the 1960s and 1990s due to the introduction of improved varieties, increased use of fertilizers and other chemicals, and the expansion of irrigation. However, during the past decade, yields have stagnated or possibly declined, and there are large gaps between potential yields, experimental yields and farmers yields (Gill 1999, Ladha e*t al* 2003). Therefore, the sustainability of RW system of the IGP and the ability to increase production in pace with population growth are major concerns. However, the biggest threat to sustaining or increasing the productivity of RW systems of South Asia is probably water shortage. Rice-wheat system are crucial for the country's food security, but to ensure sustainability of natural resources and crop production in dark zones (over-exploited groundwater zones) of the NW IGP, diversification of rice by crops requiring less water, crops such as maize is essential (Jat *et al* 2015).

The adoption of NT, which is based on the principle of no or minimum soil disturbance, is considered vital for maintaining the productivity of the RW system. No-till in the RW system has helped to save fuel and water, reduce the cost of production, and improve system productivity and soil health (Jat *et al* 2009, Saharawat *et al* 2010). The RW system on PB has been intensively studied in the Indian Punjab and the results showed that there was no yield advantage of growing crops on beds compared with flats but there was little advantage in water savings (Humphreys *et al* 2008a, Humphreys *et al* 2008b, Kukal *et al* 2008, Kukal *et al* 2010, Yadvinder-Singh *et al* 2009). Contrary to expectations, a significant reduction has occurred in area under no-till cultivation of wheat in the last few years. In fact, a NT seed drill works well when there is no rice residue in the field, a condition normally achieved by manual harvesting of rice. These problems have given impetus to pursue alternative crops and cropping systems, such as no-till maize-wheat systems to overcome all these problems.

2.2 Effect of conservation agriculture on soil properties

When evaluating an agricultural management system for sustainability, the central question is: which production system will not exhaust the resource base, will optimize soil conditions, and will reduce food production vulnerability while at the same time maintaining or enhancing productivity?

2.2.1 Effect of conservation agriculture on soil physical properties

Effects of conservation tillage on soil properties vary, and these variations depend on the particular systemc hosen. No-till (NT) systems, which maintain high surface soil coverage, have resulted in significant change in soil properties, especially in the upper few centimetres (Anikwe and Ubochi, 2007). According to Lal *et al* (2007) NT technologies are very effective in reducing soil and crop residue disturbance, moderating soil evaporation and minimizing erosion losses. More stable aggregates in the upper surface of soil have been associated with no-till soils than tilled soils and this correspondingly results in high total porosity under NT plots. In Gottingen, Germany, Jacobs *et al* (2009) found that minimum tillage (MT), compared with CT, did not only improve aggregate stability but also increased the concentrations of SOC and N within the aggregates in the upper 5–8 cm soil depth after 37–40 years of tillage treatments.

Several research workers have observed higher bulk density (BD) under ZT than CT practices (Meena and Behera 2008, Bhattacharyya *et al* 2008). Ram *et al* (2010) from Punjab reported that higher BD values under continuous ZT practices than CT practice, but lower values of soil BD under residue applied treatments compared to without residue ZT practices in maize-wheat cropping system. Jat *et al* (2013) reported that the BD in the 10-15-cm soil layer was significantly lower in the PB compared to CT. The most likely reason for higher bulk density and soil resistance in CT compared to PB is the excessive use of tillage implements causing compaction in the plough layer. The effect of tillage and residue management on soil bulk density is mainly confined to the top soil. Gal *et al* (2007) observed higher BD in the 0-30 cm layer under zero tillage than under conventional tillage on a silty clay loam after 28 years, but no difference in the 30-100 cm layer. Gwenzi *et al* (2009) stated that the conversion from conventional tillage to minimum tillage and no- tillage had no noticeable effects on BD even after six years. In another study, Bell and Raczkowski (2008) reported that no-tillage increased BD of a sandy loam from 1.3-1.5 g/cm^3 within a year due to natural setting and consolidation. Verhulst *et al* (2011) in their study reported that most of the physical soil parameters measured were significantly affected by tillage-straw system, only BD showed no effect. Conservation agriculture with residue retention improves dry aggregate size distribution. The effect on water stability of aggregates is even more pronounced, with an increase in mean weight diameter of wet sieving reported for a wide variety of soils and agroecological conditions (Pinheiro *et al* 2004, Li *et al* 2007, Govaerts *et al* 2008, Lichter *et al* 2008). Residue as mulch on soil surface increases the hydraulic conductivity due to it adds the organic matter in the soil which improves the soil macro aggregates that might facilitate easy movement of water in the soil (Rasool *et al* 2007). Hydraulic conductivity and infiltration can be improved and evaporation can be decreased by no-tillage and crop residue cover (Liu *et al* 2011). The soil aggregation improved in the PB system compared to CT system with significantly higher mean weight diameter of aggregates (Jat *et al* 2013). Verhulst *et al* (2009) have shown that similar improvements in soil quality (increased direct infiltration in the soil).

In terms of water conservation, NT has been found to be more effective in humid and sub-humid tropics. Kargas *et al* (2012) observed that untilled plots retain more water than tilled plots. In comparison with conventional ploughing. Pagliai *et al* (2004) reported that minimum tillage improved the soil pore system by increasing the storage pores (0.5–50 mm) and the amount of the elongated transmission pores (50–500 mm).They related the higher microporosity in minimum tillage soils to an increase of water content in soil and consequently, to an increase of available water for plants. Higher water holding capacity or moisture content has been found in the topsoil (0–10 cm) under NT than after ploughing (McVayetal, 2006). Using the stable isotope technique, Busari *et al* (2013) reported that soil water stable isotopes (δ18O and δD) were more enriched near the soil surface under CT compared with ZT indicating more evaporation under conventionally tilled soils. Therefore, to improve soil water storage and increase water use efficiency (WUE) most researchers have proposed replacement of traditional tillage with conservation tillage (Fabrizzi *et al* 2005, Silburn *et al* 2007).

Crop residue mulching can significantly reduce the soil evaporation and improve the soil water storage (Zhang *et al* 2007). Sharma *et al* (2011) reported that no-tillage retained the highest moisture followed by minimum tillage, raised bed and conventional tillage at different soil depths. Taser and Metinoglu (2005) and Munoz *et al* (2007) found that soil moisture content was greater under no-till than under conventional tillage at 0-15 cm soil depth because crop residue left on soil surface in no-till system protected against evaporation losses more effectively. De vita *et al* (2007) stated that higher soil water content under no-till than under conventional tillage indicated the reduced water evaporation during preceding period. They also found that across growing season, soil water content under no-till was about 20% greater than under conventional tillage. However, Rashidi and Keshavarzpour (2007) reported that conventional tillage had higher moisture content than no-till and reduced tillage. Almaraz *et al* (2009) reported that the NT system had, in most of the cases, slightly higher moisture levels than CT but significant differences were not detected.

The increase in soil aggregation under PB system is possibly due to higher level of soil organic carbon (4.46 g kg^{-1}) than in CT (4.09 g kg^{-1}) as a result of the least soil disturbance. Physical disturbance of soil structure through tillage results in a direct breakdown of soil aggregates and an increased turnover of aggregates (Six *et al* 2000) and fragments roots and mycorrhizal hyphae, which are major binding agents for macroaggregates (Tisdall and Oades 1982, Bronick and Lal 2005). Soil organic matter can increase both soil resistance and resilience to deformation and improve soil macroporosity (Kay 1990, Soane 1990). Denef *et al* (2002) found that adding wheat residue in the laboratory to three soils, differing in weathering status and clay mineralog, increased both unstable and stable macro aggregate formation in all three soils in the short term (42 days). Lichter *et al* (2008) found significantly larger macro aggregates in a soil under a wheat crop than in a soil under a maize crop.Wheat has a more horizontal growing root system than maize, and the plant population of wheat is higher resulting in a denser superficial root network. Conservation agriculture can increase infiltration and reduce runoff and evaporation compared to conventional tillage. Consequently, soil moisture is conserved and more water is available for crops. Soils under NT with residue retention generally had higher surface soil water contents compared to tilled soils (Govaerts *et al* 2008). Crop residue mulching can significantly reduce the soil evaporation and improve the soil water storage (Zhang *et al* 2007). Numerous studies showed that no-tillage practices, with crop residue left on the soil surface improve soil aggregation, and preserve the nutrients for plant and soil micro-organisms (Jacobs *et al* 2009).

2.2.2 Effect of conservation agriculture on soil chemical properties

Soil chemical properties that are usually affected by tillage systems are pH, CEC, exchangeable cations and soil total nitrogen. According to Lal (1997) soil chemical properties of the surface layer are generally more favourable under the no-till method than under the tilled soil. Annual no-tillage, implying yearly practice of no-till system over a long period of time, is beneficial to maintenance and enhancement of the structure and chemical properties of the soil, most especially the SOC content. Tillage technique is shown to have no effect on soil pH (Rasmussen, 1999), though soil pH has been reported to be lower in no-till systems compared to CT (Rahman *et al* 2008). The lower pH in ZT was attributed to accumulation of organic matter in the upper few centimetres (Rhoton, 2000) causing increases in the concentration of electrolytes and reduction in pH (Rahman *et al* 2008). Salako (2013) also observed that ZT soil had a significantly higher pH at the end of the first year after tillage but the pH became significantly lower compared with the CT soil at the end of the second year after tillage. However, the SOC and the effective cation exchange capacity (ECEC) were significantly higher at the end of the two years of study under ZT than under CT. The study however, revealed that minimum tillage (MT) resulted in significantly higher pH and SOC than CT at the end of each of the two years of the study suggesting that less soil disturbance is beneficial to soil chemical quality improvement.

When comparing soil organic carbon in different management practices, CA had higher apparent mass of soil organic carbon than the CT. Tillage practice can also influence the distribution of soil organic carbon in the profile with higher soil organic carbon content in surface layer with NT than with CT, but a higher content of soil organic carbon in the deeper layers of tilled plots where residue is incorporated through tillage (Jantalia *et al* 2007, Gal *et al* 2007). Tillage, residue management, and crop rotation have a significant impact on nutrient distribution and transformations in soils usually related to the effects of CA on soil organic carbon contents (Etana *et al* 1999, Galantini *et al* 2000). Astier *et al* (2006) observed a significantly higher total N under NT compared to CT in the highlands of Central Mexico. Similarly, Govaerts *et al* (2007) reported that increasing the amount of straw retention under PB resulted in an increased total N form 0.14 percent with no residue retained to 0.16

percentwith all residue retained. This is in line with an increase in soil organic matter as the N cycle is in extricably linked to the C cycle (Bradford and Peterson 2000). Most comparative field studies have shown that NT results in greater accumulation of soil organic matter in surface layers (0–20 cm) than does CT (Lal 1989, Kern and Johnson 1993). Similarly Govaerts *et al* (2007) observed that five years of consecutive use of PB with full residue retention increased soil organic C 1.37 times over the conventional tilled raised beds with straw incorporation for the 0-5 cm layer and 1.16 times if the 0-20 cm layer was considered.

Numerous studies have reported higher extractable P levels in NT than in CT largely due to reduced mixing of the fertilizer P with the soil, leading to lower P-fixation (Franzluebbers and Hons 1996, Du Preez *et al* 2001, Duiker and Beegle 2006). According to Govaerts *et al* (2007), PB had a concentration of K 1.65 times and 1.43 times higher in the 0–5 and 5–20 cm layer, respectively, than CT, both with crop residue retention under maize-wheat system, from 1999 to 2004. Micronutrient cations (Zn, Fe, Cu, and Mn) tend to be present in higher levels under zero tillage with residue retentions compared to CT, especially extractable Zn and Mn near the soil surface due to surface placement of crop residues (Franzluebbers and Hons, 1996). In contrast, Govaerts *et al* (2007) reported that tillage practice had no significant effect on the concentration of extractable Fe, Mn, and Cu, but that the concentration of extractable Zn was significantly higher in the 0–5 cm layer of PB compared to CT with full residue retention. The high organic matter content at the soil surface, commonly observed under CA, can increase the CEC of the topsoil (Duiker and Beegle, 2006). Govaerts *et al* (2007) observed a significantly higher pH in the topsoil of the PB with full residue retention compared to CT with residue retention.They found the Na concentration to be 2.64 and 1.80 times lower in 0–5 and 5–20 cm layer, respectively, in PB compared to CT raised beds.

2.2.3 Effect of conservation agriculture on soil microbiological properties

The soil biological property most affected by tillage is SOC content (Doran, 1980). The soil organic matter content influences to a large extent the activities of soil organism which in turn influence the SOC dynamics.The continuous and uniform supply of carbon from crop residues serves as energy source for microorganisms. Retaining crop residues also increases microbial abundance, because microbes encounter improved conditions for reproduction in the mulch cover (Salinas-Garcia *et al* 2002, Carter and Mele 1992). No tillage with residue retention results in an increase of soil biological activity, especially near the soil surface (Hargrove 1990, Hoflich *et al* 1999). Govaerts *et al* (2008) also observed that crop residue retention resulted in increased populations of soil micro-flora such as total bacteria, fluorescent pseudomonas, actinomycetes, total fungi, *Fusarium spp*. that promote plant growth and suppress diseases. No-till maize increased microbial activity by 30-102 %, and also tended to increase bacterial functional diversity (Lupwayi *et al* 2012).

Earthworms which are a major component of the soil macrofauna are important in soil fertility dynamics as their burrowing activities aid in improvement of soil aeration and water infiltration. The fact that the population of earthworms are affected by tillage practices has been documented in a no tillage review by Rasmussen (1999). A six year study by Andersen (1987) revealed a significantly higher earthworm population under no-till soil than under ploughed soil. Kemper *et al* (1987) reported that less intense tillage increased the activities of surface-feeding earthworms. Due to disruption of fungi mycelia by tillage technique, Cookson *et al* (2008) observed a decreased fungal biomass and increased bacterial biomass with increasing tillage disturbance. They also reported alteration in the composition and substrate utilization of the microbial community with distinct substrate utilization in no-till soil.

Kandeler *et al* (1999) reported that on a Chernozem a trend towards a significant increase in functional diversity caused by reduced tillage. Reduced tillage, as such, is not responsible for increased micro-flora, but rather the combination of reduced tillage and residue retention. The favourable effects of NT and residue retention on soil microbial populations are mainly due to increased soil aeration, cooler and wetter conditions, less temperature and moisture fluctuations, and higher carbon content in surface soil (Doran, 1980). The soil microbial biomass C (MBC) and N (MBN) reflect the soil's ability to store and cycle nutrients (C, N, P and S) and organic matter, and has a high turnover rate relative to the total soil organic matter (Dick 1992, Carter *et al* 1999). Liomon-Ortega *et al* (2006) observed the highest amount of MBC and MBN in PB with residue retention as compared to the CT bed with residue retention and PB with all residues burned. These results suggest that PB with residue retained have the benefit to increase the amount of soil organic matter with its concomitant effects on soil quality. Moreover, the larger amounts of MBN indicated that treatments under PB have a greater potential to provide additional N mineralized from the microbial biomass, increasing its availability to plants.

2.3 Permanent beds (PB) as a part of conservation agriculture

Tillage practices contribute greatly to the energy and labour cost in any production system resulting to lower economic returns (Labios *et al* 1997, Jat *et al* 2005, Saharawat *et al* 2010). A way of adopting CA is PB planting (Sayre 2004) which allows the bed to be re-used for succeeding crop and thus has the potential to minimize the cost of cultivation. Previous studies have shown that PB with residue retention can have more benefits over no tillage (NT) and conventional tillage (CT) (Limon-Ortega *et al* 2000, Sayre and Hobbs 2004). The benefits are attributed to better irrigation management (Sayre and Hobbs 2004, Hassen *et al* 2005), plant establishment (Khalequei *et al* 2008, Gursoy *et al* 2010), and it also increases the ability to use inter-bed cultivation for weed control (Govaerts *et al* 2005). It has been observed that crop production on PB is 9 percent more energy efficient than zero tillage, 12 per cent more efficient than fresh beds made annually beds and 19 per cent more efficient than conventional practices (Rautaray 2005). Besides these advantages, PB have been shown to increase grain yield and water use efficiency in wheat (Wang *et al* 2004, Gupta *et al* 2009) and maize (McFarland *et al* 1991, Hassen *et al* 2005). Maize planted on PB, recorded about 11percent lower water use and 16percent higher water use efficiency compared to CT and similarly, wheat planted on PB required 24.7 per cent less irrigation water than CT, with 30 per cent and 8.1 per cent higher yield of maize and wheat on PB and NT, respectively and demonstrated higher water productivity (Jat *et al* 2013). The increase in irrigation water productivity is the resultant of both increase in yield and saving in irrigation water. The higher grain yield of maize-wheat in PB than in CT suggests a greater crop responses to applied N in PB.

2.4 Maize-wheat system under conservation agriculture

Maize grown in sequence with wheat is the 5th dominant cropping system of India occupying ≈ 2.0 million ha in IGP, the heartland of RW production system of South Asia (Yadav and Subba Rao 2001, Jat *et al* 2009, Jat *et al* 2013). In Punjab, maize was cultivated on 1.30 lakh hectares with an average yield of 3.89 t ha^{-1} during 2013-14 (Anonymous 2014). Maize has a significantly lower irrigation requirement than rice and can enhance the productivity of the system, and sustain soil health and environment quality (Hassen *et al* 2005). Traditionally, maize and wheat are grown on flat system after 6–7 tillage operations and using flood irrigation. The traditional practice of growing these crops is costly and results in inefficient utilization of irrigation water and nutrients leading to low productivity and input efficiency. For the past one and a half decade or more, efforts have been in place to popularize PB of planting maize and wheat in the IGP. It is a system in which the crop is sown on ridges or raised beds of 15-20 cm height. Usually, the bed is 37.5 cm wide with furrow width of 30 cm (total bed size of 67.5 cm) to accommodate two rows of wheat and a single row of maize. The system aims at saving irrigation water and increasing nutrient-use efficiency as compared to flat system (Chauhan *et al* 2012). In this PB system, irrigation savings range from 18 per cent to 50 per cent (Gupta *et al* 2005, Jat *et al* 2005).

The permanent bed planting technique has been developed for reductions in production costs (Lichter *et al* 2008). Permanent raised beds permit the maintenance of a permanent soil cover on the bed for greater rain water capture and resource conservation (Govaerts *et al* 2007). The advantages of permanent raised bed planting over ZT with flat planting are that it saves irrigation water, and weeding and fertilization practices are performed easily by traffic in the furrow bottoms (Limon-Ortega *et al* 2002, Das *et al* 2014). Past research suggests some advantages of broad beds over narrow beds in the maize–wheat system in Mexico and elsewhere. For example, Akbar *et al* (2007) reported a water saving of

36 per cent for broad beds and 10 per cent for narrow beds compared with flat sowing and that grain yield increased by 6 per cent for wheat and 33 per cent for maize in Pakistan.

Connor *et al* (2003) suggested that PB might offer farmers significant advantages such as increased opportunities for crop diversification, mechanical weeding, placement of fertilizers, relay cropping and intercropping, reduced tillage and water savings as compared to flat systems. Permanent raised-bed system with furrow irrigation is more suitable and sustainable than a reduced or NT system on "the flat", since flood irrigation can lead to difficulty in irrigation water distribution within the field when loose residues are left on the surface (Sayre and Hobbs 2004). Permanent raised bed is not tilled on the surface of the bed where the crops are seeded but the furrows between the beds are reshaped as needed between crop cycles. Farmers growing wheat on beds obtain, 8 per cent higher yields and save, nearly 25 per cent in production costs, compared with the flood irrigation flat systems (Aquino 1998).

There are also indications that maize and wheat yields under PB can be further increased by using recommended or optimum rates of fertilizer N and irrigation because of the reduced risk of lodging (Sayre and Moreno-Ramos 1997). Jat *et al* (2013) observed that maize grown on PB showed significant increase (30 %) in yield over that CT flat because maize under flat suffered from waterlogging. Das *et al* (2014) observed that permanent bed planting and residue retention practice produced significantly higher (mean of 3 years) cotton and wheat productivity, respectively, than conventional tillage. Maize is known to be quite sensitive to excess water stress and yields poorly under waterlogged conditions (Dhillon *et al* 1998, Lal *et al* 1988). They further observed that apart from less waterlogging experienced by maize on PB, improvement in soil physical conditions also contributed to higher maize yields than flat layout. Hassan *et al* (2005) reported 13 per cent increase in wheat yield on PB compared with CT flat layout in maize-wheat system. Das *et al* (2015) recorded 16 per cent higher wheat grain yield in permanent bed planting and residue retention than conventional tillage (4·2 t ha^{-1}) in the second year. Similarly, wheat grain yield under permanent bed planting and residue retention was 10 per cent higher compared with permanent bed planting without residue retention (4·4 tha^{-1}) in the second year. Naresh *et al* (2014) also observed that wheat grain yield increased by 13.5 per cent with raised bed planting compared with flat-bed planting in Meerut, western IGP, in a maize–wheat system. Aquino (1998) also reported 8percent higher yield in wheat grown under bed planting compared with conventional tillage in Mexico.

Limon-Ortega *et al* (2000) observed that permanent beds with straw retention as compared to conventional tilled bed produced significantly higher wheat grain yield (5.57 t ha^{-1}) and N use efficiency (28.2 kg grain kg^{-1} of N supply) with positive implications for soil health.The higher grain yield of wheat and maize in PB than under CT could have various reasons. Drilling of wheat seed in line under PB may have provided better soil-seed contact than broadcasting seed under CT, resulting in a more vigorous crop growth as indicated by higher leaf area index and above ground biomassproduction, which again led to high grain yield (Gursoy *et al* 2010, Mann *et al* 2008). The constantly higher soil moisture content in PB may also have increased the nutrient availability and consequently the number of tiller-bearing plants. The increased maize grain yield in PB with N applications is attributed to various factors such as an earlier seedling emergence and stand establishment, faster growth rate, earlier teaselling, and longer grain filling periods in PB than under CT (Fischer *et al* 2002). Dhadli *et al* (2009) reported lower yields of soybean and maize under CT flat and NT flat compared with PB on a clay loam due to intermittent flooding observed during monsoon rains, which adversely affected the crop yield in the flat systems. Hassan *et al* (2005) reported increase of 30 per cent and 65 per cent in grain yield and water productivity of maize, respectively, under PB compared to traditional practice

Parihar *et al* (2016) showed the positive effects of ZT and PB, and residue retention on grain yield of maize and wheat. Wheat grain and straw yields was highest in PB plots (4.44 and 6.54 Mg ha^{-1}) compared to ZT (3.90 and 5.91 Mg ha^{-1}) and CT (3.73 and 5.72 Mg ha^{-1}). The pooled grain yield and straw yield with PB and residue retention were increased significantly by 19.0, 13.8 and 14.3, 10.7percent compared to CT and ZT, respectively, this might be due to less lodging of wheat crop under PB systems. The significantly higher wheat grain yield were recorded in the PB plots compared with ZT and CT plots, which could be attributed to the higher spike density, number of grains per spike and 1000-grain weight. Similarly the maize yield was also recorded significantly higher under ZT (4.54 Mg ha^{-1}) which was at par with PB (4.37 Mg ha^{-1}) as compared to CT (4.07 Mg ha^{-1}). The higher yield of maize and wheat in PB and ZT system could be due to the compound effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), lesser weed population (Ozpinar 2006, Chauhan *et al* 2007), improved soil physical health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009) and improved nutrient use efficiency compared to CT (Unger and Jones 1998).

Singh *et al* (2016) from a 5-year study demonstrated that zero-till direct seeded rice followed by zero-till maize with partial residue retention from both the crops improved soil organic carbon content and soil physical characteristics namely soil bulk density, Soil penetrometer resistance, infiltration rate and soil thermal regime. The overall improvement in soil conditions resulted in gradual increase in crop productivity, especially of maize, and improved profitability over conventionally tilled rice and maize. Retention of crop residues reduced the plant density by 6percent but increased the number of cobs $plant^{-1}$ by 10percent, grain weight cob^{-1} by 7percentand mean grain weight by 2percent compared to residue removed.

Yadav *et al* (2016) observed that after six cropping cycles at fixed plots the different tillage methods had significant effect on maize yield. Significantly higher maize yield was recorded in ZT and PB compared to CT planting. However, maize planted on PB yielded at par with ZT flat. Jat *et al* (2015) reported that permanent raised beds were required less irrigation water and resulted in higher water productivity and water savings of 24.5 and 29.2%, respectively, compared with no-till flat systems. Permanent raised beds also increased microbial biomass carbon and microbial biomass nitogen as a consequence of higher microbial activities indicating that this might be an effective method for increasing cropping system diversification in the IGP and other similar regions. Kumar and Yadav (2005) and Gupta *et al* (2007) reported that yield performance of wheat was marginally better under ZT practices, this could be due to various favourable factors under ZT like proper placement of the seed in the narrow slit made by zero-seed drill, early emergence of wheat seedling and availability of higher moisture content which might helped the crop to compete with the crop sown under CT practices. Mishra and Singh (2009) reported that variation in tillage systems did not influence the grain yield of wheat significantly except in 2002-03, where continuous ZT yielded significantly higher (5.13 t ha^{-1}) as compared to CT rotated with ZT (4.28 tha^{-1}).

Ram (2006) reported that more soil temperature under beds than flat planting leads to lowers soil moisture and poor growth of the wheat crop. Jat *et al.* (2005) reported that the productivity of wheat was higher by 7.3 and 8.6 percent under flat no-till (5.56 tha^{-1}) compared to no-till FIRB (5.18 tha^{-1}) and flat conventional till planting (5.12 tha^{-1}), respectively. They further reported that productivity of maize-wheat system was maximum (10.84 tha^{-1}) under FIRB system of planting followed by NT and CT systems, respectively. Research findings over the past one and half decades has shown that wheat could be grown successfully on beds in North-West India, with similar or higher yield and lower irrigation water use than for conventional sowing (Sayre *et al* 2005).

A field experiment was conducted at PAU, Ludhiana by Ram *et al* (2010) revealed that all the growth parameter (plant height, dry matter accumulation and leaf area index), yield attributes (cobs/plant, grains/cob and 1000-grain weight) and yield performance of maize under different conventional and zero tillage practices were observed statistically similar. Singh *et al.* (2011) reported that mean decrease under minimum tillage was 6.8-12.1 percent in grain yield, and 5.9-17.1 percent in stover yield compared with conventional tillage. Ram (2006) reported that the higher values of plant height, dry matter accumulation, LAI, CGR and RGR under permanent bed with residue than no-residue under both ZT and CT practices. A study conducted at IARI, New Delhi by Singh *et al* (2009) revealed that bed planting significantly improved the yield of maize crop over flat planting. Jat *et al* (2005) reported that maize productivity was highest (5.66 tha^{-1}) under FIRB system followed by NT and lowest (4.39 tha^{-1}) in conventional-tillage (CT) with an average productivity of 4.93 t ha^{-1}. Similarly, Srivastava *et al.* (2005) reported that the performance of QPM hybrids on a sandy loam soil was better under FIRB and NT planting compare to CT with respect to yield, water productivity and profitability.

Jat *et al* (2006) conducted a field experiment on a sandy loam soil in northern India and reported that yields of the highest yielding varieties were recorded an average 4 and 16% percent higher with permanent beds compared with CT and ZT-flat, respectively. Similarly, Singh *et al* (2007) reported relatively higher maize grain yield (6.9-14.6%) as compared with that of conventional tillage. Jat *et al* (2005) reported a notable increase in economic yield of maize being 19.2 and 28.9% with furrow irrigated raised bed (FIRB) planting (5.66 tha^{-1}) compared to flat no-till (4.75 tha^{-1}) and conventional till (4.39 tha^{-1}) planting systems, respectively. Bakht *et al* (2009) reported that on average, crop residue incorporation increased the wheat grain yield by 1.31 times and straw yield by 1.39 times. Govaerts *et al* (2005) reported that permanent bed planting along with rotation and residue retention had the advantages in yield potential of wheat and maize. Thus residue management under permanent bed planting and zero tillage improved the productivity of crops.

2.5 Nitrogen management in maize-wheat system

The efficiency of applied N in the world crop production system is however less than 50 per cent (Raun and Johnson 1999). The ability of crops to use the applied N depends on the uptake and utilization efficiency. Nitrogen uptake can be increased through improved cultivation practices, while the utilization efficiency is genetically predetermined (Hirel *et al* 2007). Furthermore, fertilizer use efficiency depends on fertilizer nutrient rate, method of application, soil properties and climatic conditions and also on cropping systems and tillage methods (Habtegebrial *et al* 2007). Although fertiliser consumption is increasing quantitatively, the corresponding yield increase per unit of nutrient has diminished over the years (Brar *et al* 2011). Inappropriate and imbalanced use of nutrients has led to multiple nutrient deficiencies and low nutrient-use efficiency resulting in soil degradation. Currently, 100 million tonnes (Mt) of N per annum is applied as fertiliser for agricultural production worldwide, out of which 50% is consumed in production of three major crops - wheat, maize and rice (Heffer, 2009). Only 30-50 per cent of this applied N is recovered by crop plants and more than 50 per cent of the N not assimilated by plants becomes a potential source of environmental pollution – groundwater contamination, eutrophication, acid rain, ammonia redeposition, global warming and stratospheric ozone depletion (Ladha *et al* 2005). While N losses cannot be avoided completely, there is certainly a scope to minimise losses with new and innovative precision N management techniques and technologies. Based on current cost of US$ 1000 per metric ton (MT) of N fertiliser, 5 per cent increase in NUE of major crops (wheat, maize and rice) would result in savings of about US$ 2.5 billion year-1 and substantial improvement in environmental quality.

Nutrient management is an important aspect of CA for crop productivity as it requires different management practices than CT system (Vanlauwe *et al* 2014). In CA systems, residue retention promoted the formation of more stable macro-aggregates and increased the protection of C and N in the micro-aggregates within the macro-aggregates compared to CT (Singh *et al* 2016). The distribution of SOM and nutrients in a soil under CA differs from that in CT as tillage, residue management, and crop rotation increase the stratification of nutrients and their availability near the soil surface compared to CT (Duiker and Beegle 2006, Sharma *et al* 2015). Govaerts *et al* (2006) observed that after 26 cropping seasons in a high-yielding, high input irrigated production system, the N mineralization rate was higher in permanent raised beds with residue retention than in conventionally tilled raised beds with all residues incorporated, and that it increased with increasing rate of inorganic N fertiliser application. Yadvinder-Singh *et al* (2015) suggested that although short-term soil N mineralization is lower under conservation tillage system, total soil N mineralization may be similar in ZT and CT soil over the wheat season. Rice residue adds 35-45 kg N ha^{-1} and is a key consideration when attempting to optimize N fertility in the ZT systems.

Nitrogen is the key element in increasing yield and mediates the utilization of potassium, phosphorus and other elements in plants. The optimum amounts of these elements in the soils cannot be utilized efficiently if N is deficient in plants. Therefore, N deficiency or excess can reduce yield. Increase in the dose of N from 0 to 120 kg ha^{-1} led to significant increase in leaf area index, dry matter accumulation and net assimilation rate at all the maize crop growth stages on silty clay loam soil (Shivay *et al* 2002). Increase in the N level upto 180 kg ha^{-1}, resulting in higher uptake by plants and production of larger leaves, more photosynthates and dry matter accumulation, which ultimately gave higher yield and its attributes (Bangarwa *et al* 1988). Fischer *et al* (2002) observed that maize under PB emerged three days earlier and showed greater growth during the first week after seeding due to higher soil moisture availability, which led to higher biomass accumulation than under CT.

Mahmood *et al* (2001) reported that application of N at the rate of 180 kg ha^{-1} to maize resulted in maximum plant height (228.2 cm), maximum 1000-grain weight (262.4 g) and maximum grain yield of 5.7 t ha^{-1} as compared to 140 kg N ha^{-1}. Similarly, Bangarwa *et al* (1988) reported that maximum grain yield (7.27 t ha^{-1}) was obtained with 180 kg N ha^{-1}. Nemati and Sharif (2012) reported that application of N at the rate of 225 kg ha^{-1} gave the maximum plant height (185.2 cm), maximum number of grain ear^{-1} (472.9), maximum cob length (23.6 cm) and maximum grain yield of 7.2 t ha^{-1} of maize. Sahoo and Mahapatra (2004) reported increase in number of cobs, length and weight of grain per cob, grain yield and net profit of maize with increased N levels. Leaf growth, leaf appearance and photosynthetic capacity in maize increased with increase in levels of fertilizer N (Vos *et al* 2005).

Excessive application of fertilizer N may result not only in yield losses, but also in high soil nitrate concentrations at the end of the plant growth season, increasing potential contamination of both underground and surface water due to nitrate remaining in the soil profile and possible leaching to the ground water (Pei *et al* 2009, Yi *et al* 2010). Leaching of nitrate below the root zone can be affected by a range of factors, including application rate, method of application and timing of application (Siyal *et al* 2012). Placement of fertilizer plays an important role in nutrient uptake by plants and leaching of nutrients below the root zone. The main objective of precision fertilizer placement is to make nutrients easily accessible to roots but without causing damage to the young seedlings, especially during the early stages of plant growth (Jones and Jacobsen, 2009). Benjamin *et al* (1998) showed that placing fertilizer in the non-irrigated furrow in alternate furrow irrigated systems increased fertilizer use efficiency and reduced fertilizer leaching. Waddell and Weil (2006) found that by placing fertilizer near the top of the bed, corn crop yields increased and the risk of N leaching decreased. Mailhol *et al* (2001) also reported that fertilizer N application near the top of the ridge has a beneficial impact on yield as compared to furrow application.

Siyal *et al* (2012) studied the effect of fertilizer N placement on N leaching and they found that the maximum amount of N leaching (50 kg N ha^{-1}) occurred from fertilizer placement at furrow bottom followed by fertilizer placement on furrow bottom and side (23 kg ha^{-1}). A 30-35% loss of N with fertilizer placed just beneath the surface of the soil on the bottom of the furrow can be reduced to 2%, 15%, 0% and 0% by changing fertilizer placement to sides of the furrow, bottom and sides of the furrow, on the sides of the furrow near to the top of bed, and in the middle of the top of bed, respectively. Placing fertilizer on the furrow sides near the top of bed and on the top at the centre of the bed have the lowest risk of N leaching. This was mainly due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching. Minimising direct contact will, therefore, reduce the risk of N leaching as has been reported by Lehrsch *et al* (2008).

Conservation agriculture improves NUE as it reduces soil erosion and prevents N loss from the field. This leads to the greater availability of both native and applied nutrients to crop plants which can have a significant effect on fertiliser efficiency. Rahman *et al* (2005) observed a significantly larger apparent recovery of fertiliser N under mulch than non-mulch conditions possibly due to reduction in fertiliser N losses. The build-up of SOM and increase in readily mineralized organic soil N with residue recycling suggest the potential for reducing fertiliser N rates for optimal yield of following crop after several years of residue incorporation (Eagle *et al* 2001, Thuy *et al* 2008, Yadvinder-Singh *et al* 2009). Nitrogen use efficiency (NUE) in PB could be improved by more than 10% because of improved N placement possibilities compared to CT systems (Fahong *et al* 2004). The greater grain yield of wheat in PB than in CT suggests a greater crop responses to applied N in PB. The higher soil moisture availability has led to a vigorous plant growth and hence has increased the response of applied N under PB. Higher response of maize to applied N in PB than CT could be due to earlier seedling emergence and faster growth and development of maize in PB than in CT. Gastal and Lemaire (2002) reported that N uptake rate of crops is regulated not only by N application and soil availability but also by crop growth rate. Long term trials under CSSRI-CIMMYT strategic research platform, Green Seeker-based urea application saved 10-15percent urea with full CA practices in rice-wheat- mungbean system after 3 years of experimentation (Sharma *et al* 2015). Majeed *et al* (2015) showed that wheat planting on beds produced 15.1percent higher grain yield, and 29.8percent higher NUE than flat planting at the same N rate (120 kg N ha^{-1}). Wheat planting on beds with application of 80 kg N ha^{-1} gave a yield similar to that of flat planting with 120 kg N ha^{-1}.

Govaerts *et al* (2006) reported soil C and total N contents respectively, 1.15 and 1.17 times greater in PB with straw partly removed and with straw retained on the surface, than in CT bed with straw incorporated. Similarly, the N-mineralization rate was 1.66 times greater in PB where the straw was retained on the surface than in CT bed where the straw was incorporated, but 1.25 times lower than in PB with straw partly removed in maize-wheat system. This was mainly due to effect that tillage will break down soil structure and aggregates, which normally protect otherwise rapidly decomposable soil organic matter (Six *et al* 2002). It has often been reported that during the decomposition of organic matter, inorganic N can be immobilized (Zagal and Persson, 1994), especially when organic material with a large C–N ratio is added to soil. This also explains that in the PB-straw partly removed where only wheat straw was retained having C-N ratio lower than maize, N-mineralization was significantly greater than in the PB-straw retained practice. Kumar and Goh (2002) also found that total soil N mineralization was significantly correlated with the C–N ratio of the residues. The Verhulst *et al* (2011) also reported that PB with all or part of the straw retained had significantly higher total N than CTB-straw incorporated in maize-wheat system.

The higher NUE in wheat and maize in PB than under CT is related to the higher N uptake. No significant difference in physiological efficiency in both the wheat and maize crops indicates that the change in grain yield per unit N accumulation in the aboveground biomass is largely governed by genetic factors (Yusuf *et al* 2009). However, Verachtert *et al* (2009) reported that decreased agronomic efficiency in wheat, and agronomic efficiency and apparent recovery efficiency in maize in PB with residue retained compared to residue removed could be due to immobilization of applied fertilizer N in the surface residues.

Cropping sequence and rotations involving legumes help in minimal rates of build-up of population of pest species, through life cycle disruption, biological N fixation, control of off-site pollution and enhancing biodiversity (Kassam and Friedrich 2009, Dumanski *et al* 2006). In CA, ZT combined with residue retention and legume integration could be the best management practice for SOM restoration which helps in saving of N-fertilisers after few years of establishment. The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro-organisms, but also for exploring different soil layers for nutrients that have been leached to deeper layers and can be "recycled" by the crops in rotation.

Green manure production and incorporation represents an alternate source of nutrients to mineral fertilizers (Yadvinder-Singh *et al* 2010a). However, the amount of N accumulated by green manures in many situations may not be sufficient to meet the N requirements of high yielding cultivars of rice, maize and many other crops, and fertilizer N addition may be necessary to achieve the optimum potential (Meelu *et al* 1994). The integration of green manure with chemical fertilizer will reduce application rate of fertilizers, may reduce risk of environmental pollution, and can also provide sustainability to agricultural systems (Kundu and pillai 1992). Green manures such as mungbean can fully satisfy N requirements of subsequent crops such as maize (Griffin *et al* 2000). Rekhi and Meelu (1983) reported that incorporation of mungbean residue, containing 100 kg N ha^{-1} , in combination with 60 kg fertilizer N ha^{-1} produced rice yields comparable to 120 kg fertilizer N ha^{-1}. Growing summer mungbean as a catch crop in rice-wheat rotation substituted up to 50 % NPK needs of rice, amounting to 60 kg N, 30 kg P_2O_5 and 15 kg K_2O ha^{-1} without any adverse effect on total productivity (Ghosh and Sharma 1996, Saraf and Patil 1995).

Lathwal *et al* (2010) reported that incorporation of mungbean after picking pods, increased basmati rice yield by 9-12% and the yield of following wheat by 4-6%. Sharma and Behera (2009) evaluated that grain yield of maize following cowpea, mungbeaan and sesbania summer legumes improved as compared with that after fallow, and mean increase in yield with green manure was 18 %. They found that the fertilizer N equivalent or N economy through cowpea and mungbean was about the same (37-48 kg N ha^{-1}) as the amount of N added through their residues (47-49 kg N ha^{-1}). They also observed significant residual effect of green manure on grain yield of following wheat, which increased the yield by average of 16.3 % over no green manure. Mean apparent recovery of N in maize was the highest from N fertilizer (34-40 %), followed by mungbean (35%), cowpea (30%) and sesbania (17%). Combined use of organic and mineral N ensured prolonged availability of N even beyond the growing period of maize crop, and thereby showed its residual effect on wheat. Singh *et al* (1982) reported that incorporating 49-day old sesbainia, cowpea and clusterbean green manure 7 days before sowing maize in a maize-wheat rotation, in the presence of 50 kg N ha^{-1} produced as much maize grain yield as that obtained by applying 125 kg N ha^{-1} to the no green manure plots, giving a saving of 75 kg N ha^{-1} from green manuring. Singh and Brar (1985) reported that cowpea green manure at 10 t ha^{-1} and 20 t ha^{-1} supplying 60 kg N ha^{-1} and 120 kg N ha^{-1} , increased maize grain yield by

0.7 (64%) and 1.7 t ha^{-1} (155%) over the no-green manure control, respectively. The efficient use of N in plant production is an essential goal in crop management and it is important to achieve N balance by applying correct amounts of fertilizer N to ensure high yields and maintain optimum soil N content, but minimizing N surpluses that can leach into groundwater or diffuse into the air (Janzen *et al* 2003).

2.6 Effect of irrigation methods on growth, yield and yield attributes

The efficiency of conservation tillage to improve water storage is universally recognized. This is very important in arid and semi-arid zones, where management of crop residues is of prime importance to obtain sustainable crop productions (Lampurlanes and Cantero-Martinez, 2006). The savings arise because with zero tillage wheat can be sown just after the rice harvest, making use of the residual moisture for wheat germination, potentially saving a pre-sowing irrigation, and because irrigation water advances faster in untilled soil than in tilled soil (Erenstein and Laxmi, 2008). Similarly, higher WUE was also reported in no-tillage in bed planting (Kaur and Mahey, 2005). Jat *et al* (2005) reported that the water productivity (Kg grain m^{-3} water) of either crop of maize and wheat was remarkably higher in FIRB planting (2.79 and 1.98) followed by no-till (1.74 and 1.89) and the lowest (1.36 and 1.38) in conventional till system. But, the magnitude of increase in water productivity due to FIRB/no-till systems compared to conventional till planting was higher in maize than the wheat.

In recent years, drip irrigation has become increasingly popular to reduce the amount of water and fertilizer that are applied to the crop, and also to reduce the amount of labour (Hanson *et al* 1997, Fekadu and Teshome, 1998). Because the drip irrigation is capable of applying small amounts of water where it is needed and to apply it frequently and with a high degree of uniformity, these features make it potentially much more efficient than other irrigation methods. Zwart *et al* (2004) reviewed crop water productivity for several crops around the world, including maize, and concluded that the crop water productivity could be significantly increased if irrigation was reduced and crop water deficit was intentionally induced.

Sampath *et al* (2012) reported that mild deficit irrigation through drip irrigation produced longer lateral roots from both the sides of the plant. Alternate watering imposed through alternate deficit irrigation produced longer lateral roots with higher values for root dry mass. Hassanli *et al* (2009) reported that surface drip and sub-surface drip methods led to a higher maize yield compared to the furrow irrigation method. The most water saving was obtained in the sub-surface drip method and the least water saving was obtained in the furrow irrigation method compared with conventional flood irrigation methods. Patil and Patil (2009) reported that water use efficiency (WUE) under treatments of drip irrigation with plastic mulch was 2.27 times more as compared to conventional irrigation method with no mulch.

Irrigation applied through drip in combination with black plastic mulching treatment recorded higher WUE than conventional irrigation method. Vories *et al* (2009) reported that the treatment with the lower water application had the higher irrigation WUE and replacing 60% of the estimated daily evapo-transpiration with sub-surface drip irrigation is sufficient for maximum corn yields.

Bozkurt *et al* (2011) concluded that plant growth parameters such as crop height, number of leaves, leaf area index (LAI), stem diameter, fresh above ground biomass and dry above ground biomass was affected significantly by the irrigation treatments. They concluded that irrigation with 120 per cent of Class A pan evaporation by a drip system would be optimal under adequate water source conditions. However, slightly deficient irrigation applications would be acceptable under scarce water conditions. Wang *et al* (2008) studied the effects of drip irrigation frequency on soil water-heat distribution, root distribution and yield of spring maize. The drip irrigation can significantly delay the effect of air temperature on soil temperature, which was influenced by irrigation process, soil water content and crop growth stage. In addition, the irrigation frequency affects the spring maize root distribution in the soil, and the high frequency drip irrigation treatment improves the root distribution in upper soil (0-40 cm). Vishwanatha *et al* (2002) reported that drip irrigation at 0.4, 0.6 and 0.8 pan evaporation (PE) level produced significantly higher green cob yield as compared to surface irrigation at weekly interval at 0.8 PE level at Bangalore during the summer season. They observed that, green cob yield was significantly higher in 0.8 PE (17.0 t ha^{-1}) which was 28% higher than the 0.4 PE (15.9 t ha^{-1}) which experienced more moisture stress.

Drip fertigation is a frontier technology, which saves the fertilizers and increases the use efficiency of applied nutrients and the yield of crop. Drip fertigation apparently increased the uptake rate of nutrients when compared to surface irrigation (Sampathkumar and Pandian 2011). Potential advantages of N fertilization through drip irrigation system include supply of N fertilizer directly to the center of the root zone and weed suppression caused by reduced N supply at the soil surface (Bar-Yosef, 1999). Tarkalson and Payero (2008) found that maize yield and NUE increased when N was applied through drip irrigation system during the growing season compared with a one-time application of N early in the season.

Sampathkumar and Pandian (2010) recorded that scheduling of drip fertigation in maize with 150% of RDF supplied once in six days could be the optimal management practice for effective utilization of applied water and nutrients as compared to surface irrigation with 100% RDF and fertigation with 100% of RDF at Coimbatore. Irrespective of fertilizer levels, fertigation frequency scheduled once in six days reduced the amount of nutrient uptake and SPAD values and it was on par with other frequencies (once in 9,12 and 15 days).

2.7 Plant residue decomposition and nutrient release

Returning crop residues to the soil has long been advocated as a practice that helps sustain soil quality and fertility over the long-term (Campbell and Zentner 1993). Knowledge of the process involved in the plant residue decomposition is critical to integrated and sustainable agricultural management (Angers and Caron 1998). It is therefore, important to understand the dynamics of decomposition and nutrient release pattern of plant residue as an important first step to improve organic matter management. In order to optimize the benefits of plant residues on soil quality improvement, it is critical to synchronize the release of nutrients from residue decomposition with patterns of plant nutrient uptake, which may minimize the loss of available nutrients via leaching, runoff and erosion (Sylvia *et al* 2005).

Field experiment consisting of minimum tillage (MT) with 3 t ha^{-1} crop residue mulch of the previous crop, MT without residue mulch, and CT (involving two diskings followed by planking) without residue mulch was conducted for maize-wheat sequence under rainfed conditions. Soil organic matter content, water retention, infiltration of water and aggregation of the surface soil was improved in the MT with residue relative to other treatments. Pooled grain yield in the MT with residue treatment remained below the CT treatment during the first two years but was subsequently higher than the CT indicating the necessity of using residue mulch in conjunction with MT in order to improve soil quality and sustain/improve crop production (Ghuman and Sur 2001).

Decomposition is a key process in the control of nutrient cycling and formation of soil organic matter (Berg and McClaugherty 2002). Soil and environmental factors such as soil texture, pH, nutrient availability, moisture and temperature, and biochemical composition of the residue are very important because they can modify decomposition rates due to their effects on microbial activity (Heal *et al* 1997 and Yadvinder-Singh *et al* 2005). The initial N content of plant residues is one of the crucial factors accelerating or inhibiting residue decay, as it determines the turnover of the microbial mass mineralizing the residues (Heal *et al* 1997). According to Baldock (2007), plant residues with a C/N ratio more than 40 are mineralized far more slowly than residues with the C/N ratio less than 40. Low C/N plant materials will meet the N requirements of soil microbial population and extra N will be mineralized and becomes available for plant uptake.

Litter bag technique can be used to study the pattern and rate of litter decomposition and nutrient release. In this technique a known amount of crop residue enclosed in bags and the bags are buried or left on the soil surface (Beare *et al* 2002). Bags subsequently sampled and periodically examined for loss in litter-weight as an index of decomposition (Carsky 1989). Due to more favourable conditions for microbial activity, soil-incorporated residues normally decompose at a faster rate than residues on the soil surface (Douglas and Rickman 1992, Curtin *et al* 1998, Wang *et al* 2001).

Yadvinder-Singh *et al* (2004) found that the relationship between N concentration and mass was curvilinear (quadratic) for rice straw. Burgess *et al* (2002) also reported a curvilinear relationship between N concentration and mass loss for barley (*Hordeum vulgare* L.) straw. However, for wheat and sorghum residues (with N content lower than rice residues), Schomberg *et al* (1996) observed an inverse linear relationship between dry mass remaining and N concentration. These observations imply that the relationship between N and mass loss of residues is likely tobe influenced by residue type, soil and environmental conditions and duration of decomposition. Yadvinder-Singh *et al* (2010b) reported that decomposition was significantly affected by method of residue placement, soil type and time. The buried rice residue lost about 80% of its initial mass at the end of decomposition cycle (2,537 degree-days (DGD), leading to a decomposition rate (k) of 0.5×10^{-2} –0.7×10^{-2} DGD^{-1} that was about 2.5 time as fast as that in the surface-placed residue (0.2×10^{-2} – 0.3×10^{-2} DGD^{-1}). At present no work is available on wheat and maize residue decomposition under field conditions in the IGP.

CHAPTER III

MATERIAL AND METHODS

The present study entitled, **"Enhancing Yield and Nitrogen Use Efficiency In Maize-Wheat System Under Conservation Agriculture"** was carried out for two years at Borlaug Institute for South Asia (BISA) Farm, Ladhowal, Ludhiana during *kharif* season and *rabi* season of 2013-14 and 2014-15. The detail of the material used and the methods followed are presented in this chapter.

3.1 Location and climate

Ludhiana, situated at 30°54′N latitude and 75°48′E longitude with an altitude of 247 metres above the mean sea level, is placed in the central plain region of Punjab under Trans-Gangetic agro-climatic zone of India. It represents sub-tropical and semi-arid climate with very hot and dry summer from April to June, hot and humid conditions from July to September, cold winters from November to January and mild climate during February and March. Seventy five per cent of the average annual rainfall is received during July to September. The normal data with respect to various weather parameters averaged for the period between February to June over the last 30 years reveal that normal value of total rainfall during February to June is 162.3 mm, constituting 22.1 per cent of annual rainfall. Normal maximum and minimum temperatures vary from 21.6°C and 7.2°C in February to 38.9°C and 25.6°C in June, respectively. The corresponding figures for March, April and May are 26.6°C and 11.3°C; 34.2°C and 16.9°C; and 38.6°C and 21.9°C, respectively. The normal relative humidity is 69.0 per cent in February and 49.0 per cent in June through 63, 47 and 39 per cent in the months of March, April and May, respectively.

3.2 Weather during the crop season

Ludhiana is characterized by sub-tropical, semi-arid type of climate with hot and dry summer from April to June followed by hot and humid period from July to September and cold winter during December and January. The mean maximum and minimum temperatures show considerable variations during different months of the year. Temperature often exceeds 38°C during summer and sometimes touches 45°C with dry spells during May and June. Minimum temperature falls below 0.5°C with some frosty spells during the winter months of December and January. The average annual rainfall of the Ludhiana is 650 mm, about three-fourth of which is contributed by the south-west monsoon during July to

September. Winter rains received in the months of December, January and February were mostly scanty.

The meteorological data of standard meteorological weeks (SMWs) during the crop growing seasons recorded at the meteorological observatory of the School of Climate Change and Agrometerology (SCCAM), Punjab Agricultural University, Ludhiana which is located at a distance of about 200 meters from the experimental site, are presented in Tables 1and 2 and depicted in Figures 1 and 2.

During crop season of 2013-14, the weakly mean temperature ranged between 10.3^{o}C in the 1st SMW (1-7 January) and 35.3^{o}C in the 23rd SMW (Table 1 and Fig. 1). The minimum weekly temperature during crop growth period ranged between 3.8^{o}C in 1st SMW and 29.7^{o}C in 28th SMW, whereas the maximum weekly temperature ranged between 15.1^{o}C in 51st (17-23 December) and 44.6^{o}C in 23rd SMW. The mean relative humidity during the same period varied from 41.3 (23rd SMW) to 90 (17-23 December) per cent. Rainfall of 635.3 mm was recorded during crop season with maximum rainfall of 110.0 mm received in 30th SMW. Evaporation during the crop season was 1607 mm. The maximum weekly evaporation (85.2 mm) was recorded in 23rd SMW, while minimum evaporation (7.7 mm) was recorded in 5th SMW. Daily mean sunshine hours ranged from 0.2 hours in 1st SMW (1-7 January) to 12.2 hours in 17th SMW.

During crop season of 2014-15, the weakly mean temperature ranged between 9.3^{o}C in the 52nd SMW (24-31 December) and 34.0^{o}C in the 21th SMW (Table 2 and Fig. 1). The minimum weekly temperature during crop growth period ranged between 5.2^{o}C in 52nd SMW and 27.9^{o}C in 25th SMW, whereas the maximum weekly temperature ranged between 12.5^{o}C in 51st (17-23 December) and 42.7^{o}C in 21th SMW. The mean relative humidity during the same period varied from 28.4% in 21th SMW (12-18 November) to 89% in 52nd SMW (24-31 December) per cent. Rainfall of 754.6 mm was recorded during crop season with maximum rainfall of 181.0 mm received in 28th SMW. Evaporation during the crop season was 1593.3 mm. The maximum weekly evaporation (84.0 mm) was recorded in 21th SMW, while minimum evaporation (5.4 mm) was recorded in 51st SMW. Daily mean sunshine hours ranged from 0.3 hours in 2nd SMW (8-14 January) to 11 hours in 23th SMW (19-25 March).

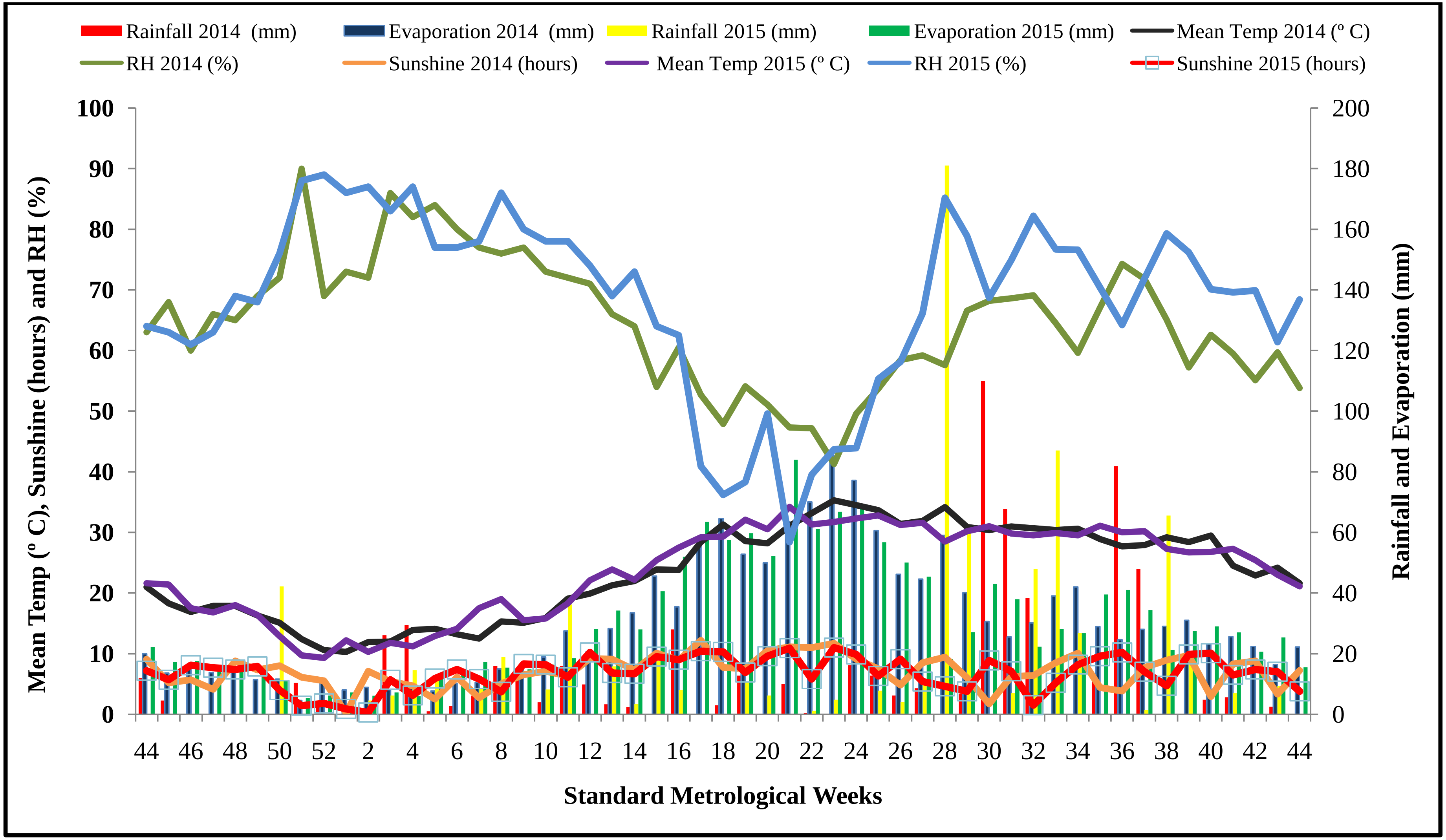


Fig. 1: Graphical presentation of mean temperature, sunshine, evaporation, rainfall and relative humidity during crop season for the year 2014 and 2015

3.3 Cropping history

Cropping history of the experimental field was as given below:

Table 1: Cropping history of the field under experiment field

Year	Crop Season	
	Kharif	***Rabi***
2011-2012	Maize	Wheat
2012-2013	Maize	Wheat
2013-2014	Maize	Wheat
2014-2015	Maize	Wheat

3.4 Soil characteristics

Composite soil samples were taken from randomly selected sites in the experimental field before planting of the experimental crop. The samples were dried in shade, ground and sieved through 2 mm sieve and analyzed for physico-mechanical properties. The details of the values obtained with respect to various properties are as follows:

3.4.1 Mechenical Composition

The proportion of sand, silt and clay was determined by International Pipette Method (Piper 1966) whereas the bulk density was determined by core sampler method as proposed by Bodman (1942). The soil of the experimental field was sandy loam in texture.

Table 2: Mechanical properties of experiment field

Sr No.	Mechanical Composition	Exp-1	Exp-2
1	Sand (%)	63.20	65.56
2	Silt (%)	30.40	29.40
3	Ckay (%)	5.86	4.50
4	Textural class	Sandy loam	Sandy loam

3.4.2 Chemical properties

The composite soil samples were collected before sowing from randomly selected sites and analysed for initial soil reaction, electrical conductivity and fertility status. The values so obtained are presented in Table 3.

The experimental field was medium in organic carbon and low in available nitrogen. However, available phosphorus and potassium status were medium. The soil pH and electrical conductivity values were within the normal range.

Table 3: Chemical properties of soil of the experimental field

Characters	Experiment-I		Experiment-II		Method used
	0-15	15-30	0-15	15-30	
pH	8.4	8.6	8.6	8.8	1:2 soil:water suspension (Jackson 1967)
EC (dSm^{-1})	0.260	0.180	0.180	0.147	1:2 soil:water supernatent Solubridge conductivity meter (Jackson 1967)
Organic carbon ($g\ kg^{-1}$)	5.40	3.53	5.40	3.33	Walkley and Black's rapid titration method (Piper 1966)
Available nutrient (kg ha^{-1})					
N	167.4	133.8	156.8	127.4	Modified alkaline potassium permanganate method (Subbiah and Asija 1956)
P	33.60	24.08	28.56	21.62	0.5 N Sodium bicarbonate extractable P by Olsen's method (Olsen *et al* 1954)
K	198.0	140.0	174	134.4	Ammonium acetate extractable K (Jackson 1967)

3.5 Experimental details

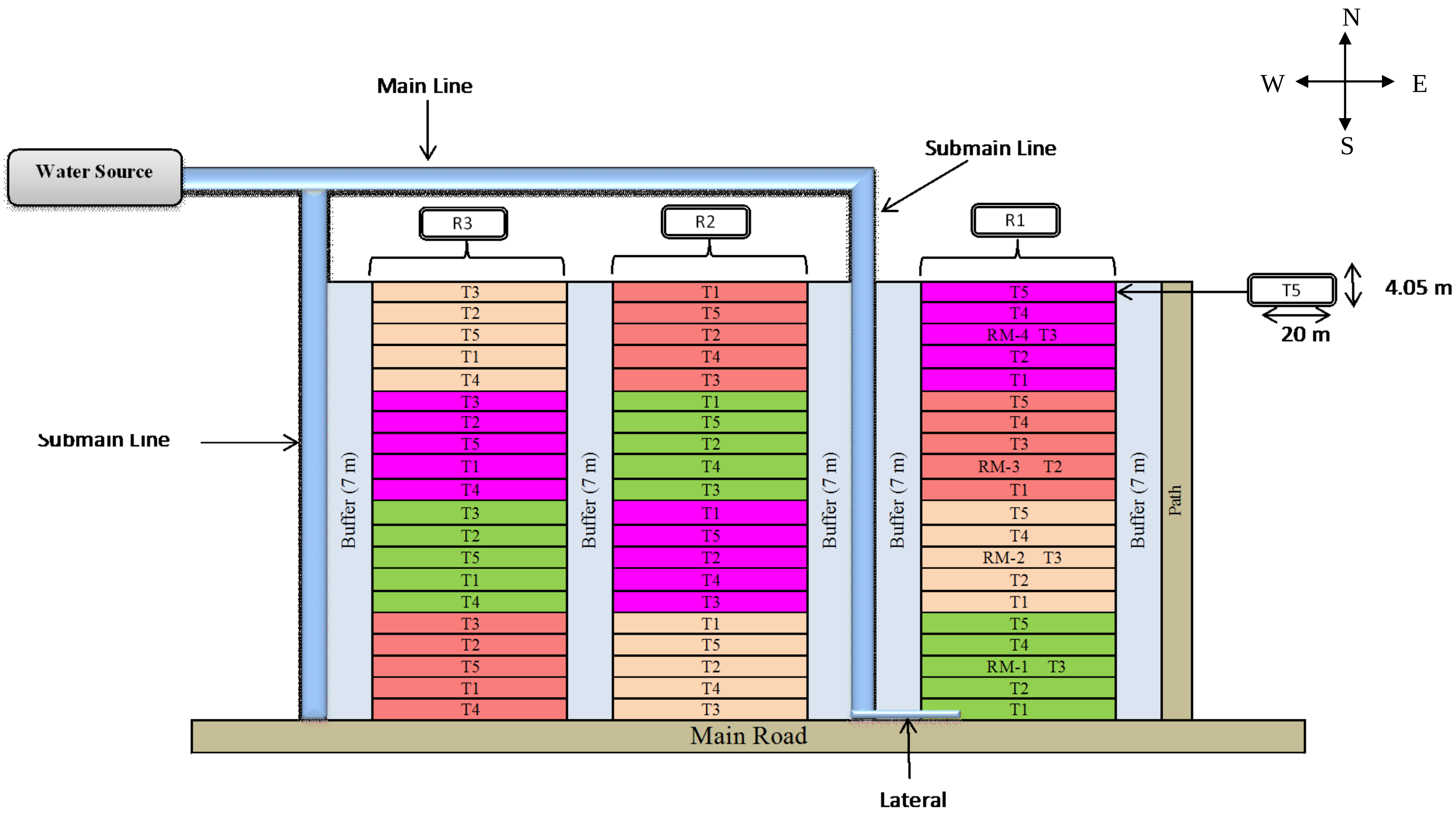
Experiment I: Enhancing nitrogen use efficiency through fertigation in maize-wheat system under conservation agriculture.

The experiment was laid out in a split plot design with four main treatments and five sub treatments (Fig. 2). The main treatments were the combinations from residue management and method of irrigation. i.e. residue removed and residue retained, furrow irrigation and drip irrigation. The sub treatments consist of five levels of N i.e. zero, 50, 75, 100 per cent of recommended N and fifth level of N on the basis of nutrient expert. The nutrient expert tool for rice, wheat and maize developed by the International Plant Nutrition Institute (IPNI), jointly with the International Maize and Wheat Improvement Center (CIMMYT) and in collaboration with several NARES partners, providing guidance to optimize source, rate, and time of fertilizer application to ensure significant improvement in yield and economics, with decreasing environmental footprint of fertilizer use in disparate geographies in China, Southeast Asia and India.

Each experimental unit was 81 m^2 (4.05 m × 20 m) in gross.The treatment details and field layout plan of the experiment are given in Table 4 and Figure 2, respectively.

Experimental design and layout

Location/Place of work	:	Borlaug Institute for South Asia (BISA) Farm, Ladhowal, Ludhiana
Design	:	Split Plot Design
Treatments	:	20
Replication	:	3
Total numbers of plots	:	60
Plot size	:	20 x 4.05 = 81 m^2



Residue removed - furrow irrigation

Residue removed - drip irrigation

Residue retained - drip irrigation
(Maize 50% + wheat 25%)

Residue retained - drip irrigation
(Maize 50% + wheat 25% + moongbean 100%)

T1 = Zero N (Control)
T2 = 50% recommended N
T3 = 75% recommended N
T4 = 100% recommended N
T5 = N on the basis NES

Fig. 2: Layout plan of Experiment-I

Table 4: Detail of treatments for Experiment-I

Treatments	Symbol
Main Treatments: Tillage and straw management systems	
Permanent raised bed-residue removed-furrow irrigation	FIPB-R
Permanent raised bed -residue removed – fertigation	DIPB-R
Permanent raised bed -residue retained (maize 50% + wheat 25%) – fertigation	DIPB+R
Permanent raised bed -residue retained (maize 50% + wheat 25% + mungbean 100%) – fertigation	$DIPB_{Mb}$+R
Sub Treatments: Rates of N	
Zero- N	N_0
50% of recommended N (60 kg N ha^{-1})	$RN_{50\%}$
75% of recommended N (90 kg N ha^{-1})	$RN_{75\%}$
100% of recommended N (120 kg N ha^{-1})	$RN_{100\%}$
Nutrient expert (140 kg N ha^{-1})	NE

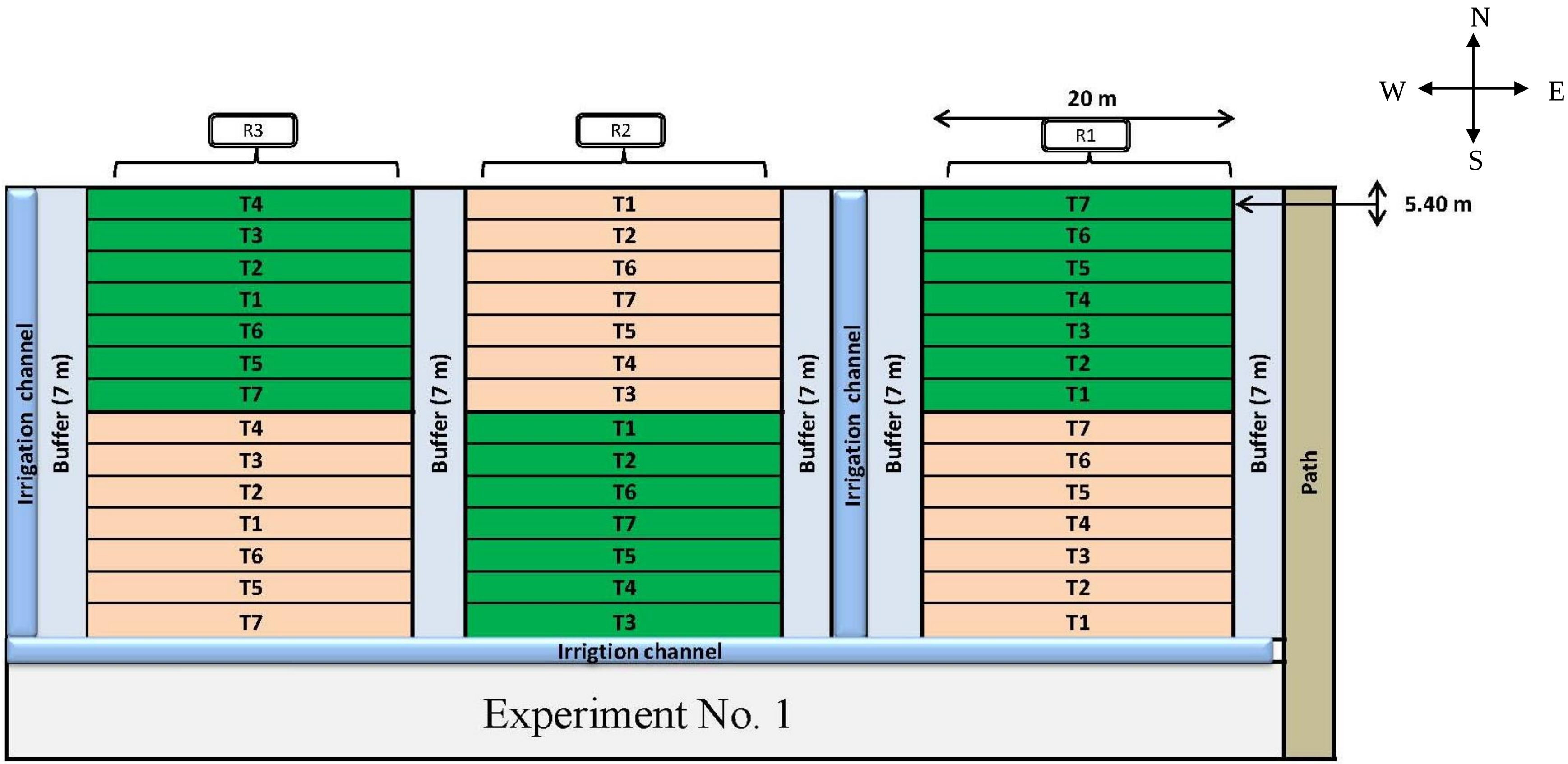
Experiment II: Evaluation of different rates and methods of nitrogen application and straw management for enhancing nitrogen use efficiency in maize-wheat system under conservation agriculture.

The experiment-II consisted of two main treatments and seven sub treatments laid out in a split plot design with three replications (Fig 3). Two main treatments were the residue management system i.e residue removed and residue retained. The sub treatments were the combination from three levels of nitrogen i.e zero N, 75 and 100 per cent of recommended N, and three methods of fertilizer application i.e uniform broadcasting, drilled/placement on top of bed and drilled/placed in furrows. Each experimental unit was 108 m^2 (5.4 m × 20 m) in gross.The treatment details and field layout plan of the experiment are given in Table 5 and Figure 3, respectively.

Experimental design and layout

Location/Place of work	:	Borlaug Institute for South Asia (BISA) Farm, Ladhowal, Ludhiana.
Design	:	Split Plot Design
Treatments	:	14
Replication	:	3
Total numbers of plots	:	42
Plot size	:	20 x 5.4 = 108 m^2

The plan of layout of the experiments is depicted in **Fig. 3.**



Residue retained

Residue removed

T1	=	Zero N (Control)
T2	=	75% recommeded N with Uniform Broadcasting
T3	=	75% recommeded N with Drilled/ Placement on top of bed
T4	=	75% recommeded N with Drilled/ Placement in furrows
T5	=	100% recommeded N with Uniform Broadcasting
T6	=	100% recommeded N with Drilled/ Placement on top of bed
T7	=	100% recommeded N with Drilled/ Placement in furrows

Fig. 3: Layout plan of Experiment-II

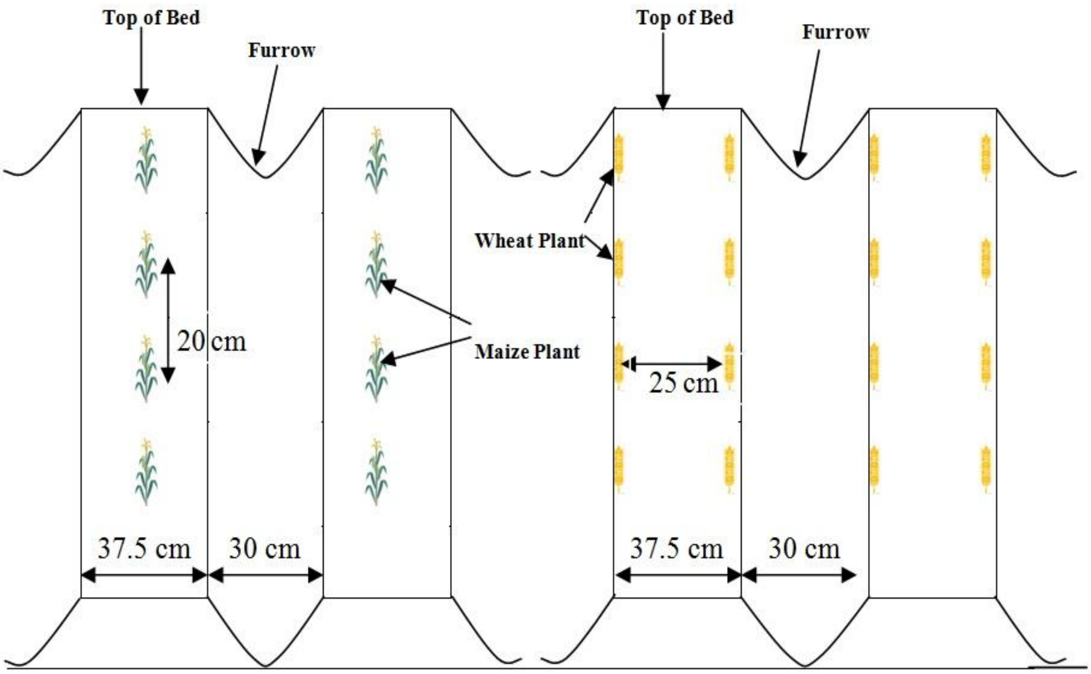


Fig 4: Layout of permanent raised beds

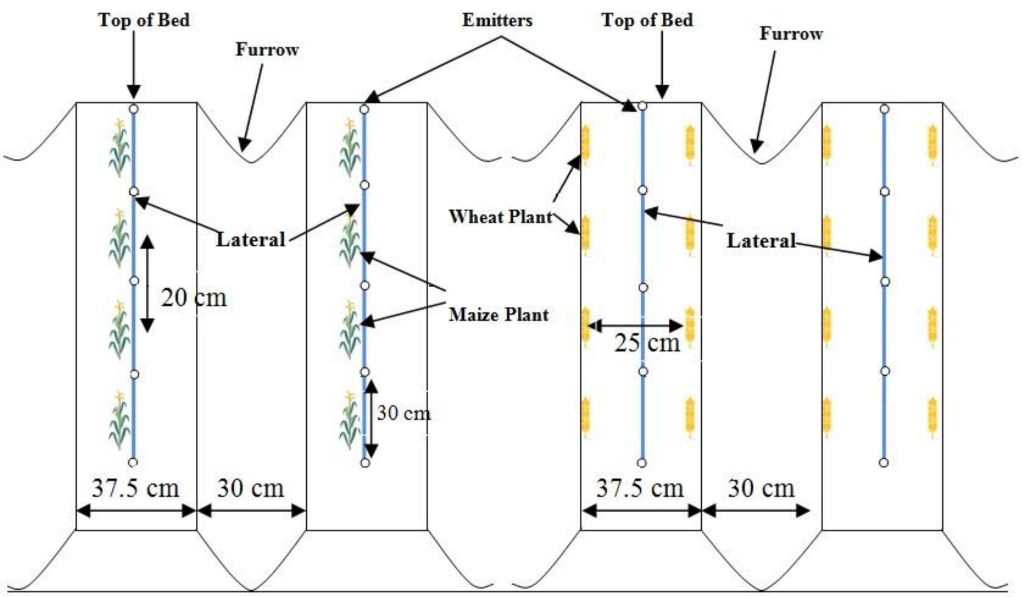


Fig 5: Layout of permanent raised beds and drip irrigation

Table 5: Detail of treatments for Experiment-II

Treatments	Symbol
Main Treatments: Tillage and straw management systems	
Permanent bed -Residue Removed	FIPB-R
Permanent raised bed -Residue Retained (maize 50% + wheat 25%)	FIPB+R
Sub Treatments: Nitrogen rate and application methods	
Zero – N control	N_0
75% of recommended N-Uniform broadcasting	$RN_{75\%}$-B
75% of recommended N-Drilled/Placement on top of bed	$RN_{75\%}$ -POT
75% of recommended N-Drilled/Placed in Furrow	$RN_{75\%}$-PIF
100% of recommended N-Uniform broadcasting	$RN_{100\%}$ -B
100% of recommended N- Drilled/Placement on top of bed	$RN_{100\%}$ -POT
100% of recommended N- Drilled/Placed in Furrow	$RN_{100\%}$-PIF

Experiment III: Decomposition rate and nutrient dynamics of crop residue as affected by depth of placement.

Maize, wheat and moongbean residue used in the experiment was collected from on-going field experiment involving permanent bed tillage-residue management and N fertilizer treatments. The trial was laid out as randomized block design with three replicates of six different type of residues and two methods of placement. The maize residues were placed during the wheat crop cycle after the harvest of maize crop and, wheat and moongbean residues were placed during maize crop cycle after the harvest of wheat and relay moong. The treatments were: (1) Maize top 50% ($MT_{50\%}$); (2) Maize lower 50% ($ML_{50\%}$); (3) Wheat top 75% ($WT_{75\%}$); (4) Wheat lower 25% ($WL_{25\%}$); (5) Moongbean 100% ($MB_{100\%}$); (6) Wheat lower 25% + Moongbean 100% ($WL_{25\%}$ + $MB_{100\%}$) and two methods of placement (1) Surface placed (2) Sub surface placed. The straws were air-dried and cut into 1-2 cm lengths before use in the experiment. The kinetics of residue decomposition and the subsequent release of N, P and K release were studied using a nylon mesh bag technique (Beare *et al,* 2002). Initial nutrient content and quality parameters of the different residue was calculated before the start of experiment (Table 6 and Table 7). Bags containing maize residues were placed in the field on 30 November 2013 after the sowing of wheat and the bags containing wheat and moongbean residues were placed in the field on 07 July 2014 after the sowing of maize. Nylon mesh bags containing different residues were sampled 7 times (30, 60, 90, 120, 150, 270 and 365 days after placement) during the growing season of maize and wheat. Fifty gram of residue (cut into 1-2 cm size) was placed in each nylon bag (1 mm mesh). On seven permanent beds each of 20 m long six sealed nylon mesh bags for i.e three on soil surface and three on sub surface (10-12 cm deep)

Table 6: Initial weight taken and initial nutrient content in different type of residues

Type of Residue	Weight (g)	N (%)	P (%)	K (%)
Maize Res $T_{50\%}$	50	0.52	0.044	1.050
Maize Res $L_{50\%}$	50	0.48	0.044	0.800
Wheat Res $T_{75\%}$	50	0.40	0.088	1.250
Wheat Res $L_{25\%}$	50	0.32	0.075	1.525
MungRes $_{100\%}$	50	1.08	0.118	1.425
$MR_{100\%}$+$WRL_{25\%}$	50	0.64	0.112	1.125

Table 7: Quality parameters of different type of residues

Type of Residue	Neutral Detergent Fibre (NDF) (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Silica (%)
Maize Res $T_{50\%}$	82	33	41	7	1
Maize Res $L_{50\%}$	82	35	38	6	3
Wheat Res $T_{75\%}$	84	29	42	9	4
Wheat Res $L_{25\%}$	86	19	45	17	5
MungRes $_{100\%}$	74	15	44	14	1
$MR_{100\%}$+$WRL_{25\%}$	82	23	41	16	2

for three replicate in each treatment were placed horizontally at equal distance. The position of each nylon bag was marked with nylon thread tied to a wooden stick. Six nylon mesh bags from each bed were removed at regular intervals on each of seven samplings for each treatment. Residue remaining on each sampling date was taken out from the bag, shaken gently over a sieve (1 mm) to remove bulk of soil and finally washed off closely with distilled water. Samples were then oven-dried at 60˚C for 48 h, weighed, and ground to pass through 1 mm sieve. The loss in residue mass of the residue in a bag was considered as decomposed. Total N in residues was determined by Kjeldahl method (Keeney and Nelson 1982). For determination of P and K content, residue was wet-digested with a mixture HNO_3–H_2SO_4–$HClO_4$ (10:4:1). Phosphorous in the wet digest was measured colorimetrically by the molybdate yellow colour method using spectrophotometer (Olsen *et al*, 1954) and K by flame photometry (Brown and Warencke 1998). Total N, P and K of the residue was calculated by multiplying % N, P and K by the weight remaining at each sampling period. The change in the N, P and K contents of the decomposing residue represented the amount that had mineralized/immobilized during the period.

3.6 Description of materials used

3.6.1 Particulars about the maize variety PMH-1

It has tall plants with well developed root system. The stem has purple coloration and is zig-zag and sturdy. The leaves are medium broad. Tassel is open and medium in size. Ears are medium long with yellow orange flint grains. Its average yield is 21 quintals per acre and matures in 95 days. The plants stay green at maturity.

3.6.2 Particulars about the wheat variety HD 2967

This variety is recommended for timely sown irrigated condition of North Western Plain Zone. Its average yield is 5.0 t ha^{-1} and was released in 2011 for cultivation. It possesses very high degree of resistance against most prevalent leaf rust disease. It has also better degree of resistance against leaf blight and matures in 143 days.

3.6.3 Particulars about the mungbean variety SML-668

Mungbean variety SML-668 was developed by Punjab Agricultural University from AVRDC line NM 94 in 2000, which gives better yield performance (upto 2.5 t ha^{-1}), synchronous and early maturity, bold and shining seeds and is also tolerant to MYMV disease. It is a medium duration variety, suitable for *kharif* and spring/summer seasons. It is also having medium plant height, seeds are bright and medium in size. Plants remain green at pods maturity, maturity period varies from 60 to 62 days.

3.6.4 Crop residues

Maize harvest manually at cob height and 50 % stover (below cob portion) was left standing in all tillage, residue and legume treatments except residue removed treatments, in which maize harvested at ground level and all maize stover removed from field. After wheat harvest, all the loose residues were removed and only the anchored wheat stubbles were retained after straw retrieval in residue retained treatments and remove of wheat stables after straw retrieval in case of residue removed treatmenst. After pod picking, all the moongbean residues were retained on soil surface in residue retained treatments.

3.7 Agronomic practices

3.7.1 Pre-sowing operations to maize and wheat

Herbicide application

Tank mix solution of glyphosate (Round up 41 %) was applied in the zero tillage treatment plots to control grassy as well as broad leaf weeds before sowing of the crops.

Land prepration

Before establishment of the cover crop at the start of experiment, the field was ploughed using disc plough to break hard pan if any. Thereafter, it was pulverized at the optimum moisture level (field capacity) with a cultivator and then levelled using a laser-assisted precision land levelling system attached with a 60- horsepower (hp) tractor. Permanent raised beds were made with a bed planter at a distance of 67.5 cm from top of the one bed to top of the second bed with 37.5 cm top and 30 cm furrow and bed height of 8 inch for sowing of crop. These permanent beds were reshaped during sowing of succeeding crops with bed planter during both years.

3.7.2 Wheat

Fertilizer application

In the 1st experiment nitrogen (N) was applied as per treatment in each experimental unit through fertigation in five splits after 25 days of sowing at 10 days interval by taking the recommended dose of nitrogen as 120 kg ha^{-1}. Rate of nitrogen application as worked out was 60, 90, 120 and 140 kg N ha^{-1} for treatments of 50, 75,100 per cent of recommended nitrogen dose and for NE treatment, respectively. The P and K were added to all the experimental units @ 60 kg P_2O_5 and 30 kg K_2O ha^{-1}, respectively.

In case of 2nd experiment N was applied as per treatment in each experimental unit through drilling with the help of double-disc seed cum fertilizer drill. Half dose of N and full dose of P_2O_5 and K_2O were applied at the time of sowing of wheat. Remaining half nitrogen was applied through drilling with the help of double-disc seed cum fertilizer drill at first irrigation at CRI stage.

Urea, Diammonium Phosphate and Muriate of Potash formed the source for N, P and K, respectively. In both the experiments DAP.

Seed treatment

Seed treatment was done with chlorpyrifos (20 EC @90 ml/100 kg seed + 5 liter water) before sowing of crop for the control of termite infestation.

Seed sowing

In both the experiments the wheat variety HD-2967 was sown by using the double-disc drilling machine was used to establish two rows of wheat crop on top of the raised beds by keeping 25 cm row spacing on the same bed. The seed rate of wheat used for sowing on beds and CT was 100 kgha^{-1}.

Gap filling

The gap filling was accomplished in wheat immediately after the germination in order to maintain uniform optimum plant population.

Weed management

Tank mix solution of Algrip 20 WP (*metsulfuron*) 25g ha^{-1}and *clodinafop* (15 WP) 400g ha^{-1}was applied to control weeds after 25 days of sowing of crop.

Irrigation

In the experiment I, irrigation was applied on the basis of tensiometer reading, by using soil matric potential of 35 kPA at 15 cm depth. In experiment I, every drop of water applied to the plots was recorded by using the water meter installed at the main pipe of the water source to calculate the water use efficiency of the crop. In experiment II, irrigation was applied at critical stages of crop growth as recommended by Punjab Agricultural University.

Harvesting and threshing

At maturity, plants from net plots were harvested separately and produce was left in the field for some days to get dried. Biological yield was recorded. Threshing was done by using thresher. Each net plot grains were cleaned and weighed for estimation of yield and was expressed in kg ha^{-1}. The weight of straw was recorded by subtracting grain weight from biological yield.

3.7.3 Mungbean

Seed inoculation

The seed of moongbean were inoculated with recommended *Rhizobium* culture at the time of sowing. To inoculate the seed, required seed was wet with minimum amount of water. The seeds were heaped on a clean cemented floor and the inoculants was poured and mixed. The inoculated seeds were dried in shade and sown immediately.

Seed sowing

Moongbean seeds were sown in the standing wheat, when the wheat crop was at its maturity stage at the rate of 20 kg ha^{-1} by kera-pora method. Two rows of moongbean crop are sown in each furrow at the two edges of the furrow with the help of kera-pora in the standing wheat.

Thinning and gap filling

Extra plants in the rows were thinned to maintain the intra-row spacing. The gap filling was accomplished immediately after the germination in order to maintain optimum and uniform plant population.

Irrigation

In the summer moongbean, irrigation was scheduled based on the crop water requirement and gap in rainfall. To supplement the rainfall two irrigations were given during both the years.

Harvesting and threshing

The harvesting of moongbean was done by manual picking of pods. The grains were separated manually. Each net plot seed were cleaned and weighed for estimation of seed yield in tha^{-1}. The weight of stover was recorded separately and used for estimating the biological yield.

3.7.4 Maize

Fertilizer application

In the 1st experiment nitrogen (N) was applied as per treatment in each experimental unit through fertigation in seven splits after 20 days of sowing at 10 days interval by taking the recommended dose of nitrogen as 120 kg ha^{-1}. Rate of nitrogen application as worked out was 60, 90, 120 and 140 kg N ha^{-1} for treatments of 50, 75, 100 per cent of recommended nitrogen dose and for NE treatment, respectively. The P and K were added to all the experimental units @ 60 kg P_2O_5 and 30 kg K_2O ha^{-1}, respectively.

In case of 2nd experiment N was applied as per treatment in each experimental unit through manual placement with the help of double-disc seed cum fertilizer drill. Half dose of N and full dose of P_2O_5 and K_2O were applied at the time of sowing of wheat. Remaining half nitrogen was applied through drilling with the help of double-disc seed cum fertilizer drill at first irrigation at CRI stage.

Urea, Diammonium Phosphate and Muriate of Potash formed the source for N, P and K, respectively.

Seed treatment

Seed was treated with Gaucho (imidacloprid) 600 FS @ 6.0 ml per kg seed before planting for protection against attack of shoot fly and with Bavistin (carbendazim) @ 3g per kg seed for protection against various fungal diseases.

Seed sowing

The maize hybrid PMH-1 was sown in both the experiments with one row on top of the raised beds at a spacing of 67.5 cm between two beds and 20 cm plant to plant distance in all tillage, residue and legume treatments by using the double-disc drilling machine. The seed rate of maize used was 20 $kgha^{-1}$.

Thinning and gap filling

Extra plants in the rows were thinned to maintain intra-row spacing at three weeks after sowing. The gap filling was accomplished immediately after the germination in order to maintain optimum and uniform plant population.

Weeding and inter-cultivation

Herbicide Atrataf 50 WP (atrazine) was applied as pre-emergence @ 1.25 kg ha^{-1} using 500 litres of water with knap sack sprayer using flat fan nozzle for controlling the weeds. One inter-cultivation was done at knee high stage with the tractor operated reshaper, by hoeing the soil which besides checking weed growth provides good aeration to plant roots. One hand weeding was also done at 55 days after planting.

Irrigation

In the experiment I, irrigation was applied on the basis of tensiometer reading, by using soil matric potential of 35 kPA at 15 cm depth. In experiment I, every drop of water applied to the plots was recorded by using the water meter installed at the main pipe of the water source to calculate the water use efficiency of the crop. In experiment II, irrigation was applied at critical stages of crop growth as recommended by Punjab Agricultural University

Plant Protection measures

Tank mix solution of chlorpyrifos (20 EC) and endosulfan (Thiodone @ 0.03%) was sprayed once in the standing crop in order to control stem borer and termite infestation.

Harvesting

The crop was harvested manually when more than 80 per cent of the cob husk turned yellowish brown and grains became hard. The net plot size harvested was 5.0 m × 2.7 m = 13.5 m^2 i.e. central four rows were harvested leaving two border rows one row each on both side of the plot. The cobs were harvested manually by plucking method.

Threshing

The cobs were dehusked manually after harvesting and were allowed to dry for another three days and thereafter the threshing was done using maize dehusker cum thresher. The maize grain yield was converted to quintal ha^{-1} at 14.5 per cent moisture.

3.8 CROP GROWTH ATTRIBUTES

3.8.1 Wheat

Plant height (cm)

Plant height was recorded at maximum tillering stage, ear emergence stage and at maturity satge from ten randomly tagged plants in central rows of each experimental unit and average value was calculated for reporting. Plant height was measured from ground level to tip of flag leaf at maximum tillering stage and from ground level to the base of the spikelet in ear emergence and at maturity stage.

Periodic dry matter accumulation (g m^{-2})

In wheat, one meter bed length area was selected after leaving the first row from either side of the plot for the measurement of dry matter accumulation. The samples were sun dried first and then in an oven at 65^0C till the constant weight arrived. The dry weight was expressed as g/m^2.

Leaf area index

The periodic leaf area index (LAI) at maximum tillerg stage, ear emergence stage and at maturity stage of wheat crop and was recorded by using the Sun Scan Canopy Analyzer, Model: Sun Scan type SS1, Manufactured by Delta-T Devices, Cambridge- England.

3.8.2 Maize

Plant height (cm)

Plant height was recorded at knee high stage, tasseling stage, silking stage and at maturity from ten randomly tagged plants in central rows of each experimental unit and average value was calculated for reporting. Plant height was measured from ground level to the base of whorl during early stages and from ground level to base of the tassel after tasselling stage.

Periodic dry matter accumulation (g/plant)

One meter bed length was randomly selected and plants were harvested every time at knee high stage, tasseling stage, silking stage and at maturity from each plot and plants were sun dried and then dried in the oven at 60^0C to a constant weight for recording dry matter accumulation which was then expressed as grams plant^{-1}.

Leaf area index

The periodic leaf area index (LAI) at maximum tillerg stage, ear emergence stage and at maturity stage of wheat crop and was recorded by using the Sun Scan Canopy Analyzer, Model: Sun Scan type SS1, Manufactured by Delta-T Devices, Cambridge- England.

3.9 Yield and yield attributes

3.9.1 Wheat

Spike length (cm)

Length (cm) of ten representative spikes from each plot was measured with the scale and then average value was expressed as length of spikes.

Number of tillers/m^2

Number of effective and ineffective tillers (ear bearing and non ear bearing tillers) were counted from one meter bed length area randomly from two spots in the net plot, averaged and expressed as number of tillers per square meter area.

1000-grain weight (g)

A representative sample of grains was taken from the produce of the each plot after drying and cleaning and weight of 1000-grains recorded and was expressed in grams.

Grain yield (t ha^{-1})

The net plots, leaving two border rows were harvested and kept for sun drying for some days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying the grain, grain yield was recorded. Final yield was expressed in t ha^{-1}.

Straw yield (t ha^{-1})

The weight of straw was computed by subtracting the weight of grain from total drymatter yield of each net plot. Final yield was expressed in kg ha^{-1}.

3.9.2 Maize

Number of cobs per plant

Total number of plants and total number of cobs obtained from each net harvested plot were counted. Number of cobs were divided by total number of plants to calculate number of cobs per plant.

$$\text{Number of cobs per plant} = \frac{\text{Total number of cobs per plot}}{\text{Total number of plants per plot}}$$

Cob length (cm)

Five cobs were randomly selected from each plot during harvest and their length from base to tip of the cob was measured and the mean value was recorded in cm.

Shelling percentage

It was calculated as the weight of grains as percentage of whole cobs' (without husk) weight

$$\text{Shelling percentage} = \frac{\text{Grain yield (q ha}^{-1})}{\text{Whole cob weight (q ha}^{-1})} \times 100$$

1000-grain weight (g)

A representative sample of grains was taken from the produce of the each plot after drying and cleaning and weight of 1000-grains recorded and was expressed in grams.

Grain yield (t ha^{-1})

After separating from stalk and shelling of husk and silk, all the cobs from each plot were dried in the sun and threshed by a mechanical thresher. The grain yield was adjusted to 14.5% moisture content and expressed as t ha^{-1}.

Stover yield (t ha^{-1})

Cobs were picked and the remaining plant material including husk was sun dried, weighed and expressed as stover yield (t ha^{-1}).

3.9.3 Moongbean

Grain yield (t ha^{-1})

The net plots, leaving two border rows were harvested and kept for sun drying for some days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying the pod, grain yield was recorded. Final yield was expressed in t ha^{-1}.

Stover yield (t ha^{-1})

Before threshing, the total biological yield from net plot area was recorded. The stover yield per plot was obtained by deducting the seed yield per plot from the biological yield.

3.10 Water use studies

3.10.1 Irrigation water applied (only in experiment 1)

The total irrigation water applied in the experiment-I was measured with the help of water meter installed at the main pipe of the water source.

3.10.2 Water use efficiency (WUE)

The water-use-efficiency was calculated by the formula (Reddy and Reddy 2006).

$$\text{WUE} = \frac{\text{Y}}{\text{W}}$$

Where,

WUE = Water-use-efficiency (kg ha^{-1}cm^{-1})

Y = Grain yield (kg ha^{-1})

W = Irrigation water applied (cm) to the crop

3.11 Chemical analysis

3.11.1 Plant analysis for NPK uptake

The dry matter samples collected at different growth stages of maize and wheat, grain and cob cores of maize were collected at harvest, dried in sun and then in oven. Plant samples were ground in Wiley Mill and passed through 32 mesh size sieve. Grain samples were ground in small grinding mill. The samples were used for estimation of nitrogen, phosphorus and potassium content.

3.11.1.1 Nitrogen uptake

Nitrogen content in different samples were determined by modified Micro-Kjeldhal's method (Subbiah and Asija 1956). Oven dried 0.5 g sample was subjected to wet digestion using 10 ml concentrated sulphuric acid plus pinch of digestion mixture [(potassium sulphate (480 g) + copper sulphate (20 g) + selenium powder (1 g) + mercury oxide(3 g)]. Digested material was taken in a 50 ml volumetric flask and the volume was made to 50 ml by adding distilled water. In the distillation flask of Micro-Kjeldhal's assembly, 5 ml of distilled sample was taken and 10 ml of sodium hydroxide (NaOH 40%) was poured into tube. Flask containing 10 ml boric acid 4% was kept under the consideration until the appearance of green colour. Then distilled sample was titrated against N/50 sulphuric acid until appearance of purple colour. Volume of N/50 H_2SO_4 used was recorded for N content calculation. The nitrogen uptake by dry matter samples at different growth stages, grains and cob cores were calculated by multiplying the per cent N content with their respective biomass yields.

3.11.1.2 Phosphorus uptake

The 0.5 g oven dried grounded sample was digested in triple acid mixture i.e. nitric acid (HNO_3), perchloric acid ($HClO_4$) and sulphuric acid (H_2SO_4) in the ratio of 9:3:1, respectively. The phosphorus in the different samples only in experiment-III were determined by using Vanado-Molybdo-Phsophoric yellow colour method in nitric acid (Jackson 1967). Intensity of colour developed was measured by using Spectronic-20 Colorimeter at wavelength of 470 nm using blue filter. Per cent content of phosphorus in different samples were multiplied by respective biomass yields to calculate the phosphorus uptake.

3.11.1.3 Potassium uptake

The aliquot (digested material of different samples) used for phosphorus determination, were used for the determination of potassium content in different samples only in experiment-III using Lange's Flame Photometer (Jackson 1967). The potassium uptake different samples were calculated by multiplying per cent content of potassium with their respective biomass yields.

3.12 Soil analysis

Soil samples were collected after the harvest of each crop during the second year. Samples were collected 0-7.5, 7.5-15, 15-30 and 30-45 cm profile from each plot. The soil samples were placed in shade air drying. The dried samples were crushed gently in wooden pestle and mortar, and then passed through 2mm sieve for separating coarse fragments, if any. The fine soil fraction passing through 2mm sieve used to carried out analysis for various phyico-chemical properties of soil.

3.12.1 Soil reaction (pH)

A soil suspension was prepared with distilled water keeping 1:2 soil to water ratio and the concentration of hydrogen ions in soil (pH) of suspension was measured by potentiometric method (Jackson 1973). The pH of the solution being proportional to the potential developed on the glass membrane was measured in conjunction with saturated calomel electrode as reference electrode.

3.12.2 Electrical conductivity (EC)

The soil suspension used for pH determination was also used to measure soluble salts after keeping them overnight to obtain a clear supernatant solution. The soluble salts in the soil were measured with a conductivity meter, also known as salt bridge. The conductivity of electric current through soil suspension is proportional to the concentration of soluble salts in it (Richard 1954). The EC was expressed as deci siemens per meter (dS m^{-1}).

3.12.3 Organic carbon (OC)

Rapid titration method (wet digestion method) was used for organic carbon determination (Walkley and Black 1934). In this determination 2 gm of dried soil was treated with 10 ml of 1*N* $K_2Cr_2O_7$ solution in a 250 ml conical flask. A 20 ml of concentrated H_2SO_4 was slowly added to the flask. After 30 minutes, about 0.5 gm of NaF, 100 ml of distilled water and 10 drops of diphenylamine indicator were added to the flask. These contents were titrated against 0.5*N* ferrous ammonium sulphate solution. The change from violent to bright green through blue colour was the end point. The value of ferrous ammonium sulphate used for titration was adopted for calculating organic carbon and was expressed as percentage. In another flask, 10 ml of 1*N* $K_2Cr_2O_7$ solution was titrated without soil against 0.5*N* ferrous ammonium sulphate solution to determine blank reading.

3.12.4 Nitrate (NO_3-N) and Ammonical (NH_4-N) Nitogen

For determining NO_3-N and NH_4-N, a 10 g portion of the fresh soil samples was extracted with 100 ml of 2 M-KCl solution after shaking for 1 hour. Suspension was filtered and filtrate was analysed for NO_3-N and NH_4-N by steam distillation using Devarda's alloy and MgO respectively (Bremner 1965).

3.12.5 Available soil phosphorus

It was determined by the 0.5 M sodium bicarbonate method given by Olsen *et al* (1954). Soil was shaken with bicarbonate extractant for half an hour. Then the clear filtered soil extract was treated with ammonium molybdate, complexing agent. In the presence of reducing agent (ascorbic acid) the soil extract gave blue colour. The intensity of the blue colour was measured with a colorimeter at a wavelength of 760 mμ using red filter. From the standard curve the amount of phosphorus present in soil was calculated.

3.12.6 Available soil potassium

Determination of available potassium was done by the method given by Merwin and Peech (1950). The index of potassium availability is the sum of exchangeable and water soluble potassium. The extraction of potassium was accomplished by using neutral normal ammonium acetate solution as the extractant. The extract, thus obtained was tested for its content of potassium with the help of a flame-photometer.

3.14 Statistical analysis

The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1983) for split plot design using SAS 9.1 software (SAS Institute, Cary, NC). The Tukey procedure was used where ANOVA was significant and results are presented at 5% level of significance (P=0.05). The split up of degrees of freedom (d.f.) for different sources of variation are given in Table 8 and 9**.**

Table 8: ANOVA table for experiment-I

Source of variation	Symbols	Degrees of freedom (d.f.)	
Replications (3)	R	(r-1)	3-1 = 2
Main treatments (4)	A	(a-1)	4-1 = 3
Main plot error (replicates × A)	R×A	(r-1) × (a-1)	2 × 3 = 6
Sub treatments (5)	B	(b-1)	5-1 = 4
AB	A × B	(a-1) × (b-1)	3 × 4 = 12
Sub plot error (replicates × AB)	R×AB	a (r-1) × (b-1)	4 × 2 × 4 =32
Total		**(r×a×b-1)**	**59**

Table 9: ANOVA table for experiment-II

Source of variation	Symbols	Degrees of freedom (d.f.)	
Replications (3)	R	(r-1)	3-1 = 2
Main treatments (2)	A	(a-1)	2-1 = 1
Main plot error (replicates × A)	R×A	(r-1) × (a-1)	2 × 1 = 2
Sub treatments (7)	B	(b-1)	7-1 = 6
AB	A × B	(a-1) × (b-1)	1 × 6 = 6
Sub plot error (replicates × AB)	R×AB	a (r-1) × (b-1)	2 × 2 × 6 =24
Total	**N**	**(r×a×b-1)**	**41**

CHAPTER IV

RESULTS AND DISCUSSION

The data recorded in relation to various parameters, results obtained and the supporting explanation with respect to the two year study entitled **“Enhancing yield and nitrogen use efficiency in maize-wheat system under conservation agriculture”** are presented in this chapter. The effect of drip irrigation along with fertigation and nitrogen levels and interaction amongst them (if any) and their comparison with flood irrigation method are presented under experiment I. The effect of different application methods of nitrogen and different nitrogen levels and interaction amongst them (if any) and their comparison with broadcasting method are presented under experiment II.

4.1 EXPERIMENT-I

The experiment was conducted in a split plot design design entitled as " Enhancing nitrogen use efficiency through fertigation in maize-wheat system under conservation agriculture". In general the method of irrigation, residue management and nitrogen levels affected various growth parameters, yield and yield attributes and nutrient uptake by plants significantly and thus has been discussed in detail along with the supporting studies. The various interaction effects were also not significant for various parameters. Hence, to avoid repetition have not been discussed under the individual parameters. Only the effects of main treatments and sub treatments have been discussed.

4.1.1 Growth attributes of wheat

4.1.1.1 Plant height

The effect of residue management and different nitrogen levels on plant height of wheat was observed at maximum tillering stage, panicle initiation stage and at maturity during the year 2013-14 and 2014-15 and is presented in Table 10. Plant height an index of growth and development representing the infrastructure build-up over a period of time, as well as an indicator of growth promoting or suppressing ability of treatments is dependent on genetic constitution of a particular cultivar and may also vary due to different agronomic manipulations which may alter the soil or above ground conditions for the better growth of crop plants. Plant height was not influenced significantly by tillage and residue management treatments at all the crop growth stages. Plant height recorded at maximum tillering stage was found to be lowest in FIPB-R (28.22 and 29.09 cm) and maximum was found in the $DIPB_{MB}$+R (29.99 and 32.20 cm) during both the years. However, the maximum plants heights (80.20 and 83.27 cm) were recorded at harvest under the residue retained treatments, while shortest plant was recorded under FIPB-Rduring both the years. This increase in plant height was mainly due to the fact that incorporating plant residues into agricultural soils can sustain organic carbon content, readily available C and N, improve soil physical properties,

Table 10: Effect of residue, irrigation and N management on plant height of wheat

Plant height (cm)						
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At maturity**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management						
FIPB-R	28.22	29.09	61.69	63.40	75.88	79.47
DIPB-R	29.17	31.15	62.81	63.90	78.57	81.97
DIPB+R	29.93	31.85	63.83	65.75	80.13	83.27
$DIPB_{MB}$+R	29.99	32.20	64.38	65.15	80.20	82.87
SEm±	**0.819**	**0.689**	**0.614**	**0.735**	**0.775**	**0.872**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels						
N_0 (Control)	23.95	24.89	52.80	53.64	65.70	67.28
$RN_{50\%}$	29.02	29.98	63.62	64.91	78.18	82.49
$RN_{75\%}$	30.53	32.25	64.84	66.76	80.41	84.81
$RN_{100\%}$	30.97	33.33	66.73	68.68	83.71	86.20
NE	32.17	34.91	67.90	68.75	85.41	88.19
SEm±	**0.661**	**0.526**	**0.665**	**0.704**	**0.905**	**0.721**
LSD (P=0.05)	**1.914**	**1.522**	**1.925**	**2.036**	**2.620**	**2.086**

enhance biological activities and increase nutrient availability (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu *et al* 2011). The increase in wheat plant height under drip irrigated treatments with applied fertigation methods than furrow irrigation may be as result of improved nitrogen use efficiency which is a major component in chlorophyll and other cellular constituents of plant (Kassem *et al* 2009). Secondly, It happened due to higher frequency of irrigation in drip irrigated plots which resulted in more availability of soil moisture for longer period. Frequent irrigation enhanced growth parameters due to quick development of extensive root system, which created a conducive environment to absorb more water and nutrients. It is well known fact that proper supply of water and nutrients helps in maintaining high photosynthetic rate, which increase cell division and its multiplication at a much faster rate which resulted in taller plants.Ram (2006) also reported higher values of plant height, dry matter accumulation, LAI, CGR and RGR under permanent bed with residue than no-residue under both zero-till and conventional till practices.

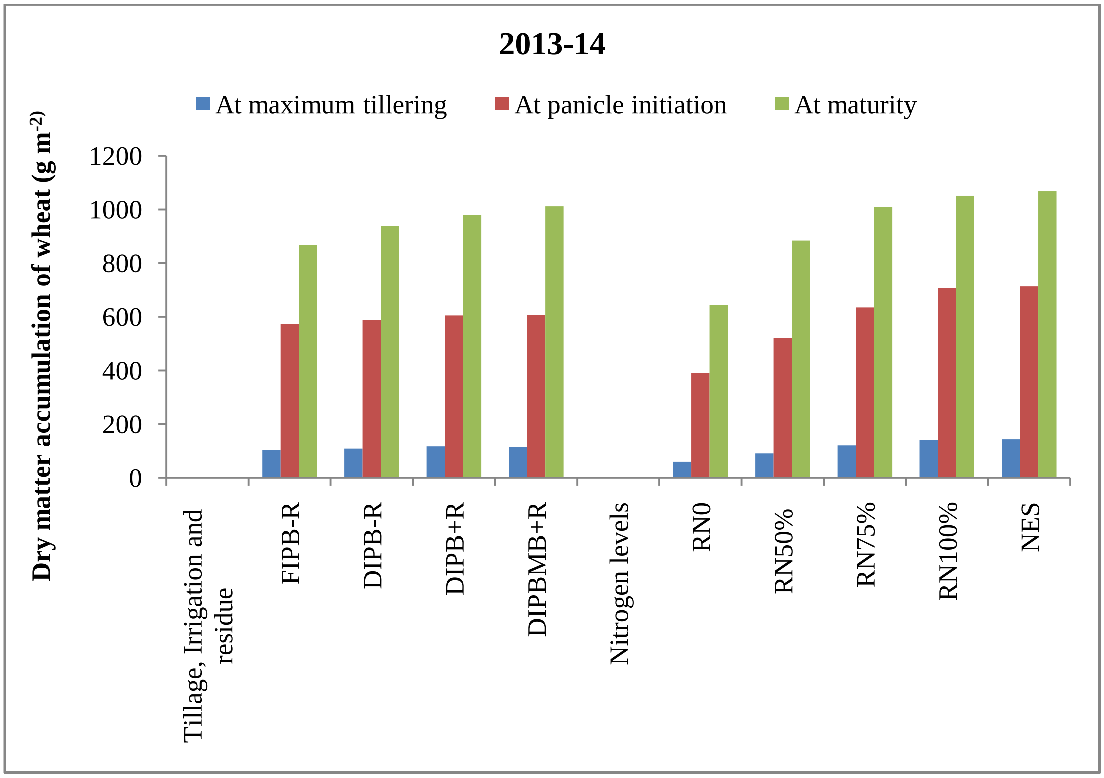
However the nitrogen levels had significant effect on plant height at all the observations i.e. at maximum tillering stage, at panicle imitation stage and at maturity. At maximum tillering stage, it was observed that with the addition of plant nutrients to crop, there was increase in the plant height of the wheat crop as compared to control. The NE i.e 140 kg N ha^{-1} resulted in significantly taller plants at maximum tillering and at panicle initiation stage and, was statistically on par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} but significantly higher than control and $RN_{50\%}$ i.e 60 kg N ha^{-1} treatments in both the years. At harvest, NE i.e 140 kg N ha^{-1} had significantly taller plants than all other nitrogen levels and was statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}, which was statistically at par with nitrogen level of $RN_{75\%}$ at all growth stagesduring both the years. The increase in plant height with increase in the nitrogen level might be due to higher accumulation of photosynthates with increased level of nitrogen fertilizer. Fluegel and Johnson (2001) reported that higher N had a positive effect on plant height on wheat varieties. Singh *et al* (2010) observed that with successive increase in nitrogen level from 0 to 150 kg N ha^{-1}, the magnitude of plant height was increased significantly. Khalil *et al* (2011) also reported that 160 kg N ha^{-1} and 80 kg N ha^{-1} gave plant heights of 81.9 cm and 76.2 cm respectively.

4.1.1.2 Dry matter accumulation

Accumulation of dry matter has been a good index to express the photosynthetic efficiency of plant under different treatments. With the advancement in the age of the crop there was increase in the dry matter of the wheat crop as presented in Table 11 and Fig. 6. Dry matter accumulation rate was slow at early growth stages, but at peak growth and plant development it accelerated tremendously during both the years. Irrigation and residue management showed significant effect on dry matter accumulation. At all growth

Table 11: Effect of residue, irrigation and N management on dry matter accumulation of wheat

Dry matter accumulation (g m^{-2})						
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At maturity**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management						
FIPB-R	103.69	105.39	572.82	584.10	867.57	882.64
DIPB-R	108.91	113.74	587.44	592.81	937.69	946.73
DIPB+R	117.14	119.35	604.73	607.47	979.86	982.20
$DIPB_{MB}$+R	114.73	118.54	606.32	613.53	1011.42	998.02
SEm±	**2.397**	**1.813**	**5.270**	**1.975**	**16.624**	**14.503**
LSD (P=0.05)	**8.456**	**6.397**	**18.592**	**6.967**	**58.646**	**51.164**
Nitrogen levels						
RN_0	59.94	60.47	389.60	389.84	643.96	660.44
$RN_{50\%}$	91.13	101.75	519.72	528.09	883.69	873.17
$RN_{75\%}$	120.48	119.04	634.36	632.85	1009.13	1001.26
$RN_{100\%}$	140.82	140.66	706.96	724.27	1051.09	1055.68
NES	143.22	149.34	713.49	722.33	1157.80	1171.43
SEm±	**2.137**	**1.713**	**6.578**	**4.33**	**19.629**	**13.340**
LSD (P=0.05)	**6.183**	**4.957**	**19.034**	**12.82**	**56.803**	**38.603**



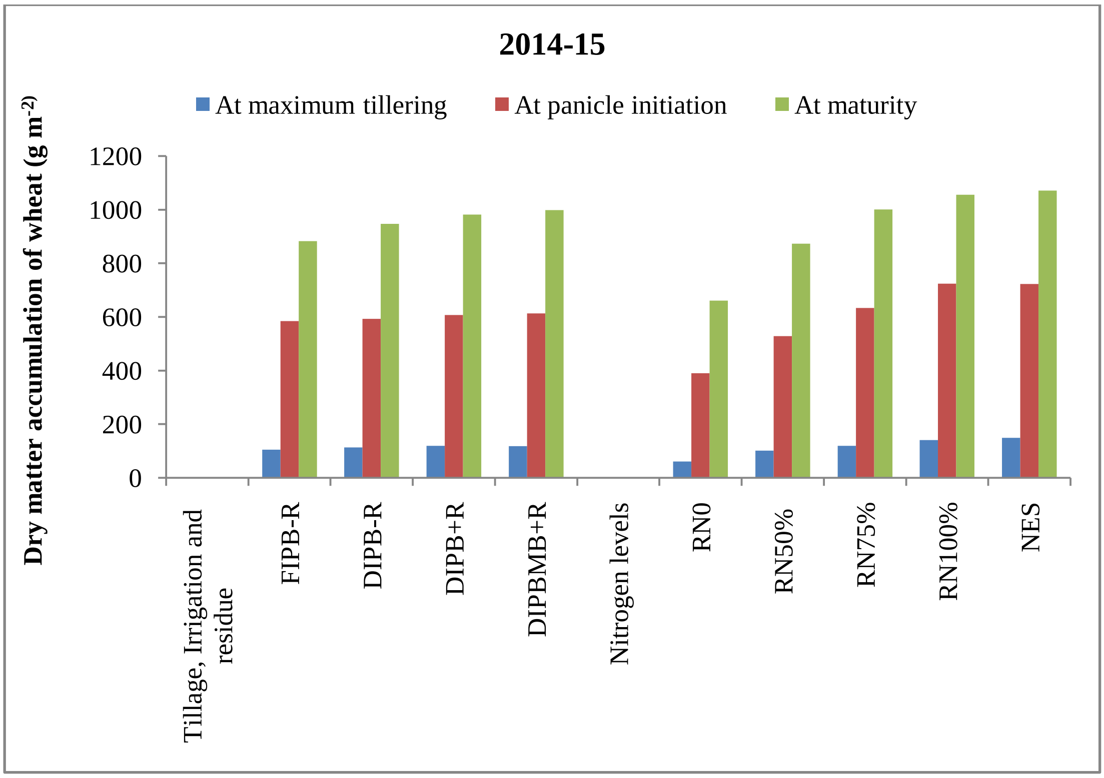


Fig.6: Effect of residue, irrigation and N management on dry matter accumulation of wheat

stages significantly higher dry matter accumulation was found in residue retained treatments as compared to the residue removed treatments. At maximum tillering stage significantly higher dry matter accumulation was found in DIPB+R (117.14 and 119.35 g m^{-2}) as compared to the FIPB-R (103.69 and105.39 g m^{-2}), which is statistically at par with $DIPB_{MB}$+R (114.73 and 108.91 g m^{-2})and DIPB-R (108.91 and 113.74 g m^{-2}) respectively during both the years. At panicle initiation and at maturity stage significantly higher dry matter accumulation was found in $DIPB_{MB}$+R as compared to the FIPB-R which is statistically at par with DIPB+R in both the years. Ram (2006) also reported higher values of plant height, dry matter accumulation, LAI, CGR and RGR under permanent bed with residue than no-residue under both zero-till and conventional till practices.

Nitrogen levels showed significant effect on dry matter accumulation at various growth stages. Significantly higher dry matter accumulation was recorded at maximum tillering and maturity stage under NE i.e 140 kg ha^{-1} than the other nitrogen levels. However, the nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} was found to be statistically at par with NE i.e 140 kg ha^{-1} at panicle initiation stage. Nitrogen involved in numerous physiological processes and constituents of chemical components of plant which may bring about higher dry matter accumulation. This could be because of utilization of nitrogen which upgraded leaf area bringing about higher photo-assimilates and thereby brought about higher dry matter accumulation. Yadav *et al* (2010) studied that the dry matter accumulation in wheat also increased with N level upto 80 $kgha^{-1}$over 0, 40 and 60 $kgha^{-1}$. Kumar *et al* (2014) also observed that the dry-matter accumulation, leaf-area index, crop growth rate and relative growth rate were significantly higher with site-specific nutrient management over the recommended dose of fertilizer under conservation agriculture.

4.1.1.1 Leaf area index

Leaf area index (LAI) is good index of crop growth and is a major character influencing the assimilating capacity of the crop. Higher the LAI means more interception of photosynthetically active radiation which is the source of energy during the process of photosynthesis. So, higher the LAI better is the crop growth, resulting in higher yield. The data on LAI recorded at various growth stages have been presented in Table 12 and Fig.7. After giving fast look at the data it was observed that LAI was not influenced significantly due to tillage, residue and legume treatments at all the growth stages of wheat. However the maximum LAI was recordered at maximum tillering stage under $DIPB_{MB}$+R and the lowest LAI reordered under FIPB-R. At early growth stage LAI were low, but it was increased on later stages and reached maximum at panicle initiation stage during both the year.

Table 12: Effect of residue, irrigation and N management on leaf area index (LAI) of wheat

LAI						
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At maturity**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management						
FIPB-R	1.59	1.47	2.01	2.42	1.76	1.73
DIPB-R	1.65	1.55	2.37	2.61	1.86	1.91
DIPB+R	1.67	1.57	2.55	2.61	1.91	1.93
$DIPB_{MB}$+R	1.71	1.62	2.51	2.64	1.92	1.97
SEm±	**0.033**	**0.054**	**0.183**	**0.127**	**0.096**	**0.087**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels						
RN_0	1.43	1.43	1.59	1.85	1.26	1.42
$RN_{50\%}$	1.59	1.46	2.34	2.59	1.91	1.88
$RN_{75\%}$	1.68	1.53	2.36	2.74	1.95	2.02
$RN_{100\%}$	1.74	1.65	2.68	2.82	2.07	2.02
NES	1.83	1.68	2.84	2.86	2.13	2.1
SEm±	**0.050**	**0.044**	**0.123**	**0.129**	**0.075**	**0.072**
LSD (P=0.05)	**0.146**	**0.128**	**0.357**	**0.373**	**0.217**	**0.208**

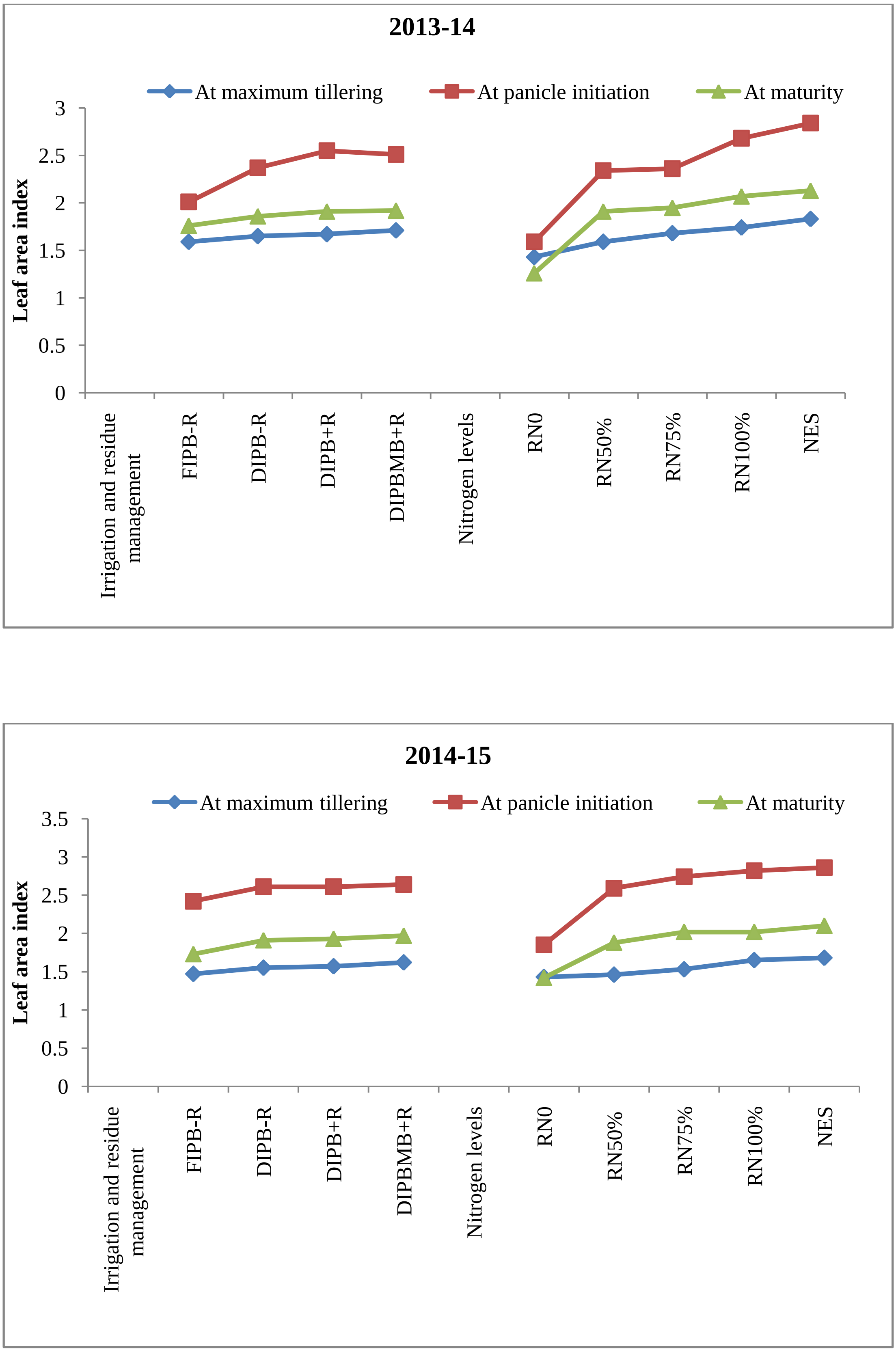


Fig.7: Effect of residue, irrigation and N management on leaf area index (LAI) of wheat

Leaf area index was significantly influenced by different N levels at various growth stages. At all growth stages NE i.e 140 kg ha^{-1} had significantly higher LAI than control, nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}. It was as excepted since vegetative growth resulting from higher photosynthetic activities is well known to be influenced by increased levels. These corroborates the findings of Kibe *et al* (2006) who reported that LAI reached its maximum value (4.22) with applied N of 140 kg ha^{-1}. These results are also supported by (Salvagiotti and Miralles 2008) who stated that increase in N concentration at anthesis stage can results increased in leaf area index by as much as 62%. It was also concluded by Saeed *et al* (2012) that application of nitrogen at tillering stage influenced the leaf architecture by maximizing the LAI. However at all growth stages nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} had LAI statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}.

4.1.2Yield attributes of wheat

4.1.2.1 Effective tillers

Wheat yield is greatly influenced by the number of effective tillers per unit area. The effect of residue management and different nitrogen levels on total number of effective tillers m^{-2} of wheat during 2013-14 and 2014-15 are presented in Table 13.The maximum value of effective tillers were observed under $DIPB_{MB}$+R (376.51 and 376.79 m^{-2}) which was statistically similar with DIPB+R (371.85 and 374.03m^{-2}) and statistically higher than the FIPB-R (347.94 and 352.0m^{-2}) and DIPB-R (362.24 and 366.92/m^2), respectively during 2012-13 and 2013-14. The application of fertilizer through drip fertigation than soil application produced significantly higher effective tillers which might be due to more nutrient uptake, fertilizer utilization efficiency and percentage of nutrient derived from fertilizer as compared with soil application (Tumbare *et al* 1999).The retention of residue under permanent bed treatment resulted higher values of effective tillers m^{-2}than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002). Parihar *et al* (2016) likewise demonstrated the beneficial outcomes of PB and residue retention on grain yield of wheat which could be ascribed to the higher effective tillers m^{-2}, higher spike density, higher number of grains per spike and 1000-grain weight. Yadav *et al* (2005) also reported that ZT led to improvement in growth and yield attributes, viz. plant height, effective tillers, grains/ear and 1000- grain weight due to better establishment of plants as a result of less weed competition under ZT. It was observed that with the increase in the N levels, there was increase in the number of effective tillers m^{-2}. However, nitrogen level of NE i.e 140 kg N ha^{-1} resulted in significantly higher effective tillers m^{-2} than the control and nitrogen level of $RN_{50\%}$

Table 13: Effect of residue, irrigation and N management on yield attributes of wheat

Treatments	Effective tillers m^{-2}		Spike length (cm)		1000-grain weight (g)	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management						
FIPB-R	347.94	352.00	14.93	15.22	39.07	41.06
DIPB-R	362.24	366.92	14.91	15.37	39.73	41.61
DIPB+R	371.85	374.03	14.96	15.56	40.13	41.53
$DIPB_{MB}$+R	376.51	376.79	15.06	15.64	40.07	41.81
SEm±	**3.800**	**3.443**	**0.227**	**0.160**	**0.302**	**0.247**
LSD (P=0.05)	**13.407**	**12.144**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels						
RN_0	270.36	274.45	14.55	15.05	38.67	40.35
$RN_{50\%}$	357.23	352.72	14.77	15.38	39.25	41.45
$RN_{75\%}$	390.59	383.83	14.85	15.31	39.42	41.91
$RN_{100\%}$	400.42	402.22	15.41	15.63	40.42	41.93
NES	404.58	406.05	15.25	15.8	41.00	41.87
SEm±	**3.596**	**3.319**	**0.126**	**0.130**	**0.421**	**0.294**
LSD (P=0.05)	**10.405**	**9.604**	**0.364**	**0.377**	**1.162**	**0.851**

i.e 60 kg N ha^{-1} , but statistically at par with nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} and nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}. Similar results were also obtained by Abdelraouf*et al* (2013), who reported that decreasing the fertigation level from 100 to 50 per cent recommended dose significantly decreased most of growth characters, spike length, effective tillers m^{-2} , biological and grain yield, and seed index, but significantly at par with the 75% of recommended dose. This is mainly because of, fertigation can maintain the desired concentration and distribution of ions and water in the soil (Bar-Yosef *et al* 1999), while minimizing leaching of N from the root zone of agricultural fields (Gardenas et al 2005). However, the application of water and N in excess of crop requirements contributes to the leaching of water and N below the root zone under drip irrigation. Significant increase in effective tillers m^{-2} with each successive increment of nitrogen from 80 to 120 kg ha^{-1} was also observed by Mishra *et al* (2011).

4.1.2.2 Spike length

Spike length may serve as reliable criteria to access crop yield as it is an indicator of yield because increase in spike length will influence the number of grains spike^{-1}. After giving fast look at the data Table 13. It was observed that spike length was not influenced significantly due to irrigation, residue and legume treatments. However the maximum spike length was reordered under $DIPB_{MB}$+R followed by DIPB+R and the lowest spike length reordered under FIPB-R. This increase in spike length was mainly due to the fact that retaining plant residues into agricultural soils can sustain organic carbon content, readily available C and N, improve soil physical properties, enhance biological activities and increase nutrient availability (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu *et al* 2011). Das *et al*(2014) also observed that permanent bed planting with residue retention practice produced significantly higher spike length than conventional tillage without residue retention.

The nitrogen levels significantly improved the spike length over control treatment. Nitrogen level NE i.e 140 kg ha^{-1} had significantly higher spike length than control, nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}.This could be due to increased photosynthates with increasing nitrogen levels. Hussain *et al* (2006) also reported increased spike length with increasing nitrogen fertilizer levels. Similar results were also obtained by Abdelraouf*et al* (2013), who reported that decreasing the fertigation level from 100% to 50% recommended dose significantly decreased spike length.

4.1.2.2 1000-grain weight

The data on 1000-grain weight have been presented in Table 13. The grain weight indicates the nature and extent of grain development. It is a function of various production factors that influence grain development and filling patterns. 1000-grain weight was not significantly influenced by different treatment combinations of irrigation, residue management and legume. However, 1000-grain weight was found to be lowest in FIPB-R (39.07 and 41.06 g) and maximum was found in the $DIPB_{MB}$+R (40.07 and 41.81g) during both the years. The retention of residue under permanent bed resulted higher values of 1000-grain weight than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues (Yadav *et al* 2005). The increase in wheat 1000-grain weight under drip irrigated treatments with applied fertigation methods than furrow irrigation may be as result of producing higher number of spikes m^{-2} and heavy kernels weight which were enhanced and produced by improved nitrogen use efficiency which is a major component in chlorophyll and other cellular constituents of plant (Kassem *et al* 2009).

The nitrogen levels had significant effect on 1000-grain weight of wheat. Nitrogen level NE i.e 140 kg ha^{-1} had significantly higher 1000-grain weight than control, nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}. Yadav *et al* (2010) also studied that the 1000-grain weight in wheat also increased with N level upto 80 kg/ha over 0, 40 and 60 kg/ha. This could be due to increased photosynthates with increasing nitrogen levels. Similar results were also obtained by Abdelraouf *et al* (2013), who reported that decreasing the fertigation level from 100 to 50 per cent recommended dose significantly decreased 1000-grain weight.

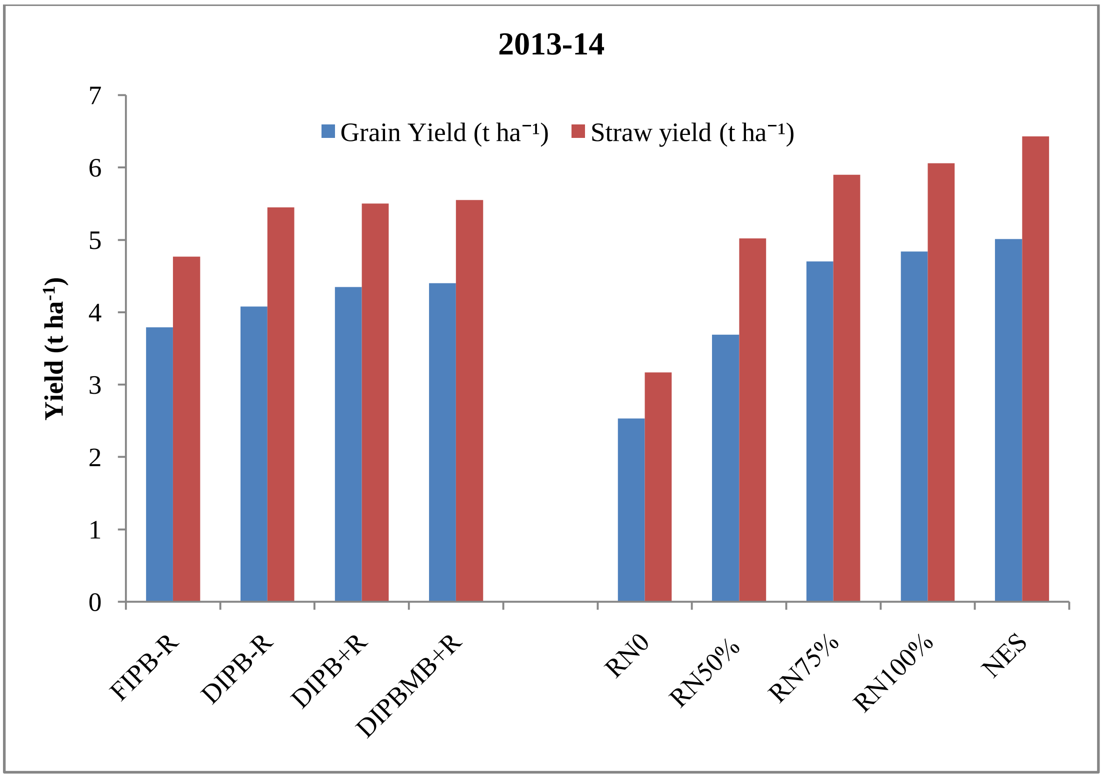
4.1.3Grain and straw yield of wheat

4.1.3.1 Grain yield

Grain yield is function of effective tillers, number of grains per ear and 1000-grain weight etc. The grain yield of wheat crop was significantly influenced due to different irrigation, residue and legume treatments. The data regarding grain yield presented in Table 14 and Fig.8. Among the different treatments highest grain yield was obtained in$DIPB_{MB}$+R (4.40 and 4.54 t ha^{-1}) which was statistically similar with DIPB+R (4.35 and 4.38) and, statistically higher than the FIPB-R (3.79 and 3.94 t ha^{-1}) and DIPB-R (4.08 and 4.20 t ha^{-1}). There is a approximately 16.09 and 15.22 per cent increase in yield with drip irrigation along with residue retention as compared to furrow irrigation without residue retention in both the years, respectively. Irrigation scheduling based on drip irrigation results into more than 90 percent irrigation efficiency. As water and nutrient is applied as often as possible and consistently, as a result there is no moisture stress in crop root zone and it comes about into 25 to 30 per cent increase in crop yield as compared to surface irrigated crop (Wang *et al* 2013, Pawar *et al* 2014). The significantly higher yield of wheat under $DIPB_{MB}$+R in comparison to FIPB-R was mainly attributed to increase in effective tillers m^{-2}, spike length and 1000- grain weight which was enhanced by optimum and favourable soil moisture, moderated soil

Table 14: Effect of residue, irrigation and N management on grain and straw yield of wheat

Treatments	**Grain yield (t ha^{-1})**		**Straw yield (t ha^{-1})**	
	2013-14	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management				
FIPB-R	3.79	3.94	4.77	4.89
DIPB-R	4.08	4.20	5.45	5.42
DIPB+R	4.35	4.38	5.50	5.49
$DIPB_{MB}$+R	4.40	4.54	5.55	5.79
SEm±	**0.061**	**0.054**	**0.124**	**0.100**
LSD (P=0.05)	**0.215**	**0.190**	**0.437**	**0.351**
Nitrogen levels				
RN_0	2.53	2.62	3.17	3.31
$RN_{50\%}$	3.69	3.78	5.02	4.78
$RN_{75\%}$	4.70	4.84	5.90	6.07
$RN_{100\%}$	4.84	4.98	6.06	6.23
NES	5.01	5.11	6.43	6.53
SEm±	**0.062**	**0.053**	**0.085**	**0.078**
LSD (P=0.05)	**0.178**	**0.154**	**0.246**	**0.225**



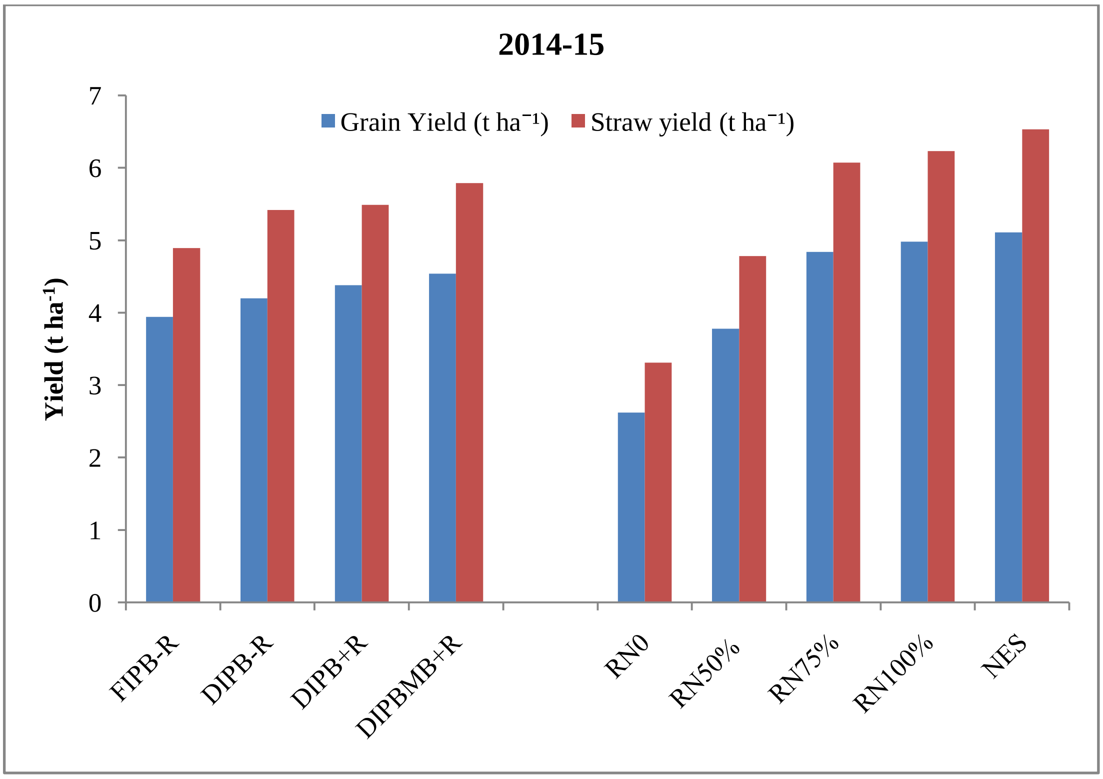


Fig.8: Effect of residue, irrigation and N management on grain and straw yield of wheat

temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues. Similarly, Ram *et al* (2010) also reported higher yields under ZT with residue due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture, tillers, grains/ear and 1000-grain weight than no-residue application under ZT and CT practices.

Positive effects of PB and residue retention on grain yield of wheat was also observed by Prihar *et al* (2016). Wheat grain and straw yields was highest in PB plots compared to ZT and CT.The significantly higher wheat grain yield were recorded in the PB plots compared with ZT and CT plots, which could be attributed to the higher spike density, number of grains per spike and 1000-grain weight.

However, the nitrogen levels significantly influenced the grain yield. All fertilizer treatments produced significantly higher grain yield than unfertilised control in both the years. The nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher grain yield than control and nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1}, but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N $ha^{-1}$and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1}. Fertigation with nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} produced similar yield with the nitrogen level $RN_{100\%}$ i.e 120 kg N ha^{-1}, and thereby saving the 25 per cent of the nitrogen fertilizer. The increase in growth and yield owing to the application N fertilizer may be attributed to the fact that this nutrient being constituents of nucleotides, protein, enzymes and chlorophyll which have direct positive effect on reproductive and vegetative growth. Kachroo and Razdan (2006) observed the similar effects. These findings are in accordance with Khan et al (2001) who reported that there is increase in grain yield with increase in N. Ram *et al* (2002) also reported significant increase in grain yield up to 120 kg N ha^{-1}. Singh *et al* (2009) also studied the same nitrogen effects of nitrogen levels on grain yield. With increase in N levels 0 to 75 kg N ha^{-1} grain yield was increased from 15.75 to 17.09 q ha^{-1} showing a linear trend (Khan *et al* 2011). Singh *et al* (2011) showed that the recommended practice of 120 kg N ha^{-1} increased the wheat yield by 61-95% over the control without N fertilizer.

4.1.3.2Straw yield

The straw yield of wheat crop was significantly influenced due to different irrigation, residue and legume treatments. The data regarding grain yield presented in Table 14. Among the different treatments highest straw yield was obtained in$DIPB_{MB}$+R (5.55 and 5.79 t ha^{-1}) which was statistically higher than the FIPB-R (4.77 and 4.89 t ha^{-1}), but statistically similar with DIPB+R (5.50 and 5.49 t ha^{-1}) and DIPB-R (5.45 and 5.42 t ha^{-1}). More straw yield under drip irrigation as compared to furrow irrigation treatment was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season (Pawar *et al* 2013, Frederick *et al* 2001). Abdullah and Pawar (2013) also reported significantly higher straw yield under drip fertigation which was mainly due to split application of fertilizers at appropriate time through drip irrigation. Parihar *et al* (2016) showed the positive effects PB and residue retention on grain and starw yield of wheat. Wheat grain and straw yields were highest in PB plots with residue retention (4.44 and 6.54 Mg ha^{-1}) as compared to CT without residue retention (3.73 and 5.72 Mg ha^{-1}), this might be due to less lodging of wheat crop under PB systems with residue retention. Increase in grain and straw yield of wheat in PB with residue retention may be attributed to the positive effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), improved soil health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009), lesser weed population (Ozpinar 2006, Chauhan *et al* 2007), and improved nutrient use efficiency compared to CT without residue retention (Unger and Jones, 1998).

Among different levels of nitrogen, all the nitrogen levels recorded significantly higher straw yield over control treatment. The nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher straw yield than control, nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}.Khalil *et al* (2011) reported that each increment of N increased straw yield and maximum yield (10095 k ha^{-1}) was recorded at 160 kg N ha^{-1}however, it was not significantly different from yield produced by 120 kg N ha^{-1}. Similar effects were also observed by Singh *et al* (2007) where straw yield was higher at 160 kg N ha^{-1} as compared to 80 kg N ha^{-1}. Increase in straw yield with with increased N levels could partly be attributed to its direct influence on dry matter production of vegetative part and indirectly through increased morphological parameters of growth i.e. plant height, dry matter, LAI and number of effective tiller m^{-2}.

4.1.4 Plant analysis

4.1.4.1 Nitrogen content

The effect of residue management and different nitrogen levels on nitrogen content of wheat was observed at different growth stages of wheat during the year 2013-14 and 2014-15 and is presented in Table 15. Nitrogen content was not influenced significantly by irrigation and residue management treatments at all the crop growth stages. Nitrogen content recorded at maximum tillering stage and at panicle initiation stage was found to be lowest in FIPB-R (3.27 and 2.79 %) and maximum was found in the $DIPB_{MB}$+R (3.39 and 3.12 %) during both the years. Similarly, $DIPB_{MB}$+R recorded higher nitrogen content in grain and straw over all other treatments but not a significant difference was observed. Higher nutrient content was found in the drip irrigation treatments as compared to furrow irrigation which was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season and due to split application of fertilizers at appropriate time through drip irrigation (Abdullah and Pawar 2013).

Table 15: Effect of residue, irrigation and N management on N content at different growth stages of wheat

Nitrogen content (%)								
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At Maturity**			
					Grain		**Straw**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management								
FIPB-R	3.27	2.79	1.44	1.42	1.73	1.68	0.45	0.38
DIPB-R	3.32	2.91	1.57	1.50	1.74	1.70	0.47	0.44
DIPB+R	3.33	2.98	1.64	1.61	1.76	1.72	0.48	0.48
$DIPB_{MB}$+R	3.39	3.12	1.69	1.68	1.81	1.71	0.50	0.49
SEm±	**0.025**	**0.071**	**0.055**	**0.061**	**0.059**	**0.045**	**0.022**	**0.025**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	2.91	2.46	1.27	1.30	1.47	1.46	0.41	0.34
$RN_{50\%}$	3.24	2.77	1.40	1.40	1.64	1.55	0.46	0.41
$RN_{75\%}$	3.44	3.08	1.66	1.56	1.74	1.69	0.45	0.44
$RN_{100\%}$	3.51	3.20	1.75	1.72	1.92	1.88	0.51	0.49
NES	3.54	3.27	1.82	1.78	2.06	1.93	0.54	0.56
SEm±	**0.034**	**0.116**	**0.047**	**0.051**	**0.064**	**0.067**	**0.026**	**0.033**
LSD (P=0.05)	**0.097**	**0.337**	**0.135**	**0.149**	**0.187**	**0.194**	**0.075**	**0.097**

However the nitrogen levels had significant effect on N content at all the observations i.e. at maximum tillering stage, at panicle imitation stage and at maturity in grain and straw. At maximum tillering stage, it was observed that with the addition of plant nutrients to crop, there was increase in the N content of the wheat crop as compared to control. The NE i.e 140 kg N ha^{-1} resulted in significantly higher N content as compared to the control and $RN_{50\%}$ i.e 60 kg N ha^{-1} treatments at maximum tillering and at panicle initiation stage and, was statistically on par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1}during both the years. In grain and straw significantly higher N content was observed in NE i.e 140 kg N ha^{-1} than control and $RN_{50\%}$ i.e 60 kg N ha^{-1} treatments and, was statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}, which was statistically at par with nitrogen level of $RN_{75\%}$ during both the years. Gill and Kaur (2003) also observed that nitrogen content in grain and straw increased with increase in the nitrogen level. Significant improvement in the N content of wheat in grain and straw with increase in the nitrogen level up to 120 kg N ha^{-1} was observed by Ahmad *et al* (2015) working in Allahabad.

4.1.4.2 Nitrogen uptake

Irrigation, residue management and legume brought significant differences in the nutrient uptake by the wheat. The data regarding N uptake presented in Table 16. Among the different treatments at maximum tillering stage highest N uptake was obtained in $DIPB_{MB}$+R (39.57 and 37.69 kg ha^{-1}) which was statistically similar with DIPB+R (39.71 and 36.75 kg ha^{-1}) and, statistically higher than the FIPB-R (34.62 and 30.08 kg ha^{-1}) and DIPB-R (36.97 and 34.11 kg ha^{-1}). Similarly, N uptake by grain and straw was significantly higher under the $DIPB_{MB}$+R (82.07, 79.08 and 28.15, 29.46 kg ha^{-1}) as compared to the FIPB-R (68.20, 68.01 and 21.85, 19.68 kg ha^{-1}), respectively in both the years. However higher nutrient uptake in the drip irrigation treatments as compared to furrow irrigation which was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season and due to split application of fertilizers at appropriate time through drip irrigation (Abdullah and Pawar 2013). Bahera *et al* (2007) also reported maximum N uptake under ZT with residue retention, which might be due to addition of nutrients through residue, better root growth, leading to more extraction of nutrient from soil, lower weed infestation and better performance of crop, improved physical environment favourable for better microbial activity that might helped in mineralization resulting better availability of nutrients (macro and micro) to crops and thus increased the uptake under these treatments.

The data regarding N uptake presented in Table 18 reveals that Nuptake under different growth stages increased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}. However, increase in the N dose up to 140 kg N ha^{-1} did not differ statistically with that of 120 Kg N ha^{-1} dose at different growth stages. At maximum tillering

Table 16: Effect of residue, irrigation and N management on N uptake at different growth stages of wheat

Nitrogen uptake (kg ha^{-1})								
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At Maturity**			
					Grain		**Straw**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management								
FIPB-R	34.62	30.08	84.41	85.81	68.20	68.01	21.85	19.68
DIPB-R	36.97	34.11	94.66	91.54	72.78	73.47	26.18	24.77
DIPB+R	39.71	36.75	101.81	99.47	77.54	76.57	26.96	27.16
$DIPB_{MB}$+R	39.57	37.69	105.00	105.19	82.07	79.08	28.15	29.46
SEm±	**0.931**	**1.120**	**3.910**	**3.632**	**2.364**	**2.076**	**1.157**	**1.895**
LSD (P=0.05)	**3.284**	**3.950**	**13.795**	**12.814**	**8.340**	**7.324**	**4.082**	**6.684**
Nitrogen levels								
RN_0	17.44	14.89	49.63	50.99	36.86	38.47	13.03	11.55
$RN_{50\%}$	29.50	28.17	72.93	74.20	60.62	58.53	23.41	19.77
$RN_{75\%}$	41.74	36.59	105.71	98.69	82.06	82.03	26.81	26.68
$RN_{100\%}$	49.50	44.80	123.96	124.89	93.37	93.59	31.02	31.42
NES	50.68	48.84	130.10	128.74	102.83	98.78	34.67	36.87
SEm±	**0.816**	**1.301**	**3.508**	**3.074**	**2.836**	**2.991**	**1.239**	**1.915**
LSD (P=0.05)	**2.362**	**3.776**	**10.151**	**8.896**	**8.207**	**8.655**	**3.586**	**5.543**

and panicle initiation stage the maximum N uptake was with the nitrogen level NE i.e 140 kg N ha^{-1}, which was statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} but significantly higher than control, $RN_{50\%}$ i.e 60 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} in both the years. The NE i.e 140 kg N ha^{-1} resulted in significantly higher N content at maximum tillering and at panicle initiation stage and, was statistically on par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1}, but significantly higher than control and $RN_{50\%}$ i.e 60 kg N ha^{-1} treatments in both the years. In grain and straw significantly higher N content was observed in NE i.e 140 kg N ha^{-1} than control and $RN_{50\%}$ i.e 60 kg N ha^{-1} treatments and, was statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}, which was statistically at par with nitrogen level of $RN_{75\%}$ during both the years. Nitrogen uptake in grain and straw was also found significantly higher with NE i.e 140 kg N ha^{-1} (102.83, 98.78 and 34.67, 36.87 kg ha^{-1}) as compared to the control (36.86, 38.47 and 13.03, 11.55 kg ha^{-1}) and $RN_{50\%}$ i.e 60 kg N ha^{-1} (60.62, 58.53 and 23.41, 19.77 kg ha^{-1}) during both the years, respectively. Similarly, Ahmad *et al* (2015) also reported significant improvement in the N uptake in wheat grain with increase in the nitrogen level up to 90 kg N ha^{-1} and, nitrogen dose up to 120 kg N ha^{-1} did not differ statistically with that of 90 Kg N ha^{-1} dose. Similar effects of nitrogen levels on nitrogen uptake were also observed by Kumar and Ahlawat (2006) in which nitrogen uptake was increased with increased nitrogen levels. Also Jing *et al* (2009) reported that the increase in nitrogen uptake at 300 kg N ha^{-1}over control, 75, 150 and 225 kg N ha^{-1}.

4.1.5 Nitrogen use efficiency (NUE)

The ability of crops to use the applied N depends on the uptake and utilization efficiency. Tillage, residue management and legume brought significant differences in the NUE by the wheat. The data regarding NUE presented in Table 17.Among the different treatments highest NUE was obtained in $DIPB_{MB}$+R (50.18 and 51.69 kg kg $^{-1}$) which was statistically higher than the FIPB-R (43.00 and 45.44 kg kg^{-1}) and DIPB-R (46.63 and 47.88 kg kg^{-1}), but statistically at par with the DIPB+R (50.02 and 49.93 kg kg^{-1}). More NUE under drip irrigation as compared to furrow irrigation treatment was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season (Pawar *et al* 2013, Frederick *et al* 2001).Fertigation empowers the utilization of dissolvable fertilizers and different chemicals alongside with irrigation water, consistently and all the more proficiently which eventually increment the utilization efficency (Patel and Rajput 2000). Abdullah and Pawar (2013) also reported significantly higher NUE under drip fertigation which was mainly due to split application of fertilizers at appropriate time through drip irrigation. Abdullah *et al* (2015) also reported significantly higher nitrogen use efficiency in drip irrigation applied fertilizer as compared to the surface irrigation in which nitrogen was applied through broadcasting, which might be due to more leaching of fertilizers in surface irrigation method.

Table 17: Effect of residue, irrigation and N management on Irrigation water productivity (IWP) and Nitrogen use efficiency (NUE) of wheat

Treatments	**IWP (kg ha^{-1}cm^{-1})**		**NUE (kg kg^{-1})**	
	2013-14	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management				
FIPB-R	131.55	147.65	43.00	45.44
DIPB-R	192.27	214.78	46.63	47.88
DIPB+R	224.07	237.98	50.02	49.93
$DIPB_{MB}$+R	226.98	245.72	50.18	51.69
SEm±	**2.234**	**3.014**	**0.670**	**0.545**
LSD (P=0.05)	**7.882**	**10.634**	**2.364**	**1.923**
Nitrogen levels				
RN_0	117.92	130.69	-	-
$RN_{50\%}$	172.36	187.33	61.49	63.06
$RN_{75\%}$	219.42	239.74	52.24	53.81
$RN_{100\%}$	225.67	246.83	40.31	41.54
NES	233.21	258.07	35.79	36.53
SEm±	**2.920**	**2.776**	**0.556**	**0.508**
LSD (P=0.05)	**8.449**	**8.032**	**1.633**	**1.491**

The data regarding NUE presented in Table 19 reveals that NUE decreased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}. Significantly higher NUE was obtained with the N level of $RN_{50\%}$ i.e. 60 kg N ha^{-1} as compared to all other N level. Nitrogen use efficiency is greater when the yield response to N is high. Therefore, this efficiency is generally high with low N rates and decreases in accordance with the rate increase of applied N (Parodi 2003). Sinebo *et al* (2004) also reported that N uptake efficiency was higher at lower rates of N application but drastically decreased with further increases in the rate of the nutrient. Rahman *et al* (2000) also observed that efficiency of N gradually decreased with increasing N rate and three split applications showed better efficiency of N with higher yield as compared to all basal or two split applications in no-till wheat. While comparing the N level NE i.e 140 kg N ha^{-1} with the N level of $RN_{75\%}$ i.e 90 kg N ha^{-1}, it was observed that N level of $RN_{75\%}$ i.e 90 kg N gave signficanly higher NUE and comparable yield with the N level NE i.e 140 kg N ha^{-1}, which is considered as a best N management strategy for drip irrigated wheat.

4.1.6 Water productivity (WP)

Irrigation and WP are positively correlated with grain yield of the crop and negatively correlated with amount of irrigation water applied. The lowest WP was obtained under FIRB-R (131.55 and 147.65 kg ha^{-1}-cm) as compared to the all other treatments during 2012-13 and 2013-14. In both the years $DIPB_{MB}$+R (226.98 and 245.72 kg $ha^{-1}cm^{-1}$) gave significantly higher WP as compared to the FIRB-R (131.55 and 147.65 kg $ha^{-1}cm^{-1}$) and DIPB-R (192.27 and 214.78 kg $ha^{-1}cm^{-1}$). The higher WP in drip irrigation as compared to the furrow irrigation was mainly due to reduction in irrigation water requirement in drip as compared to the furrow irrigation. The better root growth and lower infestation of weeds in the drip irrigation was might be other possible reasons of higher IWP under $DIPB_{MB}$+R. The higher WP in $DIPB_{MB}$+R as compared to the DIPB-R might be due to residue retention, which might suppressed the weed growth and also helped in soil moisture conservation that made available for the longer durations to the crop. Jat *et al* (2005) reported that irrigation water use (ha m^{-3}) in both maize and wheat was highest (3231 and 3700) under conventional till followed by zero-till (2723 and 2934) and the lowest being (2030 and 2619) under FIRB planting system, respectively. Remarkably higher water productivity (kg grain m^{-3} water) of either crop of maize and wheat was recorded in FIRB planting (2.79 and 1.98) followed by flat no-till (1.74 and 1.89) and the lowest (1.36 and 1.38) in conventional-till system. The increase in water productivity is the resultant of both increase in yield and saving in irrigation water.

However, the nitrogen levels significantly influenced the WP. All fertilizer treatments produced significantly higher WP than unfertilised control in both the years. The nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher WP (561.68 and 557.68 kg $ha^{-1}cm^{-1}$)than control (293.55 and 280.17 kg ha^{-1}-cm), nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} (440.47 and 417.20 kg ha^{-1}-cm) and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1}(523.87 and 524.80 kg ha^{-1}-cm),but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}(540.63 and 540.03 kg ha^{-1}-cm). The higher WP with increase in the N level was mainly due to the increase in grain yield with successive increase in N rate.

4.1.7 Growth attributes of maize

4.1.7.1 Plant Height

Plant height an index of growth and development representing the infrastructure build-up over a period of time, is dependent on genetic constitution of a particular cultivar and may also vary due to different agronomic manipulations which may alter the soil or above ground conditions for the better growth of crop plants. The data on plant height recorded at different growth stages are presented in Table 18. Plant height was influenced significantly by method of irrigation and residue management treatments at all the crop growth stages. Plant height recorded at knee height stage was found to be lowest in FIPB-R (46.61 and 46.39 cm) and maximum was found in the $DIPB_{MB}$+R (53.44 and 52.90 cm) which was statistically higher than the all other treatments during both the years. At the tasseling and silking stage, significantly higher plant height was recorded under the residue retained plots as compared to residue removed plots. Plant height increases linearly with the advancement of crop age and reaches to its maximum value at maturity stage with significantly higher value under the $DIPB_{MB}$+R (237.93 and 239.00) as compared to the all other main treatments. The higher plant height under $DIPB_{MB}$+R might be due to the effect by inclusion of summer legumes in preceding season that have improved the soil fertility; particularly N availability thereby improved growth and vigour of maize. The incorporating plant residues into agricultural soils can also sustain organic carbon content, promptly accessible C and N, improve soil physical properties, enhance biological activities and increase nutrient availability (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu*et al* 2011). The increase in plant height under drip irrigated treatments with applied fertigation methods than furrow irrigation may be as result of improved nitrogen use efficiency which is a major component in chlorophyll and other cellular constituents of plant (Kassem *et al* 2009, Rajuput *et al* 2004). Secondly, It happened due to higher frequency of irrigation in drip irrigated plots which resulted in more availability of soil moisture for longer period. Frequent irrigation enhanced growth parameters due to quick development of extensive root system, which created a conducive environment to absorb more water and nutrients. It is well known fact that proper supply of water and nutrients helps in maintaining high photosynthetic rate, which increase cell division and its multiplication at a much faster rate which resulted in taller plants.

Table 18: Effect of residue, irrigation and N management on plant height of maize

Plant height (cm)								
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**		**At maturity**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Irrigation and residue management management								
FIPB-R	46.61	46.39	189.152	191.43	209.893	216.55	213.33	220.23
DIPB-R	48.13	47.48	196.381	200.77	217.307	225.47	221.67	230.47
DIPB+R	50.43	48.90	202.478	206.53	222.973	229.30	228.33	234.97
$DIPB_{MB}$+R	53.44	52.90	212.289	213.77	233.760	237.20	237.93	239.00
SEm±	**0.981**	**0.643**	**2.047**	**1.809**	**1.686**	**1.398**	**2.216**	**1.943**
LSD (P=0.05)	**3.462**	**2.270**	**7.894**	**6.383**	**5.946**	**4.932**	**7.819**	**6.855**
Nitrogen levels								
RN_0	38.87	36.83	154.32	155.05	193.25	189.12	196.58	197.17
$RN_{50\%}$	48.03	48.39	200.51	207.58	215.10	224.78	219.33	227.88
$RN_{75\%}$	51.97	51.19	209.94	214.17	227.58	235.42	231.92	239.25
$RN_{100\%}$	53.28	52.73	215.27	217.46	232.48	241.04	236.75	243.54
NES	56.12	55.45	220.34	221.38	236.50	245.29	242.00	248.00
SEm±	**0.489**	**0.560**	**1.854**	**1.368**	**1.782**	**2.017**	**1.949**	**1.723**
LSD (P=0.05)	**1.414**	**1.621**	**5.364**	**3.959**	**5.155**	**5.838**	**5.639**	**4.895**

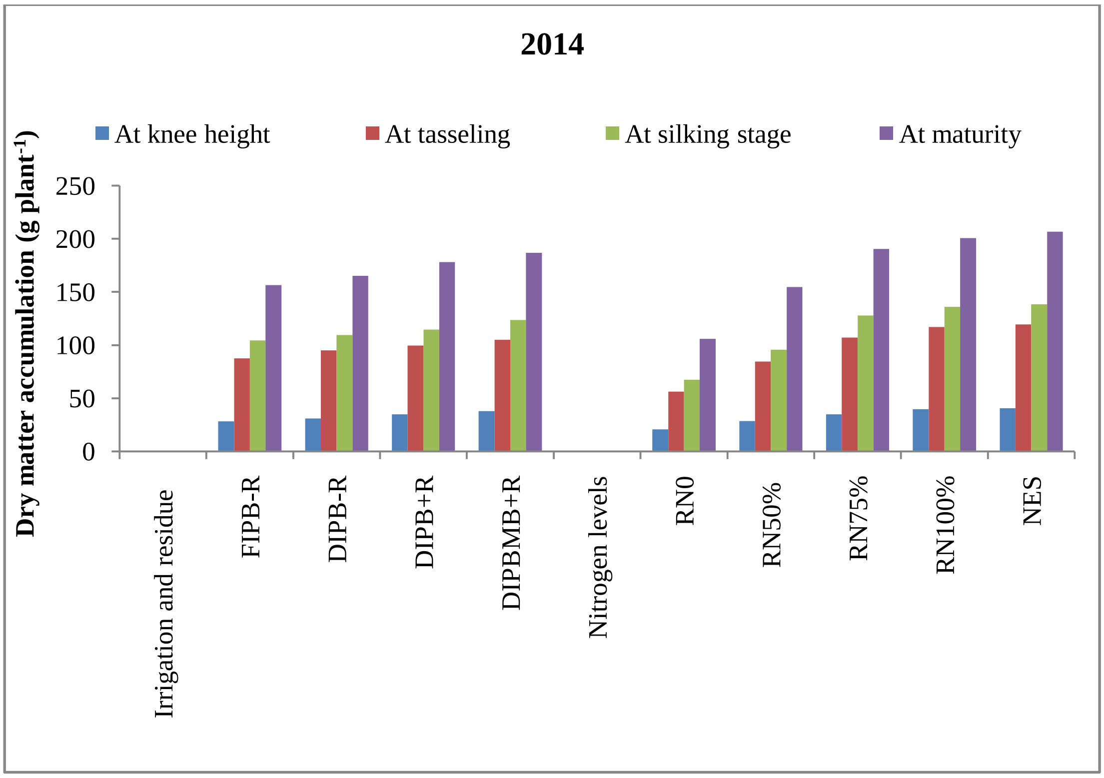
The plant height of maize increased with increase in nitrogen level (Table 18).At all growth stages, it was observed that with the addition of plant nutrients to crop, there was increase in the plant height of the maize crop as compared to control. The maximum plant height was observed under NE i.e. 140 kg N ha^{-1} which was statistically at par with $RN_{100\%}$ i.e. 120 kg N ha^{-1} but significantly better than $RN_{50\%}$ i.e 60 kg N ha^{-1} and $RN_{75\%}$ i.e 90 kg N ha^{-1}treatment at knee height stage, tasseling stage, silking stage and till harvest during both the years. Plant height under $RN_{75\%}$ i.e. 90 kg N $ha^{-1}$was statistically higher than under $RN_{50\%}$ i.e 60 kg N ha^{-1} at all growth stages and statistically at par with the $RN_{100\%}$ i.e. 120 kg N ha^{-1} during both the years. The improvement in plant height with increase in increment in nitrogen may be ascribed to the way that nitrogen a necessary component of proteins, the building building blocks of plant and it additionally helps in keeping up higher auxin level which may have brought about better plant height (Singh *et al* 2000). Similar results were reported by Kumar (2009) and Paradkar and Sharma (1993).

4.1.7.2Dry matter accumulation

Dry matter accumulation is an important feature showing the growth and metabolic efficiency of plants which ultimately affect the yield of crop. Optimum accumulation of dry matter followed by adequate partitioning of assimilates to the sink leads to higher grain yield. The data with respect to dry matter accumulation are reported in Table 19 and Fig. 9 Values of dry matter accumulation increased progressively with the advancement of crop age and maximum values were recorded at harvest stage of crop. In general, more accumulation of dry matter was recorded in year 2015 as compared to 2014 due to better growth of crop attributed due to better climatic conditions in that season. Among the different treatments, $DIPB_{MB}$+R and DIPB+R statistically at par but recorded significantly higher dry matter as compared to the FIPB-R during both the years of study. The treatment $DIPB_{MB}$+R maintained its superiority on the basis of dry matter accumulation to the other treatments at all growth stages by recording significantly higher dry matter accumulation over FIPB-R and DIPB-R during the two years of study. At harvest stage significantly higher dry matter accumulation was found in DIPB+R (178.08 and 185.73 g $plant^{-1}$) as compared to the DIPB-R (165.07 and173.29 g $plant^{-1}$) and FIPB-R (156.53 and162.97 g $plant^{-1}$) which is statistically at par with $DIPB_{MB}$+R (186.81 and 192.02 g $plant^{-1}$) respectively during both the years. The higher dry matter accumulation under the residue retained treatments was mainly due to the fact of better root growth (Aggarwal *et al* 2006), which might helped in better soil moisture extraction during dry periods and maintained the plant vigour. Secondly, better response of plant growth parameters towards fertigation as compared to furrow irrigation which affects the dry matter accumulation may be described due to continuously moist soil surface and water availability with drip irrigation which will also ensure optimum nutrient supply to plant roots with smooth mobility. Govaerts *et al* (2005) also reported that permanent bed planting along with rotation

Table 19: Effect of residue, irrigation and N management on dry matter accumulation of maize

Treatments	Dry matter accumulation (g $plant^{-1}$)							
	At knee height stage		At tasseling stage		At silking stage		At maturity	
	2014	2015	2014	2015	2014	2015	2014	2015
Irrigation and residue management management								
FIPB-R	28.19	31.79	87.63	95.78	104.35	109.34	156.53	162.97
DIPB-R	30.93	33.82	95.07	98.66	109.56	113.78	165.07	173.29
DIPB+R	34.91	35.10	99.55	103.71	114.68	120.45	178.08	185.73
$DIPB_{MB}$+R	37.81	37.54	105.08	107.28	123.73	131.63	186.81	192.02
SEm±	**1.894**	**0.967**	**2.589**	**1.263**	**2.178**	**3.106**	**2.865**	**3.096**
LSD (P=0.05)	**6.683**	**3.411**	**9.133**	**4.457**	**7.683**	**10.957**	**10.107**	**10.922**
Nitrogen levels								
RN_0	20.86	22.34	56.36	66.44	67.51	71.40	105.82	111.01
$RN_{50\%}$	28.65	31.85	84.47	89.83	95.59	101.36	154.65	158.19
$RN_{75\%}$	34.98	36.48	106.97	107.48	127.93	130.09	190.38	193.13
$RN_{100\%}$	39.57	40.40	116.96	119.45	135.86	143.08	200.74	214.69
NES	40.72	41.74	119.4	123.57	138.52	148.06	206.53	215.49
SEm±	**1.134**	**0.967**	**2.340**	**1.886**	**1.718**	**2.016**	**3.245**	**2.672**
LSD (P=0.05)	**3.282**	**2.423**	**6.772**	**5.458**	**4.971**	**5.835**	**9.390**	**7.731**



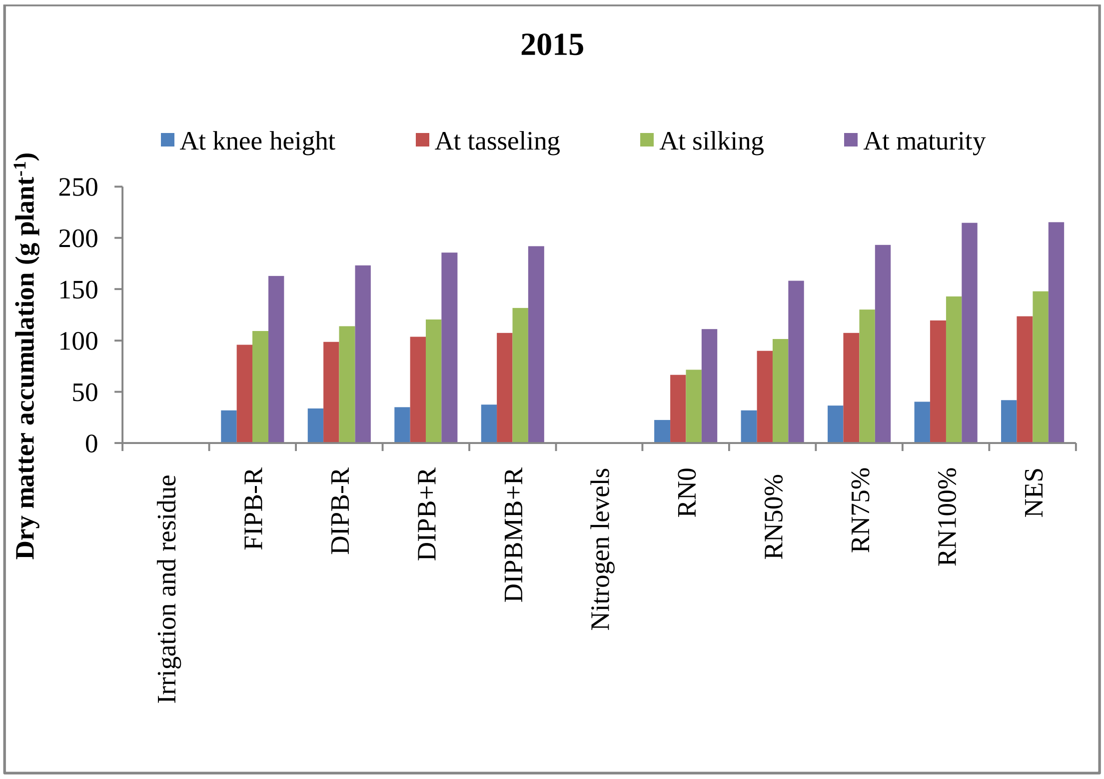


Fig.9: Effect of residue, irrigation and N management on dry matter accumulation of maize

and residue retention had the advantages in growth parameters of maize. Similar results were also reported by Hassan *et al* (2005) and Jat *et al* (2013).

Nitrogen levels showed significant effect on dry matter accumulation at various growth stages. Among the different N levels, NE i.e. 140 kg ha^{-1} recorded significantly higher dry matter accumulation than $RN_{50\%}$ i.e. 60 kg N ha^{-1} and $RN_{75\%}$ i.e. 90 kg N ha^{-1} while it was statistically at par with $RN_{100\%}$ i.e. 120 kg N ha^{-1} at all the growth stages of the crop during both the years.The improvement in dry matter accumulation with increment in nitrogen may be ascribed to the effect that, nitrogen has major role in many physiological reactions and constituents of chemical components of plant which may cause higher dry matter accumulation. Secondly higher dry matter accumulation with increase in N levels could be due to application of nitrogen which enhanced leaf area resulting in higher photo-assimilates Significantly higher amount of dry matter accumulated with increase in N-level was due to the cumulative effect of higher plant height and higher LAI under higher N-level as compared to the lower N-level as also reported by Bangarwa *et al* (1988). Terman *et al* (1977) also observed that application of nitrogen increased plant height by increasing length and number of internodes and the increase in leaf number and size would result in more and larger photosynthetic apparatus by increasing total leaf area and leaf area index of the crop consequently influencing assimilates production, which has direct bearing on dry matter production per plant and per unit area.

4.1.7.3Leaf area index

Leaf area index (LAI) is an important index to judge the production potential of a crop. It is an indicator of source size. More LAI might helped in better photosynthesis and assimilation rate which resulted more dry matter and better growth indices, these ultimately gave good performance of crop. The periodic data on LAI are presented in Table 20 and Fig.10. Leaf area index increased with the advancement of crop age up to silking stage and it declined thereafter when crop advanced towards maturity due to senescence of lower leaves. After giving fast look at the data it was observed that LAI was not influenced significantly due to irrigation, residue and legume treatments at all the growth stages of wheat. However the maximum LAI was reordered at knee height stage under $DIPB_{MB}$+R (1.74 and 1.84) and the lowest LAI reordered under FIPB-R (1.40 and 1.58) during both the years of study, respectively. Leaf area index increases linearly with the advancement of crop age and reaches to its maximum value at silking stage with significantly higher value under the $DIPB_{MB}$+R (3.07 and 3.28) as compared to the all other main treatments.The higher LAI under the $DIPB_{MB}$+R treatment as compared to the DIPB+R trerment might be due to the positive effect of mungbean residue in easy access of resources like moisture and nutrient by maize (Kumar and Bangarwa, 1997). Secondly, the higher LAI under the drip irrigation with fertigation treatments as compared to furrow irrigation may be due to the more precise water distribution, reduced soil-borne diseases, weed growth

Table 20: Effect of residue, irrigation and N management on Leaf area index of maize

LAI								
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**		**At maturity**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Irrigation and residue management management								
FIPB-R	1.43	1.58	2.51	2.55	2.78	3.01	1.61	1.67
DIPB-R	1.50	1.63	2.59	2.66	2.84	3.11	1.72	1.73
DIPB+R	1.62	1.77	2.70	2.77	2.90	3.17	1.77	1.79
$DIPB_{MB}$+R	1.75	1.83	2.75	2.81	3.07	3.28	1.81	1.83
SEm±	**0.094**	**0.055**	**0.072**	**0.058**	**0.065**	**0.056**	**0.059**	**0.036**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	1.27	1.33	2.13	2.20	2.39	2.54	1.39	1.43
$RN_{50\%}$	1.42	1.60	2.51	2.64	2.74	3.00	1.60	1.73
$RN_{75\%}$	1.67	1.81	2.78	2.82	2.97	3.26	1.77	1.78
$RN_{100\%}$	1.72	1.83	2.80	2.87	3.16	3.40	1.86	1.90
NES	1.81	1.95	2.98	2.96	3.23	3.50	2.03	1.95
SEm±	**0.084**	**0.052**	**0.077**	**0.060**	**0.055**	**0.051**	**0.078**	**0.044**
LSD (P=0.05)	**0.243**	**0.149**	**0.224**	**0.173**	**0.158**	**0.147**	**0.225**	**0.127**

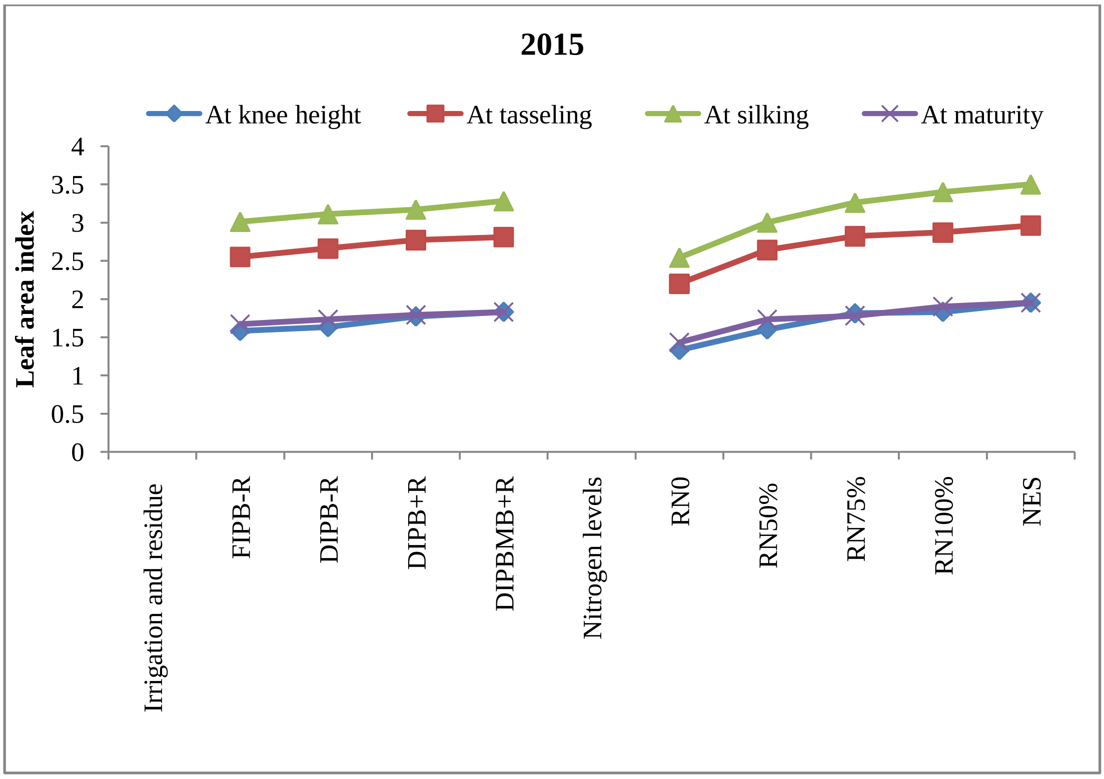


Fig.10: Effect of residue, irrigation and N management on Leaf area index of maize

and better uptake of nitrogen by plants as fertigation improves nutrient availability and the transformation of nutrients or fertilizers in the soil (Li *et al* 2009).

Nitrogen is a primary nutrient required for better development of leaves. LAI (Table 20) in general showed increasing trend with increase in N level. The nitrogen levels had significant effect on leaf area index at various growth stages. At initial growth phase i.e. at knee height stage and at tasseling stage the N level NE i.e 140 kg ha^{-1} had significantly higher LAI than control and nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} and $RN_{75\%}$ i.e 90 kg N ha^{-1}. However the N levels, NE i.e 140 kg ha^{-1} and $RN_{100\%}$ i.e 120 kg N ha^{-1}were statistically superior to the nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} and $RN_{75\%}$ i.e 90 kg N ha^{-1}on the basis of LAI during both the years at silking and maturity stage. The increase in LAI with increasing nitrogen level was due to better number of tillers $plant^{-1}$ (Table 10) which might be due to lesser senescence and longer leaf retention period with higher nitrogen application. Uhart and Andrade (1995) have reported more leaf elongation and less leaf senescence with higher nitrogen supply. Similar results were reported by Vedivel *et al* (2001).The positive effect of nitrogen on LAI has also been reported by Prasad *et al* (1990).

4.1.8 Yield attributes of maize

4.1.8.1 Number of cobs per plant

The cob bearing capacity is one of the most important crop yield components. The data regarding the number of cobs $plant^{-1}$ are presented in Table 21. More or less it is a genetic character of the cultivar but some improvement can be expected due to agronomic manipulations. Number of cobs per plant was not significantly influenced by different treatment combinations of irrigation, residue management and legume. However, number of cobs per plant was found to be lowest in FIPB-R (0.958 and 0.971) and maximum was found in the $DIPB_{MB}$+R (1.001 and 1.012) during both the years. However the drip irrigation along with fertigation resulted into higher number of cobs per plant as compared to furrow irrigation, which might be due to the more nutrient uptake, fertilizer utilization efficiency and percentage of nutrient derived from fertilizer as compared with soil application (Mohammad 2004). Secondly, the higher number of cobs per plant $DIPB_{MB}$+R might be due to the effect by inclusion of summer legumes in pre-ceding season that have improved the soil fertility; particularly N availability thereby improved growth and vigour of maize.

It was observed that with the increase in the N levels, there was increase in the number of cobs per plant. However, nitrogen level of NE i.e 140 kg N ha^{-1} resulted in significantly higher number of cobs per plant, than the control, nitrogen level of $RN_{50\%}$ i.e. 60 kg N ha^{-1} and of $RN_{75\%}$ i.e 90 kg N ha^{-1} , but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}. The increase in number of cobs per plant with increase in N level might be due to the fact that the application of more N resulted in More LAI which might helped in better photosynthesis and assimilation rate which resulted more dry matter and better growth

Table 21: Effect of residue, irrigation and N management on yield attributes of maize

Treatments	No of cobs plant^{-1}		Cob length (cm)		1000-grain weight (g)		Shelling (%)	
	2014	2015	2014	2014	2015	2015	2014	2015
Irrigation and residue management management								
FIPB-R	0.958	0.971	16.23	68.21	70.98	16.53	252.53	257.20
DIPB-R	0.973	0.985	16.62	70.01	71.94	16.84	260.13	263.20
DIPB+R	0.977	0.994	17.14	71.28	72.98	17.43	266.13	270.07
$DIPB_{MB}$+R	1.001	1.012	17.54	72.08	73.41	17.93	269.07	273.06
SEm±	**0.016**	**0.023**	**0.200**	**0.267**	**0.227**	**0.141**	**5.107**	**3.332**
LSD (P=0.05)	**NS**	**NS**	**0.706**	**0.942**	**0.800**	**0.498**	**NS**	**NS**
Nitrogen levels								
RN_0	0.856	0.874	14.68	65.82	66.86	14.73	229.00	235.17
$RN_{50\%}$	0.954	0.967	16.96	69.85	71.81	17.02	257.50	262.50
$RN_{75\%}$	0.987	1.015	17.27	71.12	73.88	17.73	269.83	272.00
$RN_{100\%}$	1.041	1.044	17.57	72.37	74.24	18.02	276.33	278.75
NES	1.049	1.053	17.93	72.82	74.85	18.43	277.17	281.00
SEm±	**0.018**	**0.018**	**0.113**	**0.229**	**0.319**	**0.189**	**3.496**	**2.330**
LSD (P=0.05)	**0.052**	**0.051**	**0.326**	**0.663**	**0.924**	**0.548**	**10.117**	**6.742**

indices. Hussain (2014) also reported that maize crop responded to higher dose of fertilizers which were applied as water soluble fertilizers through fertigation resulted in higher uptake and lead to higher yield and yield attributes.

4.1.8.2 Cob length

Cob length may serve as reliable criteria to access crop yield as it is an indicator of yield because increase in cob length will influence the number of grains cob^{-1}. After giving fast look at the data Table 21. It was observed that cob length was influenced significantly due to irrigation, residue and legume treatments. Among the different treatments, the cob length recorded under $DIPB_{MB}$+R (17.54 and 17.93 cm) and DIPB+R (17.14 and 17.43 cm) statistically at par but recorded significantly higher cob length as compared to the DIPB-R (16.62 and 16.84 cm) and FIPB-R (16.23 and 16.54 cm) during both the years of study. Significantly higher cob length recorded under drip fertigation along with residue retention might be due to more nutrient uptake, fertilizer utilization efficiency and percentage of nutrient derived from fertilizer as compared with soil application (Mohammad 2004. Secondly, the retention of residue under permanent bed treatment resulted higher values of cob length than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002). Govaerts *et al* (2005) and Talukder *et al* (2004) also reported the increased cob length under permanent bed planting along with rotation and residue retention as compared to conventional tillage with residue removal.

The average cob length increased with increase in nitrogen level. Cob length was significant higher under N level NE i.e 140 kg ha^{-1} than $RN_{50\%}$ i.e 60 kg N ha^{-1} and $RN_{75\%}$ i.e 90 kg N ha^{-1} but significantly at par with the N level of $RN_{100\%}$ i.e 120 kg N ha^{-1}. However, the cob length was statistically comparable under $RN_{75\%}$ and $RN_{100\%}$ but both these treatments were statistically superior to $RN_{50\%}$ during the two years of study. The results get support from the findings by Rathore *et al* (1976) and Paradkar and Sharma (1993).

4.1.8.31000-grain weight

The data on 1000-grain weight have been presented in Table 21**.** The grain weight indicates the nature and extent of grain development. It is a function of various production factors that influence grain development and filling patterns. 1000-grain weight was not significantly influenced by different treatment combinations of irrigation, residue management and legume. However, 1000-grain weight was found to be lowest in FIPB-R (252.53 and 257.20 g) and maximum was found in the $DIPB_{MB}$+R (269.07 and 273.06 g) during both the years. However the drip irrigation along with fertigation resulted into higher 1000-grain weight as compared to furrow irrigation, which might be due to the more nutrient uptake, fertilizer utilization efficiency and percentage of nutrient derived from fertilizer as compared with soil application (Mohammad 2004, Tumbare *et al* 1999). Kahlon and Khera (2016) also reported that irrespective of irrigation levels, higher 1000-grain weight were observed in drip irrigation (255.0 g) followed by as compared to the furrow irrigation treatment (242.9 g). Secondly, the retention of residue under permanent bed resulted higher values of 1000-grain weight than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues (Yadav *et al* 2005).

It was observed that with the increase in the N levels, there was increase in the 1000-garin weight. However, nitrogen level of NE i.e 140 kg N ha^{-1} resulted in significantly higher 1000-grain weight, than the control and nitrogen level of $RN_{50\%}$ i.e. 60 kg N ha^{-1} , but statistically at par with nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} and nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}. The increase in 1000-grain weight with increase in N level might be due to the fact that the application of more N resulted in More LAI which might helped in better photosynthesis and assimilation rate which resulted more dry matter and better growth indices. Hussain (2014) also reported that maize crop responded to higher dose of fertilizers which were applied as water soluble fertilizers through fertigation resulted in higher uptake and lead to higher yield and yield attributes. Li *et al* (2001)also reported that crops maintained higher biomass with optimum N application, causing an ascribed to overall improvement in plant vigour in term of development of leaves, stems and grains. Similar results were obtained by Paolo.

4.1.8.4 Shelling percentage

The data presented in Table 21 reveal that shelling percentage influenced significantly by irrigation method and residue management treatments. The $DIPB_{MB}$+R (72.08 and 73.41 %) resulted in significantly higher shelling percentage than that DIPB-R (70.01 and 71.94 %), which in turn was significantly better than FIPB-R (68.21 and 70.98 %) which recorded significantly the lowest shelling percentage during the two years of study. The higher shelling percentage under the $DIPB_{MB}$+R treatment as compared to the DIPB+R and FIPB-R treatment might be due to the higher cob length with positive effect of mungbean residue in easy access of resources like moisture and nutrient by maize (Kumar and Bangarwa, 1997). Secondly, the retention of residue under permanent bed treatment resulted higher values of shelling than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002).

Shelling percentage under NE i.e 140 kg N ha^{-1}as statistically at par with recorded under $RN_{100\%}$ i.e 120 kg N ha^{-1} but it was significantly superior to that obtained under $RN_{75\%}$ i.e. 90 kg N ha^{-1} and $RN_{50\%}$ i.e. 60 kg N ha^{-1} during 2014 and 2015. Shelling percentage under

$RN_{75\%}$ i.e. 90 kg N ha^{-1} was at par with that recorded under $RN_{100\%}$ i.e. 120 kg N ha^{-1} during 2015 only, but it was significantly higher than recorded in under $RN_{50\%}$ i.e. 60 kg N ha^{-1} during both years. The increase in shelling percentage under NE i.e 140 kg N ha^{-1} was 0.62 and 0.82 per cent than $RN_{100\%}$ i.e 120 kg N ha^{-1} which in turn recorded 3.61 and 3.38 per cent higher shelling percentage over $RN_{50\%}$ i.e. 60 kg N ha^{-1} during the two years, respectively. The results are in close agreement with the findings of Hussaini *et al* (2002) and Rathore *et al* (1976). Shivay and Singh (2000) observed increased shelling percentage with increased N-levels.

4.1.9 Grain and straw yield of maize

4.1.9.1 Grain yield

Grain yield is function of cob length, no of cobs $palnt^{-1}$ and 1000-grain weight etc. The grain yield of maize crop was significantly influenced due to different irrigation, residue and legume treatments. The data regarding grain yield presented in Table 22. Grain yield was significantly higher under $DIPB_{MB}$+R (6.20 and 6.17 t ha^{-1}) as compared to DIPB-R (5.41 and 5.57 t ha^{-1}) which in turn was significantly better than FIPB-R (4.88 and 5.00 t ha^{-1}) during both the years. However grain yield obtained under DIPB+R (5.96 and 5.99) was significantly at par with the $DIPB_{MB}$+R (6.20 and 6.17 t ha^{-1}) during both the years, respectively. The per cent increase in grain yield was 27.05 and 23.40 under $DIPB_{MB}$+R, and 22.13 and 19.80 per cent under DIPB+R over that of FIPB-R during the year 2014 and 2015, respectively. The higher grain yield under drip irrigation when compared with furrow irrigation may be because of the way that as water and nutrient is supplied as often as possible and consistently, usually there is no moisture stress in crop root zone and it comes about into 25 to 30 per cent increase in crop yield as compared to surface irrigated crop (Wang *et al* 2013) reported 39 per cent higher maize yield with drip irrigation as compared to surface irrigation. The significantly higher yield of wheat under $DIPB_{MB}$+R in comparison to FIPB-R was may also attributed to increase in cob length and 1000-grain weight which was enhanced by optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues.Parihar *et al* (2016) also showed the positive effects of PB and residue retention on grain yield of maize. The inclusion of summer legumes in pre-ceding season might have improved the soil fertility; particularly N availability thereby improved growth and yield of maize (Congreves *et al,* 2015). Sharma and Behera (2009) also reported that growth and yield of maize was improved significantly after inclusion of a summer legume into the maize-wheat system as compared with fallow.

Grain yield of maize is a function of yield attributes which are favorably influenced by nitrogen application (Singh *et al* 2000). Grain yield increased with increase in N-levels from $RN_{50\%}$ i.e. 60 kg N ha^{-1} to NE i.e. 140 kg N ha^{-1}(Table 22). The treatment NE i.e. 140 kg N $ha^{-1}$was significantly superior than $RN_{75\%}$ i.e. 90 kg N ha^{-1} but was at par with $RN_{100\%}$ i.e.

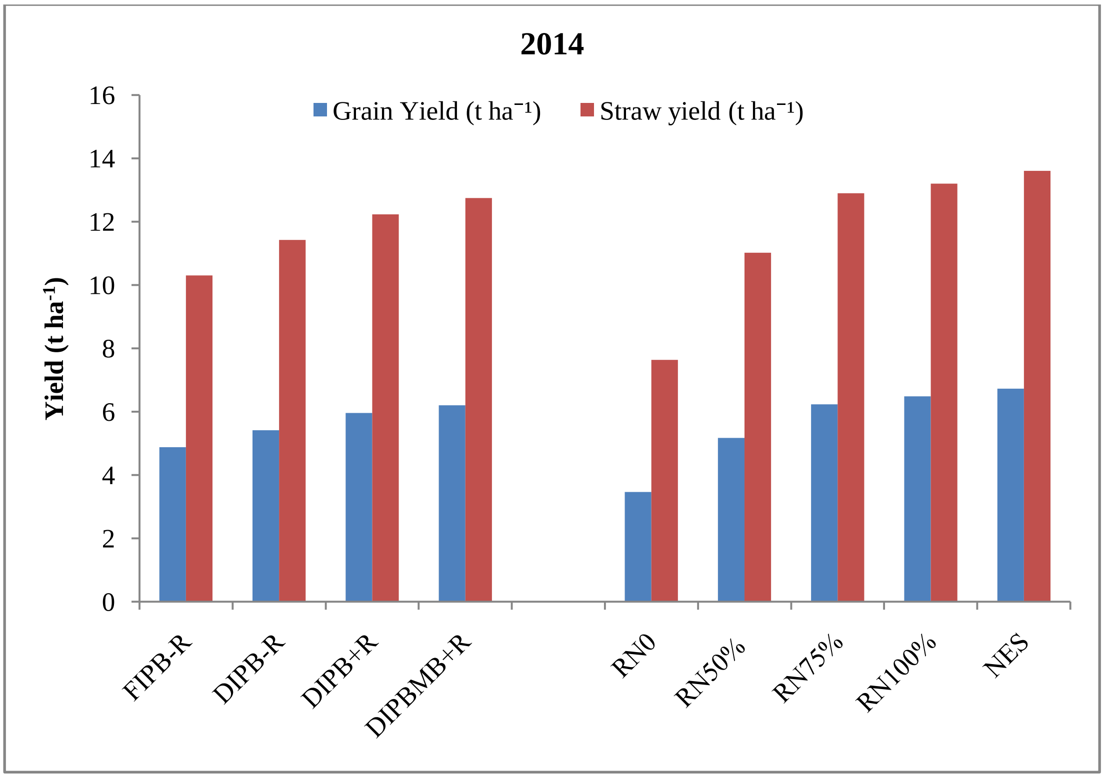
120 kg N ha^{-1} on the basis of grain yield during both the years of study. The yield under $RN_{100\%}$ i.e. 120 kg N ha^{-1} (6.48 and 6.54 t ha^{-1}) was statistically higher than recorded under $RN_{50\%}$ i.e. 60 kg N ha^{-1} (5.17 and 5.04 t ha^{-1}) but it was at par with that obtained under $RN_{75\%}$ i.e. 90 kg N ha^{-1} (6.23 and 6.43 t ha^{-1}). The per cent increase in grain yield was 30.17 and 36.71 under NE i.e. 140 kg N $ha^{-1}$and 25.3 and 29.76 per cent under $RN_{100\%}$ i.e. 120 kg N ha^{-1}over that of $RN_{50\%}$ i.e. 60 kg N ha^{-1} during 2014 and 2015, respectively. The corresponding increase in grain yield under $RN_{100\%}$ i.e. 120 kg N $ha^{-1}$was 4.01 and 1.71 per cent over $RN_{75\%}$ i.e. 90 kg N ha^{-1} for the two years, respectively. The higher yield with increase in nitrogen doses could be supported probably by higher levels of chlorophyll since nitrogen is an important constituent of chlorophyll as reported by Singh (2010). Thus, the photosynthesis might have taken place at an efficient level there by producing photosynthates for higher growth and development as indicated by higher plant height (Table 19) and LAI (Table 20). When the plant shifted from vegetative to reproductive phase higher amount of source resulted in better development of sink size as indicated by cob length (Table 21). Better pollination under adequately supplied nitrogen conditions reduced the barrenness and helped to develop the sink capacity as indicated by 1000-grain weight (Table 21) and higher shelling percentage (Table 21). All these factors helped to fill the sink to the capacity which resulted in higher yield. Rana and Choudhary (2006), Khanday and Thakur (1991) and Ramu and Reddy (2007) recorded similar observations.

4.1.9.2 Straw yield

The data regarding straw yield presented in Table 22 and Fig. 11. After giving fast look at the data it was observed that straw yield was influenced significantly due to irrigation, residue and legume treatments. Among the different treatments, the straw yield recorded under $DIPB_{MB}$+R (12.75 and 12.67 t ha^{-1}) and DIPB+R (12.23 and 12.46 t ha^{-1}) statistically at par but recorded significantly higher straw yield as compared to the FIPB-R (10.30 and 10.71t ha^{-1}) during both the years of study. The straw yield recorded under the DIPB-R (11.42 and 11.70 t ha^{-1}) was significantly higher than the FIPB-R (10.30 and 10.71 cm) but statistically at par with the DIPB+R (12.23 and 12.46 t ha^{-1}). More straw yield under drip irrigation as compared to furrow irrigation treatment was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season (Pawar *et al* 2013, Frederick *et al* 2001). Kahlon and Khera (2016) also reported that irrespective of irrigation levels, drip irrigation (13.0 t ha^{-1}) produced highest maize stover yield than furrow irrigation (11.3 t ha^{-1}). Maize grain and straw yields were highest in residue retention as compared to without residue retention, this might be due to less lodging of maize crop under PB systems with residue retention. Increase in grain and straw yield of wheat in PB with residue retention may be attributed to the positive effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), lesser weed population (Ozpinar 2006,

Table 22: Effect of residue, irrigation and N management on grain and straw yield of maize

Treatments	Grain Yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2014	**2015**	**2014**	**2015**
Irrigation and residue management management				
FIPB-R	4.88	5.00	10.30	10.71
DIPB-R	5.41	5.57	11.42	11.70
DIPB+R	5.96	5.99	12.23	12.46
$DIPB_{MB}$+R	6.20	6.17	12.75	12.67
SEm±	**0.133**	**0.115**	**0.258**	**0.214**
LSD (P=0.05)	**0.469**	**0.406**	**0.909**	**0.756**
Nitrogen levels				
RN_0	3.46	3.40	7.64	7.59
$RN_{50\%}$	5.17	5.04	11.02	10.74
$RN_{75\%}$	6.23	6.43	12.90	13.42
$RN_{100\%}$	6.48	6.54	13.20	13.62
NES	6.73	6.89	13.61	14.03
SEm±	**0.094**	**0.083**	**0.210**	**0.198**
LSD (P=0.05)	**0.273**	**0.239**	**0.607**	**0.572**



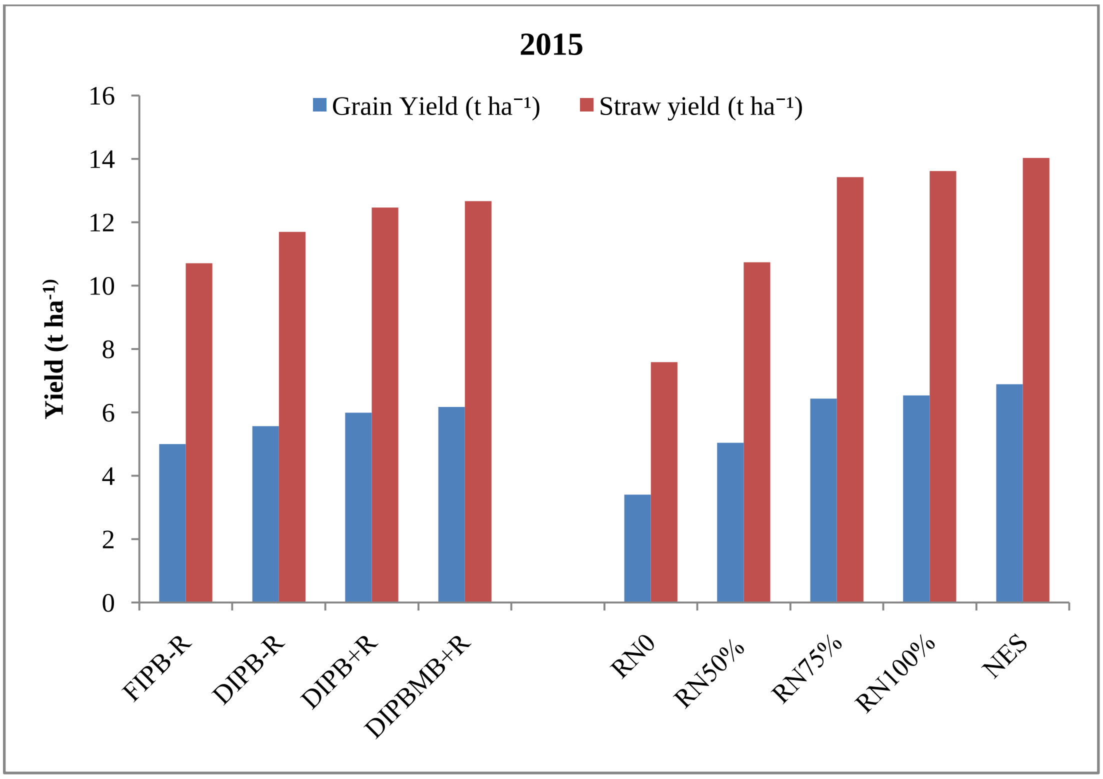


Fig.11: Effect of residue, irrigation and N management on grain and straw yield of maize

Chauhan *et al* 2007), improved soil physical health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009) and improved nutrient use efficiency compared to CT without residue retention (Unger and Jones, 1998). Parihar *et al* (2016) also showed the positive effects PB and residue retention on grain and starw yield of maize.

Straw yield influenced significantly by nitrogen application during both the years of study (Table 22). Highest straw yield was obtained under NE i.e. 140 kg N ha^{-1}which was statistically at par with the yield recorded under $RN_{100\%}$ i.e. 120 kg N ha^{-1}and both the N-levels were significantly better than $RN_{50\%}$ i.e. 60 kg N ha^{-1}.However the yield under $RN_{100\%}$ i.e. 120 kg N ha^{-1} (13.20 and 13.62 t ha^{-1}) was statistically higher than recorded under $RN_{50\%}$ i.e. 60 kg N ha^{-1} (11.02 and 10.74 t ha^{-1}) but it was statistically at par with that obtained under $RN_{75\%}$ i.e. 90 kg N ha^{-1} (12.90 and 13.42 t ha^{-1}). The per cent increase in straw yield was 23.50 and 30.6 under NE i.e. 140 kg N ha^{-1}and 19.78 and 26.8 per cent under $RN_{100\%}$ i.e. 120 kg N ha^{-1}over that of $RN_{50\%}$ i.e. 60 kg N ha^{-1}during 2014 and 2015, respectively. The N level NE i.e. 140 kg N ha^{-1}and $RN_{100\%}$ i.e. 120 kg N ha^{-1}were statistically better by 5.50 and 4.55 per cent and 2.33 and 1.49 per cent respectively over $RN_{75\%}$ i.e. 90 kg N ha^{-1} during the two years, respectively. Khanday and Thakur (1991), Brar *et al* (2001) and Singh (2010) also reported similar trends in stover yield under various N-levels.

4.1.10 Maize-wheat-Moongbean System system

4.1.10.1 System productivity

The system productivity of maize–wheat-moongbean (wheat equivalent yield) cropping system was influenced significantly during the year 2013-14 and 2014-15 (Table 23). In general, the system productivity enhanced in $DIPB_{MB}$+R over the other main treatments. The highest system productivity was recorded under $DIPB_{MB}$+R (12.40 and 12.32 t ha^{-1}) followed by DIPB+R (9.73 and 9.60 t ha^{-1}) over FIPB-R and DIPB-R in both the year of experimentation. The lowest system productivity was obtained under FIPB-R (8.20 and 8.28 t ha^{-1}) followed by PB (8.97 and 9.04 t ha^{-1}) as compared to $DIPB_{MB}$+R and FIPB-R during both year of study, respectively. The treatment $DIPB_{MB}$+R increased system productivity like 51.22 and 48.79 % as compared to FIPB-R during 2013-14 and 2014-15, respectively. The higher system productivity under $DIPB_{MB}$+R was due to good crop growth, higher values of yield attributes and yield under this treatment. Maize and wheat performed significantly better under $DIPB_{MB}$+R, while mungbean was the also component under $DIPB_{MB}$+R treatment, thus contribution of all crops resulted in higher productivity of the system under this treatment.The WEY of the system maize–wheat-mungbean cropping system was significantly influenced due to different N levels. The system productivity was increased from $RN_{75\%}$ to $RN_{100\%}$ to NES. The highest system productivity was recorded under NES, which was significantly higher than $RN_{75\%}$ and $RN_{100\%}$ in both the years.

Table 23: Effect of residue, irrigation and N management on grain yield of maize, wheat and system productivity (wheat equivalent)

Treatments	Wheat (t ha^{-1})		Maize (t ha^{-1})		System Productivity	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management management						
FIPB-R	3.79	3.94	4.88	5.00	8.20	8.28
DIPB-R	4.08	4.20	5.41	5.57	8.97	9.04
DIPB+R	4.35	4.38	5.96	5.99	9.73	9.60
$DIPB_{MB}$+R	4.40	4.54	6.20	6.17	12.4	12.32
SEm±	**0.061**	**0.054**	**0.133**	**0.115**	**0.122**	**0.130**
LSD (P=0.05)	**0.215**	**0.190**	**0.469**	**0.406**	**0.430**	**0.458**
Nitrogen levels						
RN_0	2.53	2.62	3.46	3.40	6.24	6.18
$RN_{50\%}$	3.69	3.78	5.17	5.04	8.96	8.76
$RN_{75\%}$	4.70	4.84	6.23	6.43	10.93	11.04
$RN_{100\%}$	4.84	4.98	6.48	6.54	11.30	11.37
NES	5.01	5.11	6.73	6.89	11.69	11.71
SEm±	**0.062**	**0.053**	**0.094**	**0.083**	**0.086**	**0.084**
LSD (P=0.05)	**0.178**	**0.154**	**0.273**	**0.239**	**0.249**	**0.242**

4.1.11 Plant analysis

4.1.11.1 Nitrogen content

The effect of residue management and different nitrogen levels on nitrogen content of maize was observed at knee height stage, tasseling stage, silking stage and at maturity during the year 2014 and 2015 and is presented in Table 24 and Table 25. Nitrogen content was not influenced significantly by irrigation and residue management treatments at all the crop growth stages. Nitrogen content recorded at knee height stage was found to be lowest in FIPB-R (1.47 and 1.48 %) and maximum was found in the $DIPB_{MB}$+R (1.55 and 1.71 %) during both the years. Similarly, $DIPB_{MB}$+R recorded higher nitrogen content at tasseling and silking stage over all other treatments but not a significant difference was observed. Similarly, $DIPB_{MB}$+R recorded higher nitrogen content in grain, straw and cob cores over all other treatments but not a significant difference was observed. Higher nutrient content was found in the drip irrigation treatments as compared to furrow irrigation which was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season and due to split application of fertilizers at appropriate time through drip irrigation (Pawar *et al* 2013, Frederick *et al* 2001, Abdullah and Pawar 2013).

However the nitrogen levels had significant effect on N content at different growth stages of maize. At all growth stages of maize, it was observed that with the addition of plant nutrients to crop, there was increase in the N content of the maize crop as compared to control. The NE i.e. 140 kg N ha^{-1} resulted in significantly higher N content as compared to the $RN_{50\%}$ i.e. 60 kg N $ha^{-1}$and nitrogen level of $RN_{75\%}$ i.e. 90 kg N ha^{-1} at knee height stage, tasseling stage and at silking stage and, was statistically on par with nitrogen level of $RN_{100\%}$ i.e. 120 kg N $ha^{-1.}$ during both the years. Nitrogen content in grain and cob cores was also observed significantly higher under NE i.e. 140 kg N ha^{-1} than control, $RN_{50\%}$ i.e. 60 kg N ha^{-1} and $RN_{75\%}$ i.e. 90 kg N ha^{-1} treatments and, was statistically at par with nitrogen level of $RN_{100\%}$ i.e. 120 kg N ha^{-1}, which was statistically at par with nitrogen level of $RN_{75\%}$ i.e. 90 kg N ha^{-1}during both the years. However the N content in straw was found significantly higher under the NE i.e. 140 kg N ha^{-1} as compared to control and $RN_{50\%}$ i.e. 60 kg N ha^{-1}, but significantly at par with the $RN_{75\%}$ i.e. 90 kg N ha^{-1} and $RN_{100\%}$ i.e. 120 kg N ha^{-1}. Increase in N content with increase in rate might be attributed to enhanced N uptake by maize followed by partitioning of more assimilates to plant. Similar results were obtained by Hassan *et al* (2010).

Table 24: Effect of residue, irrigation and N management on nitrogen content at different growth stages of maize

Treatments	Nitrogen content (%)					
	At knee height stage		At tasseling stage		At silking stage	
	2014	2015	2014	2015	2014	2015
Irrigation and residue management management						
FIPB-R	1.47	1.48	1.27	1.35	1.17	1.23
DIPB-R	1.49	1.56	1.36	1.45	1.25	1.30
DIPB+R	1.51	1.72	1.37	1.47	1.27	1.32
$DIPB_{MB}$+R	1.55	1.71	1.39	1.48	1.29	1.34
SEm±	**0.017**	**0.057**	**0.041**	**0.027**	**0.025**	**0.037**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels						
RN_0	1.33	1.42	1.11	1.25	1.05	1.19
$RN_{50\%}$	1.46	1.52	1.27	1.38	1.20	1.26
$RN_{75\%}$	1.51	1.62	1.32	1.45	1.21	1.28
$RN_{100\%}$	1.58	1.75	1.46	1.54	1.36	1.34
NES	1.65	1.77	1.57	1.56	1.41	1.41
SEm±	**0.043**	**0.067**	**0.044**	**0.044**	**0.032**	**0.038**
LSD (P=0.05)	**0.123**	**0.194**	**0.127**	**0.126**	**0.093**	**0.109**

Table 25: Effect of residue, irrigation and N management on nitrogen content in grain, stover and cob cores at maturity stage of of maize

Nitrogen content (%)						
Treatments	**Grain**		**Stover**		**Cob cores**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Irrigation and residue management						
FIPB-R	1.26	1.29	0.49	0.46	0.45	0.50
DIPB-R	1.29	1.32	0.53	0.53	0.47	0.53
DIPB+R	1.32	1.35	0.54	0.53	0.51	0.57
$DIPB_{MB}$+R	1.34	1.38	0.59	0.59	0.54	0.60
SEm±	**0.027**	**0.020**	**0.024**	**0.027**	**0.021**	**0.019**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels						
RN_0	1.13	1.19	0.42	0.43	0.39	0.40
$RN_{50\%}$	1.25	1.32	0.51	0.52	0.47	0.50
$RN_{75\%}$	1.31	1.33	0.55	0.53	0.49	0.59
$RN_{100\%}$	1.39	1.40	0.60	0.58	0.53	0.60
NES	1.42	1.43	0.62	0.59	0.57	0.65
SEm±	**0.028**	**0.028**	**0.025**	**0.026**	**0.017**	**0.015**
LSD (P=0.05)	**0.080**	**0.082**	**0.074**	**0.076**	**0.050**	**0.45**

4.1.11.2 Nitrogen uptake

Irrigation, residue management and legume brought significant differences in the nutrient uptake by the wheat. The data regarding N uptake presented in Table 26 and Table 27. Among the different treatments at knee height stage highest N uptake was obtained inDIPB$_{MB}$+R (43.81 and 48.52 kg ha^{-1}) which was statistically similar with DIPB+R (39.52 and 45.91 kg ha^{-1}) and, statistically higher than the FIPB-R (31.11 and 35.31 kg ha^{-1}) during both years of study. Similarly at tasseling and silking stage higher N uptake was recorded under the DIPB$_{MB}$+R which was stastically at par with the DIPB+R and stastically higher than the FIPB-R and DIPB-R during both years of study. A perusal of data reveal that on quantitative basis nitrogen uptake followed the trend grain > stover > cob cores during both the years. In grain and starw, significantly higher nitrogen uptake was observed under DIPB$_{MB}$+R as compared to DIPB-R, which in turn was significantly better than FIPB-R during both the years. But nitrogen uptake by cob cores was at par under DIPB-R and FIPB-R which are significantly lower than the DIPB$_{MB}$+R during both years of study. However higher nutrient uptake in the drip irrigation treatments as compared to furrow irrigation which was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season and due to split application of fertilizers at appropriate time through drip irrigation (Pawar *et al* 2013, Frederick *et al* 2001, Abdullah and Pawar 2013). Bahera *et al* (2007) also reported maximum N uptake under ZT with residue retention, which might be due to addition of nutrients through residue, better root growth, leading to more extraction of nutrient from soil, lower weed infestation and better performance of crop, improved physical environment favourable for better microbial activity that might helped in mineralization resulting better availability of nutrients (macro and micro) to crops and thus increased the uptake under these treatments.

The data regarding N uptake presented in Table 26 and Table 27reveals that Nuptake under different growth stages increased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}. During both the years of study, maximum nitrogen uptake at different growth stages observed under NE i.e. 140 kg N ha^{-1} which was statistically at par with that recorded under RN$_{100\%}$ i.e. 120 kg N ha^{-1} but significantly higher than observed under RN$_{75\%}$ i.e. 90 kg N ha^{-1} during both years. Maximum N uptake in grain and stover was with the nitrogen level NE i.e 140 kg N ha^{-1} (95.64, 100.25 and 67.83, 66.76 kg ha^{-1}), which was statistically at par with nitrogen level of RN$_{100\%}$ i.e 120 kg N ha^{-1} (90.44, 94.93 and 62.61, 63.79 kg ha^{-1}) but significantly higher than control (39.12, 40.62 and 23.88, 24.75 kg ha^{-1}), RN$_{50\%}$ i.e 60 kg N ha^{-1} (65.16, 67.15 and 43.43, 44.35 kg ha^{-1}) and nitrogen level of RN$_{75\%}$ i.e 90 kg N ha^{-1} (81.74, 85.41 and 55.87, 57.73 kg ha^{-1}) in both the years. Similarly, the maximum N uptake in cob cores was observed under NE i.e. 140 kg N ha^{-1} which was statistically at par with that recorded under RN$_{100\%}$ i.e. 120 kg N ha^{-1} but significantly higher

Table 26: Effect of residue, irrigation and N management on nitrogen uptake at different growth stages of maize

Treatments	Nitrogen uptake (kg ha^{-1})					
	At knee height stage		At tasseling stage		At silking stage	
	2014	2015	2014	2015	2014	2015
Irrigation and residue management						
FIPB-R	31.11	35.31	84.68	97.67	92.14	98.78
DIPB-R	34.85	39.40	98.33	108.00	103.86	112.19
DIPB+R	39.52	45.91	104.18	114.63	110.31	119.02
$DIPB_{MB}$+R	43.81	48.52	110.76	118.99	121.47	132.94
SEm±	**1.942**	**2.665**	**2.921**	**2.847**	**3.029**	**3.411**
LSD (P=0.05)	**6.851**	**9.401**	**10.303**	**10.042**	**10.686**	**12.034**
Nitrogen levels						
RN_0	20.51	23.51	46.69	61.69	52.49	62.87
$RN_{50\%}$	31.17	36.09	79.49	91.64	84.68	94.59
$RN_{75\%}$	39.01	44.15	104.92	115.46	115.08	124.15
$RN_{100\%}$	46.27	52.53	126.69	136.97	137.86	142.40
NES	49.64	55.15	137.85	143.35	144.61	154.66
SEm±	**1.543**	**2.146**	**3.844**	**4.121**	**3.003**	**4.346**
LSD (P=0.05)	**4.465**	**6.210**	**11.124**	**11.925**	**8.689**	**12.576**

Table 27: Effect of residue, irrigation and N management on nitrogen uptake by grain, stover and cob cores at maturity stage of maize

Treatments	Nitrogen uptake (kg ha^{-1})					
	Grain		**Stover**		**Cob cores**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Irrigation and residue management						
FIPB-R	62.50	66.39	38.71	39.82	11.30	12.00
DIPB-R	70.59	75.02	48.97	50.51	11.87	13.32
DIPB+R	80.26	82.53	53.76	53.64	13.29	14.48
$DIPB_{MB}$+R	84.33	86.77	61.47	61.94	13.95	15.29
SEm±	**1.358**	**2.098**	**2.603**	**2.894**	**0.550**	**0.543**
LSD (P=0.05)	**4.791**	**7.400**	**9.184**	**10.210**	**1.939**	**1.916**
Nitrogen levels						
RN_0	39.12	40.62	23.88	24.75	7.68	7.75
$RN_{50\%}$	65.16	67.15	43.43	44.35	11.71	11.62
$RN_{75\%}$	81.74	85.41	55.87	57.73	13.58	15.68
$RN_{100\%}$	90.44	94.93	62.61	63.79	14.38	16.16
NE	95.64	100.25	67.83	66.76	15.66	17.65
SEm±	**2.101**	**2.025**	**2.499**	**2.961**	**0.597**	**0.437**
LSD (P=0.05)	**6.080**	**5.861**	**7.231**	**8.568**	**1.726**	**1.564**

than observed under $RN_{75\%}$ i.e. 90 kg N ha^{-1} during both years.The significant increase in nitrogen accumulation in light of increasing N rates could be attributed, to extra nutrient accessibility and to lifted N focus specifically, to fast development and advancement of roots and shoots, to enhanced microbial movement and consequently to expanding soil N mineralization making accessible more soil N to plants (Niaz *et al* 2014). Similar effects of nitrogen levels on nitrogen uptake were also observed by Kumar and Ahlawat (2006) in which nitrogen uptake was increased with increased nitrogen levels. Also Jing *et al* (2009) reported that the increase in nitrogen uptake at 300 kg N^1ha^{-1}over control, 75, 150 and 225 kg N^1ha^{-1}.

4.1.12Nitrogen use efficiency (NUE)

The ability of crops to use the applied N depends on the uptake and utilization efficiency. Tillage, residue management and legume brought significant differences in the NUE by the wheat.Among the different treatments highest NUE was obtained in$DIPB_{MB}$+R (70.61 and 70.76 kg kg $^{-1}$) which was statistically higher than the FIPB-R (55.70 and 56.55 kg kg^{-1}) and DIPB-R (61.83 and 63.44 kg kg^{-1}), but statistically at par with the DIPB+R (69.36 and 68.79 kg kg^{-1}). More NUE under drip irrigation as compared to furrow irrigation treatment was mainly due to the nutrient application through fertigation which helps in water and nutrient availability in root zone throughout the crop season (Pawar *et al* 2013, Frederick *et al* 2001). Fertigation enables the application of soluble fertilizers and other chemicals along with irrigation water, uniformly and more efficiently which ultimately increase the nutrient use efficency (Patel and Rajput 2000). Fanish and Muthukrishnan (2013) reported that higher NUE in trickle watered maize may be because of the effect that fertigation with all the more promptly accessible form clearly brought about higher accessibility of all the three (NPK) major nutrients in the soil solution which prompted to higher uptake and better translocation of assimilates from source to sink in this way thus improved the NUE and yield

The data regarding NUE presented in Table 28reveals that NUEdecreased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}. Significantly higher NUE was obtained with the N level of $RN_{50\%}$ i.e. 60 kg N as compared to all other N level. Nitrogen use efficiency is greater when the yield response to N is high. Therefore, this efficiency is generally high with low N rates and decreases in accordance with the rate increase of applied N (Parodi 2003). Sinebo et al (2004) likewise reported that N use efficiency was higher at lower rates of N application however radically diminished with further increments in the rate of the nutrient. While comparing the N level NE i.e 140 kg N ha^{-1} with the N level of $RN_{75\%}$ i.e 90 kg N ha^{-1}, it was observed that N level of $RN_{75\%}$ i.e 90 kg N gave signficanly higher NUE and comparable yield with the N level NE i.e 140 kg N ha^{-1}, which is considered as a best N management strategy for drip irrigated maize.

Table 28: Effect of residue, irrigation and N management on irrigation water use efficiency and nitrogen use efficiency of maize

Treatments	**IWUE (kg ha^{-1}-cm)**		**NUE (kg kg^{-1})**	
	2013-14	**2014-15**	**2013-14**	**2014-15**
Irrigation and residue management				
FIPB-R	172.55	174.06	55.70	56.55
DIPB-R	421.73	480.02	61.83	63.94
DIPB+R	634.05	591.93	69.36	68.79
$DIPB_{MB}$+R	659.82	609.89	70.61	70.76
SEm±	**9.332**	**9.188**	**1.734**	**1.445**
LSD (P=0.05)	**32.921**	**32.411**	**6.116**	**5.096**
Nitrogen levels				
RN_0	293.55	280.17	-	-
$RN_{50\%}$	440.47	417.20	86.23	83.96
$RN_{75\%}$	523.87	524.80	69.23	71.40
$RN_{100\%}$	540.63	540.03	53.99	55.45
NES	561.68	557.68	48.04	49.23
SEm±	**8.703**	**7.005**	**0.875**	**0.784**
LSD (P=0.05)	**25.185**	**20.272**	**1.339**	**0.657**

4.1.13 Water productivity (WP)

Irrigation and WP are positively correlated with grain yield of the crop and negatively correlated with amount of irrigation water applied. Among the different treatments highest WP was obtained in$DIPB_{MB}$+R (659.82 and 609.89 kg $ha^{-1}cm^{-1}$) which was statistically higher than the FIPB-R (172.55 and 174.03 kg ha^{-1} cm^{-1}) and DIPB-R (421.73 and 480.02 kg $ha^{-1}cm^{-1}$), but statistically at par with the DIPB+R (634.05 and 591.89 kg ha^{-1} cm^{-1}). The higher WUE in drip irrigation as compared to the furrow irrigation was mainly due to reduction in irrigation water requirement in drip as compared to the furrow irrigation. The better root growth and lower infestation of weeds in the drip irrigation was might be other possible reasons of higher IWP under $DIPB_{MB}$+R. The higher WP in residue retained plots as compared to the residue removed plots might be due to residue retention, which might suppressed the weed growth and also helped in soil moisture conservation that made available for the longer durations to the crop. Jat *et al* (2005) reported that irrigation water use (m^3 ha^{-1}) in both maize and wheat was highest (3231 and 3700) under conventional till followed by zero-till (2723 and 2934) and the lowest being (2030 and 2619) under FIRB planting system, respectively. Remarkably higher water productivity (kg grain m^{-3} water) of either crop of maize and wheat was recorded in FIRB planting (2.79 and 1.98) followed by flat no-till (1.74 and 1.89) and the lowest (1.36 and 1.38) in conventional-till system. The increase in water productivity is the resultant of both increase in yield and saving in irrigation water.

However, the nitrogen levels significantly influenced the WP. All fertilizer treatments produced significantly higher WP than unfertilised control in both the years. The nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher WP (233.21 and 258.07 kg $ha^{-1}cm^{-1}$)than control (117.92 and 130.69 kg $ha^{-1}cm^{-1}$), nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} (172.36 and 187.33 kg $ha^{-1}cm^{-1}$) and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1}(219.42 and 239.74 kg $ha^{-1}cm^{-1}$),but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}(225.67 and 246.83 kg $ha^{-1}cm^{-1}$). The higher WP with increase in the N level was mainly due to the increase in grain yield with successive increase in N rate.

4.1.14 Soil analysis

4.1.14.1 Soil pH

The data on soil pH after the harvest of wheat and maize crop in the second year at different depths i.e. 0-7.5, 7.5-15, 15-30 and 30-45 cm along with statistical analysis was presented in Table 29.The perusal of data shows that soil pH was not influenced significantly due to irrigation and residue management treatments after the harvest of wheat and maize in the second year. It might be due to buffering capacity of soil, which offered resistant against change in pH. However the soil pH increased with soil depth. The soil pH ranged from 8.38 - 8.45, 8.48 to 8.54, 8.56-8.64 and 8.63 to 8.71 at soil depth 0-7.5, 7.515, 15- 30 and 30-45 cm,

Table 29 : Effect of residue, irrigation and N management on soil pH after the harvest of wheat and maize crop in the second year of experiment

	pH							
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After Wheat	**After Maize**	**After Wheat**	**After Maize**	**After Wheat**	**After Maize**	**After Wheat**	**After Maize**
Irrigation and residue management								
FIPB-R	8.45	8.36	8.54	8.51	8.64	8.60	8.68	8.72
DIPB-R	8.43	8.30	8.49	8.45	8.56	8.55	8.63	8.64
DIPB+R	8.40	8.28	8.55	8.40	8.58	8.53	8.65	8.62
$DIPB_{MB}$+R	8.38	8.24	8.48	8.36	8.61	8.49	8.71	8.67
SEm±	**0.034**	**0.076**	**0.035**	**0.068**	**0.059**	**0.054**	**0.045**	**0.069**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	8.47	8.25	8.58	8.47	8.65	8.60	8.72	8.73
$RN_{50\%}$	8.42	8.31	8.51	8.42	8.59	5.58	8.66	8.70
$RN_{75\%}$	8.41	8.29	8.49	8.45	8.57	8.53	8.65	8.65
$RN_{100\%}$	8.39	8.33	8.53	8.41	8.55	8.46	8.63	8.61
NES	8.38	8.30	8.48	8.39	8.62	8.54	8.69	8.63
SEm±	**0.036**	**0.047**	**0.053**	**0.044**	**0.041**	**0.051**	**0.041**	**0.045**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

respectively after the harvest of wheat crop during 2014-15 and 8.24-8.36, 8.36-8.51, 8.49-8.60 and 8.62-8.72 at soil depth 0-7.5, 7.5-15, 15-30 and 30-45 cm, respectively after the harvest of maize crop during 2015 under different irrigation and residue management treatments. At the end of the experiment after the harvest of maize the maximum value of soil pH was recorded under FIPB-R followed by DIPB-R, while minimum was recorded under the $DIPB_{MB}$+R at different soil depths. However as compared to the initial soil pH (8.4), slightly lower pH was recorded for $DIPB_{MB}$+R under the uppermost layer (0-7.5) which might be due to the acidifying processes attributing to mineralization of organic matter, nitrification of applied N fertilizer and root exudation. A decrease of pH is among the short-term chances of soil properties which can result during decomposition of crop residues due to production of organic acids and microbial respiration (Hulugalle and Weaver 2005). These findings were in conformity with Malhi *et al* (2011). Rasmussen (1999) reported that tillage and residue management technique is often shown to have no effect on soil pH (Rasmussen, 1999), though soil pH has been reported to be lower in no-till systems compared to CT (Rahman *et al* 2008). The lower pH in ZT was attributed to accumulation of organic matter in the upper few centimetres under ZT soil (Rhoton, 2000) causing increases in the concentration of electrolytes and reduction in pH (Rahman *et al* 2008). However, the nitrogen levels had not showed any significant influenced on the soil pH.

4.1.14.2 Electrical conductivity (dS m^{-1})

The data on soil electrical conductivity (EC)after the harvest of wheat and maize crop in the second year at different depths i.e. 0-7.5, 7.5-15, 15-30 and 30-45 cm along with statistical analysis was presented in Table 30. The perusal of data shows that EC of the soil was not influenced significantly due to irrigation and residue management treatments after the harvest of wheat and maize in the second year. However the soil EC decreased with soil depth. The EC of the soil ranged from 0.239-0.250, 0.210-0.219, 0.180-0.191 and 0.138-0.141.38 dS m^{-1} at soil depth 0-7.5, 7.515, 15-30 and 30-45 cm, respectively after the harvest of wheat crop during 2014-15 and 0.226-0.244, 0.207-0.215, 0.173-0.193 and 0.139-0.149 dS m^{-1} at soil depth 0-7.5, 7.5-15, 15-30 and 30-45 cm, respectively after the harvest of maize crop during 2015 under different irrigation and residue management treatments.

The data presented in Table 32reveals that EC of the soil was influenced significantly upto the 15-30 cm soil depth with increase in the N level up to 140 kg N ha^{-1}. Significantly higher EC was recorded under the NE i.e. 140 kg N ha^{-1} at different soil depths as compared to the control after the harvest of wheat and maize in the second year. However the soil EC recorded under the NE i.e. 140 kg N ha^{-1} at different soil depths was statistically at par with that recorded under $RN_{100\%}$ i.e. 120 kg N ha^{-1}, $RN_{75\%}$ i.e. 90 kg N ha^{-1} and $RN_{50\%}$ i.e. 60 kg N ha^{-1}. The increase in the EC with increase in the N levels might because of the

Table 30 : Effect of residue, irrigation and N management on soil EC after the harvest of wheat and maize crop in the second year of experiment

EC (dS m^{-1})								
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After Wheat	**After Maize**	**After Wheat**	**After Maize**	**After Wheat**	**After Maize**	**After Wheat**	**After Maize**
Irrigation and residue management								
FIPB-R	0.250	0.244	0.219	0.212	0.186	0.178	0.140	0.139
DIPB-R	0.246	0.232	0.210	0.207	0.189	0.173	0.145	0.144
DIPB+R	0.243	0.226	0.214	0.215	0.191	0.193	0.138	0.143
$DIPB_{MB}$+R	0.239	0.240	0.217	0.210	0.180	0.185	0.141	0.149
SEm±	**0.005**	**0.008**	**0.005**	**0.004**	**0.003**	**0.007**	**0.004**	**0.004**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	0.233	0.221	0.196	0.200	0.176	0.172	0.138	0.140
$RN_{50\%}$	0.238	0.225	0.209	0.207	0.181	0.182	0.140	0.144
$RN_{75\%}$	0.248	0.235	0.222	0.213	0.188	0.180	0.143	0.145
$RN_{100\%}$	0.249	0.249	0.221	0.215	0.191	0.192	0.149	0.147
NES	0.256	0.245	0.228	0.219	0.198	0.186	0.147	0.145
SEm±	**0.006**	**0.008**	**0.008**	**0.004**	**0.005**	**0.006**	**0.003**	**0.003**
LSD (P=0.05)	**0.017**	**0.023**	**0.023**	**0.013**	**0.016**	**0.017**	**NS**	**NS**

fertilizer salts were not mixed into the soil; salts may also move to the surface during evaporation and then accumulate when not remixed by tillage (Veenstra *et al*, 2006).

4.1.14.3 Soil organic carbon (mg kg^{-1})

Soil organic carbon (SOC) was affected significantly due to different irrigation and residue management treatments at 0-7.5 and 7.5-15 cm soil depth and did not influenced at lower layer of soil profile (Table 31). The data revealed that crop residues application significantly increased the SOC under $DIPB_{MB}$+R and DIPB+R by 6.59% and 5.88%, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. Similarly the SOC observed under the $DIPB_{MB}$+R at the 7.5-15 cm depth was statistically at par with that recorded under DIPB+R, but significantly higher than observed under the FIPB-R and DIPB-R after the harvest of wheat and maize in the second year of the experiment. The increase in the SOC under the $DIPB_{MB}$+R and DIPB+R was might be because of crop residues added to these treatments which decayed and added the organic matter to the soil. Govaerts *et al* (2007) reported that Permanent raised beds with full residue retention increased soil organic matter content 1.4 times in the 0-5 cm layer compared to conventionally tilled raised beds with straw incorporated and it increased significantly with increasing amounts of residue retained on the soil surface in the permanent raised beds. Similar findings were also reported by Sarkar and Kar (2011). Also inside CA frameworks, repeated application of residues and in addition decreased mineralisation of these through reduced soil disturbance added to better SOC status as compared to CT frameworks

The effect of different N levels was was observed to be non-significant after the harvest of wheat and maize in the second year of the experiment. Statistically similar results were reported at different levels of N at different depths of soil.

4.1.14.4 Ammonical-N (mg kg^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to Ammonical-N(NH_4^+-N) in soil after harvest of wheat and maize crop in the second year. Ammonical-Nwas affected significantly due to different irrigation and residue management treatments at 0-7.5 and 7.5-15, cm soil depth (Table 32). The data revealed that crop residues application significantly increased the NH_4^+-N under $DIPB_{MB}$+R and DIPB+R by 10.92 and 10.49 percent, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. Although the chemical fertilizer sources have immediate effect and supply of ammonical nitrogen to soil but on long term basis, the treatments in which continuous application of residue i.e. organic sources have higher ammonical nitrogen content in soils which may be due to slow release of ammonical nitrogen from organic sources (crop residue) and more availability to the soil as compared to chemical fertilizer sources which have immediate more availability but on long

Table 31: Effect of residue, irrigation and N management on soil OC after the harvest of wheat and maize crop in the second year of experiment

Treatments	OC (g kg^{-1})							
	0-7.5		7.5-15		15-30		30-45	
	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize
Irrigation and residue management								
FIPB-R	5.51	5.61	4.86	5.05	3.60	3.76	1.94	1.98
DIPB-R	5.58	5.60	4.93	5.06	3.78	3.80	1.92	2.05
DIPB+R	5.80	5.94	5.25	5.26	3.93	3.91	2.04	2.01
$DIPB_{MB}$+R	5.86	5.98	5.23	5.46	3.90	3.95	1.97	2.07
SEm±	**0.080**	**0.097**	**0.082**	**0.095**	**0.110**	**0.059**	**0.035**	**0.044**
LSD (P=0.05)	**0.277**	**0.335**	**0.282**	**0.330**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	5.64	5.70	4.96	5.23	3.74	3.74	1.94	1.96
$RN_{50\%}$	5.64	5.77	5.01	5.19	3.89	381	1.97	1.98
$RN_{75\%}$	5.68	5.74	5.04	5.24	3.70	3.86	1.96	2.05
$RN_{100\%}$	5.74	5.80	5.10	5.18	3.93	3.94	2.00	2.06
NES	5.72	5.83	5.22	5.20	3.76	3.94	1.96	2.09
SEm±	**0.057**	**0.077**	**0.090**	**0.080**	**0.103**	**0.078**	**0.037**	**0.050**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 32: Effect of residue, irrigation and N management on ammonical-N after the harvest of wheat and maize crop in the second year of experiment

NH_4^+-N (mg kg^{-1})								
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After Wheat	**After Maize**	**After Wheat**	**After Maize**	**After Wheat**	**After Maize**	**After Wheat**	**After Maize**
Irrigation and residue management								
FIPB-R	17.27	18.59	14.47	16.03	12.02	13.77	10.27	10.77
DIPB-R	17.62	19.11	15.17	17.58	12.25	14.47	10.62	11.20
DIPB+R	18.67	20.54	16.22	18.28	13.30	14.86	11.08	11.82
$DIPB_{MB}$+R	19.71	20.62	16.57	18.90	13.18	14.63	10.97	11.47
SEm±	**0.538**	**0.483**	**0.525**	**0.453**	**0.465**	**0.322**	**0.267**	**0.385**
LSD (P=0.05)	**1.861**	**1.673**	**1.817**	**1.568**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	14.44	14.06	11.52	12.35	9.63	10.99	8.46	8.46
$RN_{50\%}$	17.94	19.45	15.31	16.82	12.10	13.91	10.21	11.38
$RN_{75\%}$	18.67	21.39	15.89	18.96	12.98	14.68	11.23	11.18
$RN_{100\%}$	19.69	21.78	16.77	20.32	14.15	16.23	11.67	12.88
NES	20.85	21.88	18.52	20.03	14.58	16.34	12.10	12.68
SEm±	**0.582**	**0.553**	**0.718**	**0.528**	**0.698**	**0.525**	**0.569**	**0.467**
LSD (P=0.05)	**1.675**	**1.592**	**2.07**	**1.522**	**2.01**	**1.513**	**1.638**	**1.344**

term basis its available decreases in the soil. More ammonical nitrogen in combined application of organic along with inorganic fertilizers may be due to continuous release of nitrogen from the organic sources whereas in chemical treatments the supply of ammonical nitrogen to the plant was for a short period but in excess amounts as reported by Hao and Chang (2002).

The data regarding NH_4^+-N presented in Table 32reveals that NH_4^+-N under different soil depths increased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}. After the harvest of wheat and maize in the second year, the maximum NH_4^+-N content was observed under NE i.e. 140 kg N ha^{-1} which was statistically at par with that recorded under $RN_{100\%}$ i.e. 120 kg N ha^{-1} but significantly higher than observed under $RN_{75\%}$ i.e. 90 kg N ha^{-1}, $RN_{50\%}$ i.e. 60 kg N ha^{-1} and controlup to the soil depth of 0-7.5 and 7.5-15 cm. However at lower soil depths significantly higher NH_4^+-N content was observed with increase in N levels as compared to the control. The significant increase in NH_4^+-N content in response to increasing N rates could be credited; to additional nutrients availability and to elevated N concentration in particular, to improved microbial activity and thus to increasing soil N mineralization making available more soil N to plants (Niaz *et al* 2014).

4.1.14.5Nitrate-N (mg kg^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to nitrate-nitrogen in soil after harvest of wheat and maize crop in the second year. Nitrate-N (NO_3^--N) was affected significantly due to different irrigation and residue management treatments at 0-7.5 and 7.5-15 cm soil depth and did not influenced at lower layer of soil profile (Table 33). The data revealed that crop residues application significantly increased the NO_3^--N under $DIPB_{MB}$+R and DIPB+R by 19.46% and 15.76%, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. This may be due to the continuous application of organic sources to the treatments $DIPB_{MB}$+R and DIPB+R which may play a major role in adding nitrate nitrogen to the soil. Further, data indicated that nitrate-nitrogen was highest in 0-7.5 cm soil depth and thereafter it continued to decrease in 7.5-15, 15-30 and 30-45 cm depths. Bahera *et al* (2007) also reported maximum N uptake under ZT with residue retention, which might be due to addition of nutrients through residue, better root growth, leading to more extraction of nutrient from soil, lower weed infestation and better performance of crop, improved physical environment favourable for better microbial activity that might helped in mineralization resulting better availability of nutrients.

The data regarding NO_3^--N presented in Table 33reveals that NO_3^--N under different soil depths increased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}. After the harvest of wheat and maize in the second year, the maximum NO_3^-N

Table 33 : Effect of residue, irrigation and N management on nitrate-N after the harvest of wheat and maize crop in the second year of experiment

Treatments	NO_3^--N (mg kg^{-1}) 0-7.5		7.5-15		15-30		30-45	
	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize
Irrigation and residue management								
FIPB-R	12.48	14.85	11.32	13.34	10.63	12.84	9.68	10.81
DIPB-R	12.92	15.56	12.13	14.31	11.55	13.07	10.47	11.28
DIPB+R	15.17	17.19	13.65	14.94	12.25	13.46	10.97	11.51
$DIPB_{MB}$+R	16.10	17.74	13.77	15.48	12.48	14.08	11.20	11.90
SEm±	**0.514**	**0.609**	**0.307**	**0.540**	**0.593**	**0.402**	**0.493**	**0.417**
LSD (P=0.05)	**1.779**	**2.106**	**1.062**	**1.867**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	12.21	12.54	8.89	10.41	7.88	9.34	7.44	8.66
$RN_{50\%}$	12.98	15.85	11.52	13.18	10.81	13.23	9.77	10.70
$RN_{75\%}$	14.29	16.92	13.27	15.95	12.98	14.30	11.08	11.77
$RN_{100\%}$	15.56	17.89	14.44	16.33	13.42	14.69	11.96	12.45
NES	17.79	18.47	15.46	16.73	13.56	15.27	12.65	13.32
SEm±	**0.820**	**0.446**	**0.645**	**0.473**	**0.580**	**0.388**	**0.547**	**0.514**
LSD (P=0.05)	**2.361**	**1.285**	**1.858**	**1.364**	**1.671**	**1.118**	**1.576**	**1.481**

content was observed under NE i.e. 140 kg N ha^{-1} which was statistically at par with that recorded under $RN_{100\%}$ i.e. 120 kg N ha^{-1} but significantly higher than observed under $RN_{75\%}$ i.e. 90 kg N ha^{-1}, $RN_{50\%}$ i.e. 60 kg N ha^{-1} and controlup to the soil depth of 0-7.5 and 7.5-15 cm. However at lower soil depths significantly higher NO_3-N^- content was observed with increase in N levels as compared to the control. The significant increase in NO_3-N^- content in response to increasing N rates could be credited; to additional nutrients availability and to elevated N concentration in particular, to improved microbial activity and thus to increasing soil N mineralization making available more soil N to plants (Niaz *et al*, 2015).

4.1.14.6Soil P (kg ha^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to soil P content in soil after harvest of wheat and maize crop in the second year. Soil P was affected significantly due to different irrigation and residue management treatments at 0-7.5 and 7.5-15 cm soil depth and did not influenced at lower layer of soil profile (Table 34). The data revealed that crop residues application significantly increased the Soil P under $DIPB_{MB}$+R and DIPB+R by 11.40 and 10.28 per cent, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. This may be due to the continuous application of organic sources to the treatments $DIPB_{MB}$+R and DIPB+R which may play a major role in adding nitrate nitrogen to the soil..

The effect of different N levels was was observed to be non-significant after the harvest of wheat and maize in the second year of the experiment. Statistically similar results were reported at different levels of N at different depths of soil.

4.1.14.7Soil K (kg ha^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to nitrate-nitrogen in soil after harvest of wheat and maize crop in the second year. Soil K content was affected significantly due to different irrigation and residue management treatments at 0-7.5 and 7.5-15 cm soil depth and did not influenced at lower layer of soil profile (Table 35). The data revealed that crop residues application significantly increased the Soil P under $DIPB_{MB}$+R and DIPB+R by 9.24 and 7.27 per cent, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. This may be due to the continuous application of organic sources to the treatments $DIPB_{MB}$+R and DIPB+R which may play a major role in adding nitrate nitrogen to the soil..

The effect of different N levels was observed to be non-significant after the harvest of wheat and maize in the second year of the experiment. Statistically similar results were reported at different levels of N at different depths of soil.

Table 34: Effect of residue, irrigation and N management on Soil-P content after the harvest of wheat and maize crop in the second year of experiment

Soil P (kg ha^{-1})								
Treatments	0-7.5		7.5-15		15-30		30-45	
	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize
Irrigation and residue management								
FIPB-R	38.83	40.13	26.88	29.13	24.65	25.95	16.53	18.58
DIPB-R	40.23	40.68	28.55	30.53	25.75	26.50	17.83	18.83
DIPB+R	43.28	44.25	29.33	31.93	26.13	28.55	18.03	18.73
$DIPB_{MB}$+R	43.95	44.70	30.43	32.10	26.33	28.18	19.23	20.15
SEm±	**0.849**	**0.609**	**0.794**	**0.450**	**0.653**	**0.952**	**0.982**	**0.746**
LSD (P=0.05)	**2.938**	**2.107**	**2.747**	**1.557**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels								
RN_0	39.90	40.95	27.53	29.88	24.50	26.13	17.03	17.63
$RN_{50\%}$	40.38	41.18	27.78	31.28	25.68	26.38	17.73	19.73
$RN_{75\%}$	43.00	43.75	29.63	30.58	26.13	28.00	17.85	19.10
$RN_{100\%}$	41.08	42.83	28.93	30.33	25.90	28.23	18.20	19.38
NES	43.50	43.53	30.10	32.55	26.38	27.78	18.68	19.55
SEm±	**1.265**	**1.507**	**0.916**	**0.962**	**0.875**	**0.770**	**0.755**	**0.770**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 35: Effect of residue, irrigation and N management on Soil-K content after the harvest of wheat and maize crop in the second year of experiment

Treatments	Soil K (kg ha^{-1})							
	0-7.5		7.5-15		15-30		30-45	
	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize	After Wheat	After Maize
Irrigation and residue management								
FIPB-R	243.59	246.40	162.03	169.120	143.73	151.20	76.91	84.00
DIPB-R	250.88	255.73	173.97	177.33	151.57	155.31	81.34	83.25
DIPB+R	262.08	264.32	181.07	186.67	153.81	159.04	87.36	88.48
$DIPB_{MB}$+R	260.96	269.17	183.31	184.27	152.69	154.19	83.25	87.30
SEm±	**2.164**	**4.665**	**5.834**	**3.932**	**4.537**	**3.371**	**3.932**	**2.309**
LSD (P=0.05)	**7.490**	**16.140**	**20.191**	**13.606**	**15.701**	**NS**	**13.606**	**NS**
Nitrogen levels								
RN_0	253.87	254.33	177.33	177.80	144.67	155.40	83.53	83.07
$RN_{50\%}$	254.80	261.33	174.53	175.93	153.99	154.00	84.00	83.53
$RN_{75\%}$	247.33	256.20	172.20	178.73	150.27	154.00	81.20	87.27
$RN_{100\%}$	256.88	259.93	176.87	183.87	147.47	153.53	80.27	85.87
NES	259.00	262.73	174.53	180.60	155.87	157.73	82.13	89.13
SEm±	**5.126**	**4.628**	**3.404**	**3.484**	**4.340**	**4.552**	**2.882**	**2.539**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.2 EXPERIMENT-II

The experiment was conducted in a split plot design design entitled as " Evaluation of different rates and methods of nitrogen application and straw management for enhancing nitrogen use efficiency in maize-wheat system under conservation agriculture". In general the different rates and method of nitrogen application affected various growth parameters, yield and yield attributes and nutrient uptake by plants significantly and thus has been discussed in detail along with the supporting studies. The various interaction effects were also not significant for various parameters. Hence, to avoid repetition have not been discussed under the individual parameters. Only the effects of main treatments and sub treatments have been discussed.

4.2.1 Growth attributes of wheat

4.2.1.1 Plant height

The effect of residue management and, different nitrogen levels and method of application on plant height of wheat was observed at maximum tillering stage, panicle initiation stage and at maturity during the year 2013-14 and 2014-15 and is presented in Table 36. Plant height is an index of growth and development of crop plants. It is one of the indices for determining the growth and competing ability of the crop as well as an indicator of growth promoting or suppressing ability of treatments. Plant height was not influenced significantly by tillage and residue management treatments at all the crop growth stages. Plant height increased almost quadratically with increasing plant age and maximum height was attained at harvest. Although, an increase of more than two folds was noticed between maximum tillering stage and panicle initiation stage, but the residue management could not bring any significant change in plant height of wheat at maximum tillering stage and panicle initiation stage. Plant height recorded at maximum tillering stage was found to be lower in FIPB-R (28.94 and 29.70 cm) as compared to the FIPB+R (31.10 and 31.17 cm) during both the years. In both the years, at panicle initiation stage, FIPB+R (64.05 and 62.88 cm) produced tall plants as compared to the FIPB-R (62.88 and 62.43 cm), respectively. Similarly, at harvest stage maximum height (76.45 and 77.67 cm) was recorded from FIPB+R plots, whereas minimum (75.85 and 76.48 cm) was noticed in FIPB-R plots in both 2013-14 and 2014-15, respectively. This increase in plant height was mainly due to the fact that residue retention generally increases soil organic carbon content (Saharawat *et al* 2010) and improves soil physical health (Naresh *et al* 2012) which ultimately affects the crop growth parameters. Ram (2006) also reported higher values of plant height, dry matter accumulation, LAI, CGR and RGR under permanent bed with residue than no-residue under both zero-till and conventional till practices.

Nitrogen application method and N rate significantly affected plant height of wheat at maximum tillering stage, panicle initiation stage and at maturity stage. It was observed that

Table 36: Effect of residue and N management on plant height of wheat

Plant height (cm)						
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At maturity**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Residue Management						
FIPB-R	28.94	31.10	62.88	62.43	75.85	76.48
FIPB+R	29.70	31.17	64.05	62.88	76.45	77.67
SEm±	**0.369**	**0.127**	**0.359**	**0.406**	**0.838**	**0.300**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application						
RN_0 (Control)	24.32	24.40	49.37	43.01	53.23	54.45
$RN_{75\%}$ -B	26.40	28.68	62.02	63.17	75.01	74.81
$RN_{75\%}$ -DOT	27.95	29.48	64.37	65.19	76.29	77.22
$RN_{75\%}$-DIF	27.08	29.21	63.88	63.03	75.12	76.73
$RN_{100\%}$ -B	32.27	34.87	67.52	67.43	83.79	84.28
$RN_{100\%}$ -DOT	33.93	35.73	69.07	69.10	85.76	86.26
$RN_{100\%}$-DIF	33.30	35.60	68.03	67.68	83.83	85.77
SEm±	**0.621**	**0.346**	**0.964**	**0.760**	**1.010**	**0.911**
LSD (P=0.05)	**1.824**	**1.015**	**2.831**	**2.222**	**2.966**	**2.676**

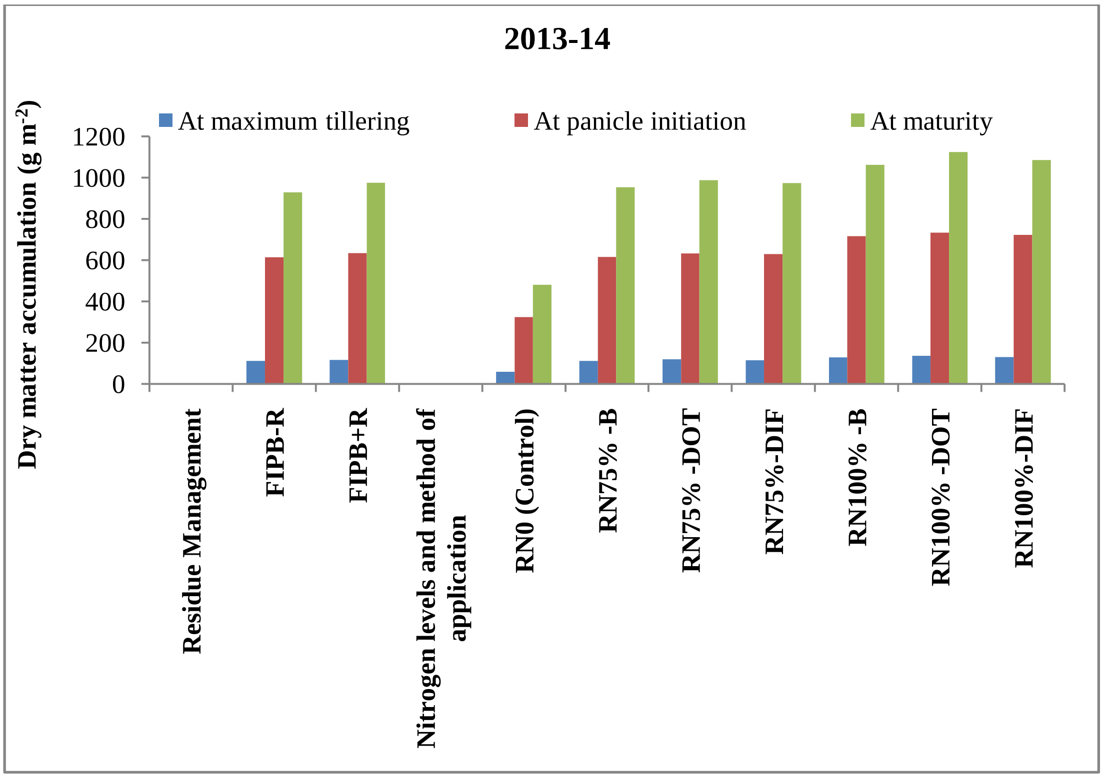
with the addition of plant nutrients to crop, there was increase in the plant height of the wheat crop as compared to control. At all growth stages, the plant height of wheat was higher for the $RN_{100\%}$ -DOT treatment as compared to all other treatments. In both years, the $RN_{100\%}$ -DOT resulted in significantly taller plants as compared to $RN_{75\%}$ -DOT, and, was statistically on par with nitrogen level $RN_{100\%}$ -B and $RN_{100\%}$-DIF at maximum tillering and at panicle initiation stage. Similarly at harvest stage the tallest plants was observed under the treatment $RN_{100\%}$ -DOT (85.76 and 86.26 cm) in both the years, respectively. The higher plant height under the top placement was might be ascribed to the view that there was adequate supply of nutrients and metabolities under top placement of N for growth and development of each reproductive structure of the plant (Kumar *et al* 2013). Inadequate supply of nitrogen under broadcast of N might have resulted into poor initiation of tillers due to depressed growth of lateral bud at early stage of crop and on account of competition between vegetative and generative parts for nutrients and metabolities at later stage (Kumar *et al* 2013, Chen *et al* 2016). Siyal *et al* (2012) also reported that N leaching can be reduced to zero percent by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching.Similar advantages of placement of N have been reported by Hossain and Maniruzzaman (1992) and Singh and Prasad (1998). The improvement in plant height with increase in increment in nitrogen may be ascribed to the way that nitrogen a necessary component of proteins, the building blocks of plant and it additionally helps in keeping up higher auxin level which may have brought about better plant height Singh *et al* (2010) observed that with successive increase in nitrogen level from 0 to 150 kg N ha^{-1}, the magnitude of plant height was increased significantly. Khalil *et al* (2011) also reported that 160 kg N ha^{-1} and 80 kg N ha^{-1} gave plant heights of 81.9 cm and 76.2 cm respectively.

4.2.1.2Dry matter accumulation

Dry matter accumulation is an important feature showing the growth and metabolic efficiency of plants which ultimately affect the yield of crop. The data with respect to dry matter accumulation are reported in Table 37 and Fig. 12. Dry matter accumulation increased almost quadratically with increasing plant age and maximum accumulation of dry matter was attained at harvest. Dry matter accumulation rate was slow at early growth stages, but at peak growth and plant development it accelerated tremendously during both the years. Residue management could not bring any significant change in accumulation of dry matter of wheat at maximum tillering stage. In both years, residue management caused significant variation in dry matter accumulation at panicle initiation stage and at harvest. Significantly higher dry matter accumulation was recorded under FIPB+R (634.73 and 637.02 g m^{-2}) as compared to the FIPB-R (614.69 and 622.45 g m^{-2}) at panicle initiation stage in both years, respectively. Results revealed that in both the years at harvest stage, dry matter accumulation was significantly higher under the FIPB+R (975.62 and 992.00 g m^{-2}) as compared to the FIPB-R (929.44 and 951.53 g m^{-2}), respectively. Das *et al* (2014) also reported significantly higher

Table 37: Effect of residue and N management on dry matter accumulation of wheat

Dry matter accumulation (g m^{-2})						
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At maturity**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Residue Management						
FIPB-R	112.06	113.95	614.69	622.45	929.44	951.53
FIPB+R	116.39	119.34	634.73	637.02	975.62	992.90
SEm±	**1.443**	**1.656**	**2.127**	**2.133**	**4.444**	**4.934**
LSD (P=0.05)	**NS**	**NS**	**13.932**	**13.976**	**29.113**	**32.327**
Nitrogen levels and method of application						
RN_0 (Control)	58.28	56.24	323.60	333.44	480.53	521.32
$RN_{75\%}$ -B	111.97	115.78	615.73	621.78	953.36	961.56
$RN_{75\%}$ -DOT	119.33	120.78	632.68	646.04	987.74	1006.99
$RN_{75\%}$-DIF	114.42	118.01	628.95	636.21	974.27	979.82
$RN_{100\%}$ -B	128.98	131.92	716.21	714.14	1062.73	1086.86
$RN_{100\%}$ -DOT	136.43	140.78	733.42	735.14	1123.34	1135.07
$RN_{100\%}$-DIF	130.18	133.02	722.40	721.02	1085.72	1113.87
SEm±	**1.960**	**1.656**	**5.025**	**6.519**	**10.551**	**13.309**
LSD (P=0.05)	**5.755**	**4.862**	**14.755**	**19.142**	**30.980**	**39.079**



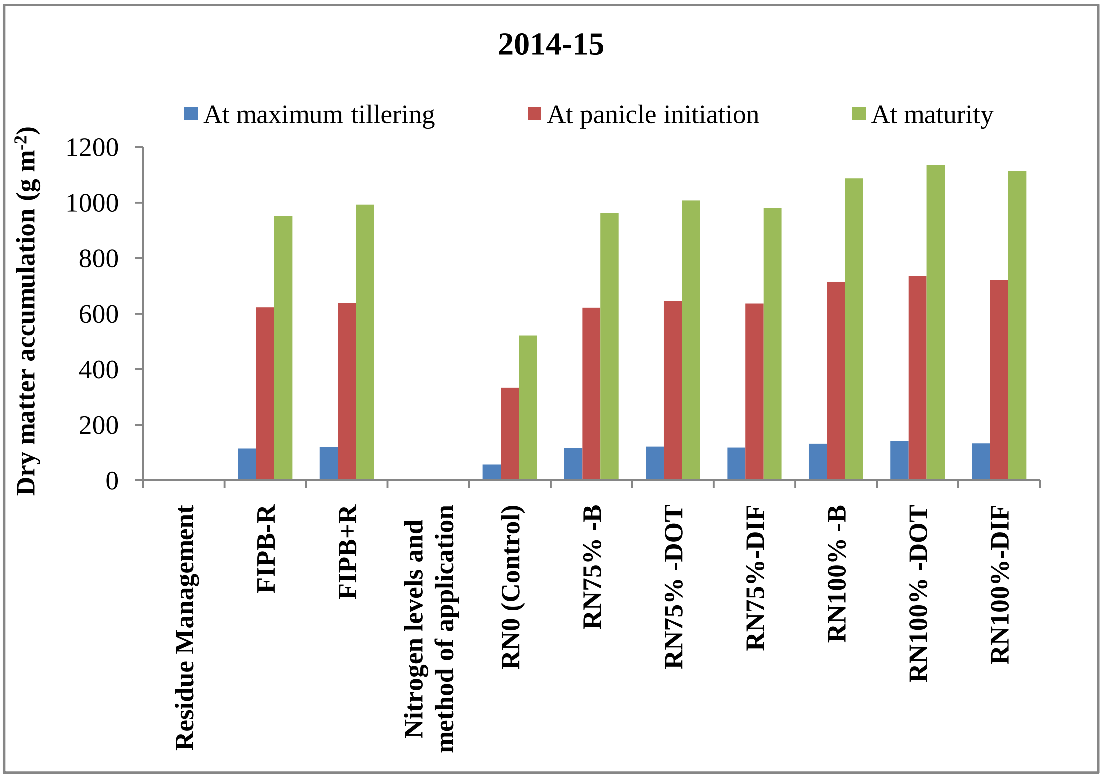


Fig.12: Effect of residue and N management on dry matter accumulation of wheat

dry matter accumulation under permanent beds with residue retention as compared to the permanent beds with residue removal and conventional tillage practice. Prasad and Power (1991) also reported beneficial effect of retaining crop residues in the field in a wide variety of crops, which increase organic matter, aggregation, water holding capacity and infiltration (Bhattacharyya *et al* 2008).

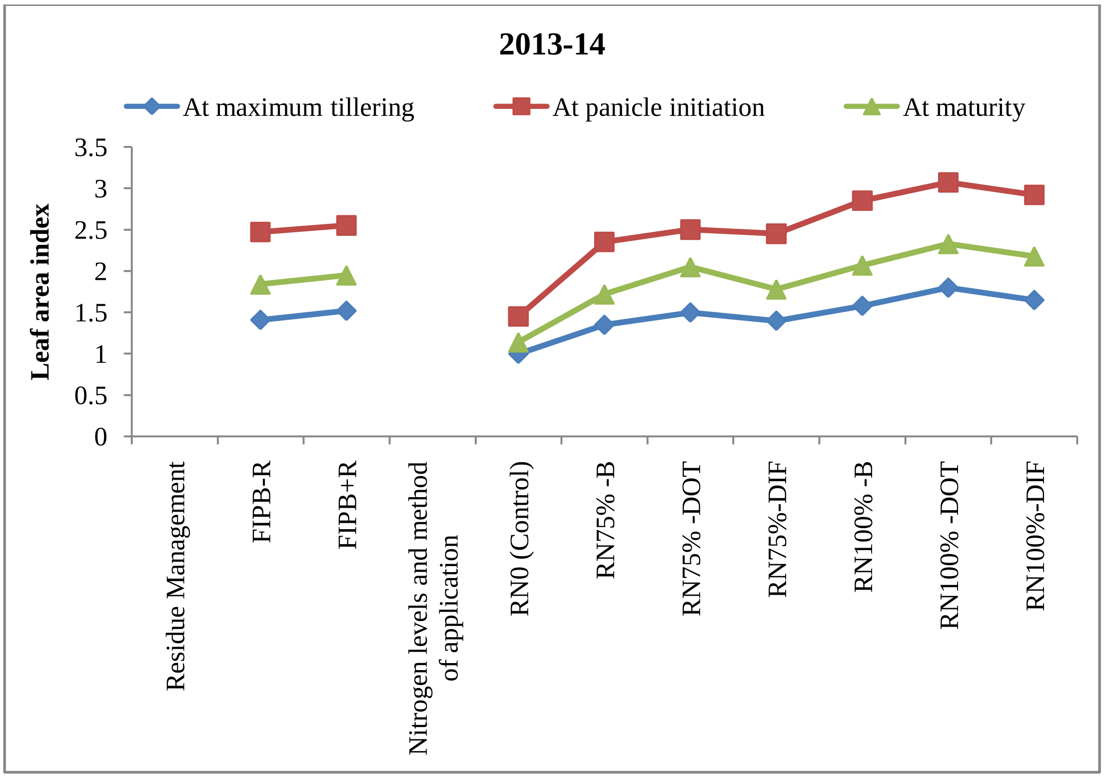
Nitrogen application method and N rate significantly affected dry matter accumulation of wheat at maximum tillering stage, panicle initiation stage and at maturity stage. Among the different N levels the application of N at the rate of $RN_{100\%}$, irrespective of the method of application results into significantly higher dry matter accumulation as compared $RN_{75\%}$ and control at all growth stages. In both years, the $RN_{100\%}$ -DOT resulted in significantly higher dry matter accumulation as compared to $RN_{100\%}$ -B and $RN_{100\%}$-DIF at maximum tillering. At harvest stage in the year 2013-14 significantly higher dry matter accumulation was observered under the $RN_{100\%}$ -DOT as compared to the $RN_{100\%}$ -B and $RN_{100\%}$-DIF, but in the second year dry matter accumulation under the $RN_{100\%}$ -DOT was significantly at par with $RN_{100\%}$-DIF. Similarly in the N level of $RN_{75\%}$ significantly higher dry matter accumulation was recorded under the top placement of fertilizer as compared to the broadcasting. The higher dry matter accumulation under the top placement was might be ascribed to the view that there was adequate supply of nutrients and metabolities under top placement of N for growth and development of each reproductive structure of the plant (Kumar *et al* 2013). Secondly, in the placement of N fertilizer on the top of bed as compared to broadcasting can reduce N loss via ammonia volatilization and improve NUE of plants (Malhi *et al* 1999). Yadav *et al* (2010) also reported that the dry matter accumulation in wheat also increased with N level upto 80 kg ha^{-1} over 0, 40 and 60 kg ha^{-1}.

4.2.1.3 Leaf area index

Leaf area index (LAI) is good index of crop growth and is a major character influencing the assimilating capacity of the crop. Higher the LAI means more interception of photosynthetically active radiation which is the source of energy during the process of photosynthesis. So, higher the LAI better is the crop growth, resulting in higher yield. The data on LAI recorded at various growth stages have been presented in Table 38 and Fig.13.The LAI recorded at different growth stages was found to be not significantly differed among the residue management treatments. The LAI recorded at maximum tilllering stage, panicle initiation stage and at harvesting was highest under the residue retained plots as compared to residue removed plots. At maturity stage FIPB+R recorded higher LAI (1.95 and 1.99) as compared to the FIPB-R (1.84 and 1.88), but significantly at par with each other. The more LAI under the residue retained might be due to fact that residue retention generally increases soil organic carbon content (Saharawat *et al* 2010) and improves soil physical health (Naresh *et al* 2012) which

Table 38: Effect of residue and N management on leaf area index (LAI) of wheat

LAI						
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At maturity**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Residue Management						
FIPB-R	1.41	1.51	2.47	2.54	1.84	1.89
FIPB+R	1.52	1.58	2.55	2.61	1.95	2.01
SEm±	**0.076**	**0.015**	**0.083**	**0.052**	**0.102**	**0.032**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application						
RN_0 (Control)	1.00	1.02	1.45	1.52	1.14	1.22
$RN_{75\%}$ -B	1.35	1.45	2.35	2.38	1.72	1.78
$RN_{75\%}$ -DOT	1.50	1.57	2.50	2.62	2.05	2.07
$RN_{75\%}$-DIF	1.40	1.50	2.45	2.50	1.78	1.87
$RN_{100\%}$ -B	1.58	1.63	2.85	2.92	2.07	2.12
$RN_{100\%}$ -DOT	1.80	1.85	3.07	3.13	2.33	2.37
$RN_{100\%}$-DIF	1.65	1.75	2.92	2.95	2.18	2.25
SEm±	**0.096**	**0.079**	**0.150**	**0.171**	**0.068**	**0.087**
LSD (P=0.05)	**0.283**	**0.232**	**0.439**	**0.502**	**0.198**	**0.255**



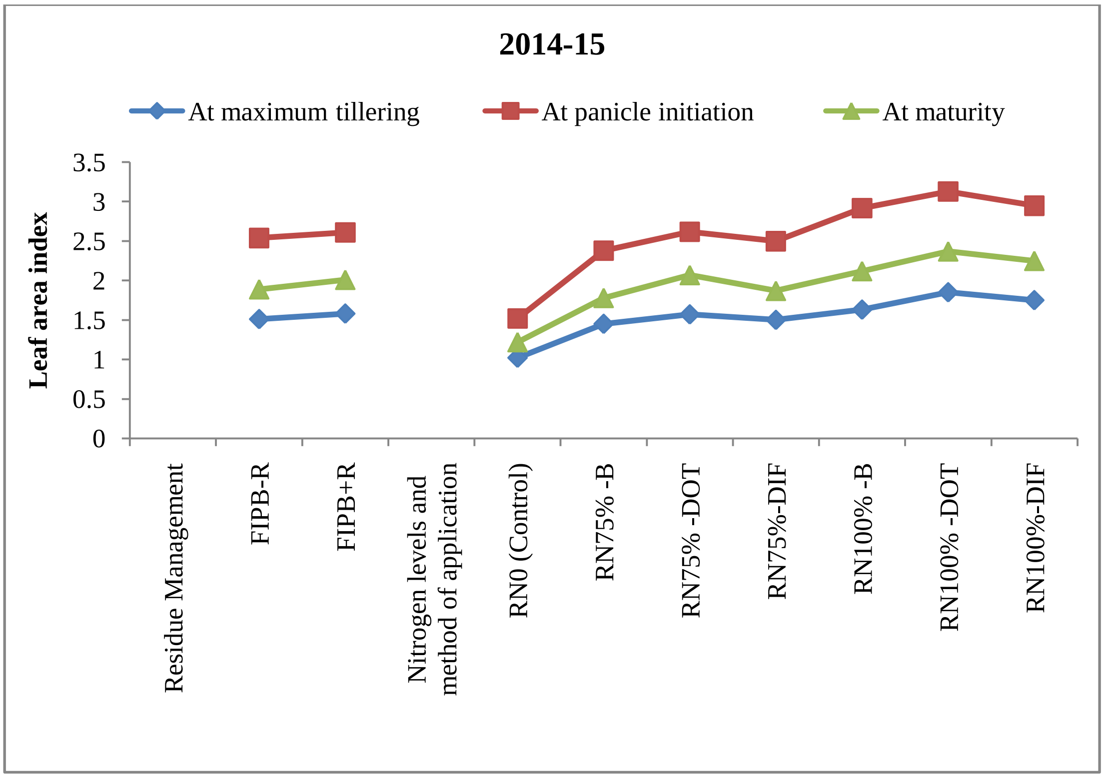


Fig.13: Effect of residue and N management on leaf area index (LAI) of wheat

ultimately affects the crop growth parameters. Das *et al* (2014) also reported higher values of LAI under permanent bed with residue than no-residue.

Nitrogen application method and N rate significantly affected the LAI of wheat at maximum tillering stage, panicle initiation stage and at maturity stage. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher LAI as compared all other treatments at all growth stages. At maximum tillering and panicle initiation stage significantly higher LAI was recorded under the $RN_{100\%}$-DOT as compared to the control, $RN_{75\%}$ -DOT, $RN_{75\%}$-DIF and $RN_{75\%}$ -B but statically at par with the $RN_{100\%}$ -B and $RN_{100\%}$-DIF, in both years. However the LAI recorded under $RN_{75\%}$ -DOT was significantly at par with the $RN_{100\%}$ -B and $RN_{100\%}$-DIF at all growth stages during both the years. Hartmann *et al* (2015) reported that the placement of fertilizer at the top of the bed results into the higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE, which ultimately affects the various growth parameters of crop. Additionally, placing N fertilizer into soil can reduce the immobilization of N by soil microorganisms and increases uptake by plants (Mooleki *et al* 2010). Placing of N fertilizer into the soil can also improve the competition of wheat with weeds compared to broadcast (Petersen, 2001).

4.2.2 Yield attributes of wheat

4.2.2.1 Effective tillers

The effect of residue management and different N levels on total number of effective tillers m^{-2} of wheat during 2013-14 and 2014-15 are presented in Table 39. Wheat yield is greatly influenced by the number of effective tillers per unit area. Effective tillers m^{-2}were recorded at the time of harvest of wheat crop and it was observed that with residue retention and with the increase in the N doses, there was increase in the number of effective tillers m^{-2}. Among residue management plots significantly higher effective tillers were obtained in the residue retained plots i.e. FIRB+R (360.66 and 363.03) as compared to the residue removed plots i.e. FIRB-R (349.14 and 348.92) during both years, respectively. The retention of residue under permanent bed treatment resulted higher values of effective tillers m^{-2} than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002). Parihar *et al* (2016) also showed the positive effects of PB and residue retention on grain yield of wheat which could be attributed to the higher effective tillers m^{-2}, higher spike density, higher number of grains per spike and 1000-grain weight.

Among the different N levels the application of N at the rate of $RN_{100\%}$, irrespective of the method of application results into higher effective tillers as compared $RN_{75\%}$ and control at all growth stages. Significantly higher effective tiller count was observed under the

Table 39: Effect of residue and N management on yield attributes of wheat

Treatments	Effective tillers m^{-2}		Spike length (cm)		1000-grain weight (g)	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Residue Management						
FIPB-R	349.14	348.92	15.39	15.51	39.24	40.48
FIPB+R	360.66	363.03	15.50	15.67	40.19	41.07
SEm±	**0.933**	**0.670**	**0.083**	**0.035**	**0.089**	**0.061**
LSD (P=0.05)	**6.114**	**4.388**	**NS**	**NS**	**0.584**	**0.398**
Nitrogen levels and method of application						
RN_0 (Control)	243.38	232.59	14.18	14.33	37.00	34.45
$RN_{75\%}$ -B	348.23	353.33	15.33	15.50	38.83	39.83
$RN_{75\%}$ -DOT	367.80	372.35	15.52	15.65	40.17	40.88
$RN_{75\%}$-DIF	362.88	363.95	15.43	15.59	39.33	40.75
$RN_{100\%}$ -B	376.45	375.31	15.63	15.71	40.50	41.08
$RN_{100\%}$ -DOT	395.52	399.75	16.05	16.27	41.50	42.08
$RN_{100\%}$-DIF	390.03	394.57	15.98	16.07	40.67	41.33
SEm±	**4.962**	**5.547**	**0.131**	**0.097**	**0.408**	**0.398**
LSD (P=0.05)	**14.570**	**16.288**	**0.386**	**0.286**	**1.199**	**1.169**

top placement of fertilizer both for the $RN_{75\%}$ and $RN_{100\%}$ as compared to the broadcasted. In both the years, significantly higher effective tillers were recorded under the $RN_{100\%}$ -DOT (395.52 and 399.75) as compared to the $RN_{100\%}$ -B (376.45 and 375.31), but statistically at par with $RN_{100\%}$ -DIF (390.03 and 394.57), respectively. Similarly, significantly higher effective tillers were recorded under the $RN_{75\%}$-DOT (367.80 and 372.35) as compared to the $RN_{75\%}$ -B (348.23 and 353.33) which isstatistically at par with $RN_{100\%}$ -B (376.45 and 375.31) and $RN_{75\%}$ -DIF (362.88 and 363.95), respectively. The higher effective tiller count under the top placement of fertilizer as compared to the broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria, so as reduce the N loss due to leaching and increases the NUE, which ultimately affects the effective tiller count (Hartmann *et al* 2015). Chen *et al* (2016) also reported increased number of effective tillers with band placement of fertilizer as compared to the broadcasting.

4.2.2.2Spike length

Spike length may serve as reliable criteria to access crop yield as it is an indicator of yield because increase in spike length will influence the number of grains spike^{-1}.A reference to data in Table 39 revealed that the residue management does not bring any significant effect on spike length. However higher spike length was found under the residue retained plots i.e. FIRB+R (15.50 and 15.67cm) as compared to the residue removed plots i.e. FIRB-R (15.39 and 15.51) during both years, respectively. This increase in spike length was mainly due to the fact that retaining plant residues into agricultural soils can sustain organic carbon content, readily available C and N, improve soil physical properties, enhance biological activities and increase nutrient availability (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu *et al* 2011). Das *et al*(2014) also observed that permanent bed planting with residue retention practice produced significantly higher spike length than conventional tillage without residue retention.

Spike length was significantly affected by N application method and rate. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher spike length as compared to the control, $RN_{75\%}$ -DOT, $RN_{75\%}$-DIF, $RN_{75\%}$ -B and $RN_{100\%}$ -B but statically at par with the $RN_{100\%}$-DIF, in both years. However, the spike length recorded under the $RN_{100\%}$ -B was significantly at par with the $RN_{75\%}$ -DOT, $RN_{75\%}$-DIF and $RN_{75\%}$ -B during both the years. Kumar *et al* (2013) reported that placement of N fertilizer resulted in significant improvement of various yield attributes over broadcast application of N. Compared to N broadcast, the placement of N increased 3.4 and 4.1% spike length and 8.5 and 5.9% grains spike^{-1} during both years, respectively. This might be ascribed to the view that there was adequate supply of nutrients and metabolites under placement of N for growth and development of each reproductive structure of the plant. Similar advantages of placement of N have been reported by Hossain and Maniruzzaman (1992) and for spike length and grains spike^{-1}

4.2.2.3 1000-grain weight

The data on 1000-grain weight have been presented in Table 29. The grain weight indicates the nature and extent of grain development. It is a function of various production factors that influence grain development and filling patterns. 1000-grain weight was significantly influenced by different treatment combinations of residue management and, different N rates and method of application. However, 1000-grain weight was found to be lower in FIPB-R (39.24 and 40.48 g) as compared to the FIPB+R (40.19 and 41.07g) during both the years, respectively. The retention of residue under permanent bed resulted higher values of 1000-grain weight than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues (Yadav *et al* 2005).

Nitrogen application method and N rate significantly affected the 1000 grain weight of wheat. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher 1000 grain weight (41.50 and 42.08 g) as compared to the control (37.00 and 34.45g), $RN_{75\%}$ -DOT (40.17 and 40.88g), $RN_{75\%}$-DIF (39.33 and 40.75g), $RN_{75\%}$ -B (38.33 and 39.83g) but statically at par with the $RN_{100\%}$-DIF (40.67and 41.33g) and $RN_{100\%}$-B (40.50 and 41.08g) during both years, respectively. However the 1000-grain weight recorded under the $RN_{75\%}$ -DOT (40.17 and 40.88g) was significantly at par with the $RN_{100\%}$-DIF (40.67and 41.33g) and $RN_{100\%}$-B (40.50 and 41.08g) during both years, respectively. Siyal *et al* (2012) also reported that N leaching can be reduced to zero percent by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching.The higher 1000-grain weight under the top placement was might be ascribed to the view that there was adequate supply of nutrients and metabolities under top placement of N for growth and development of each reproductive structure of the plant (Kumar *et al* 2013).

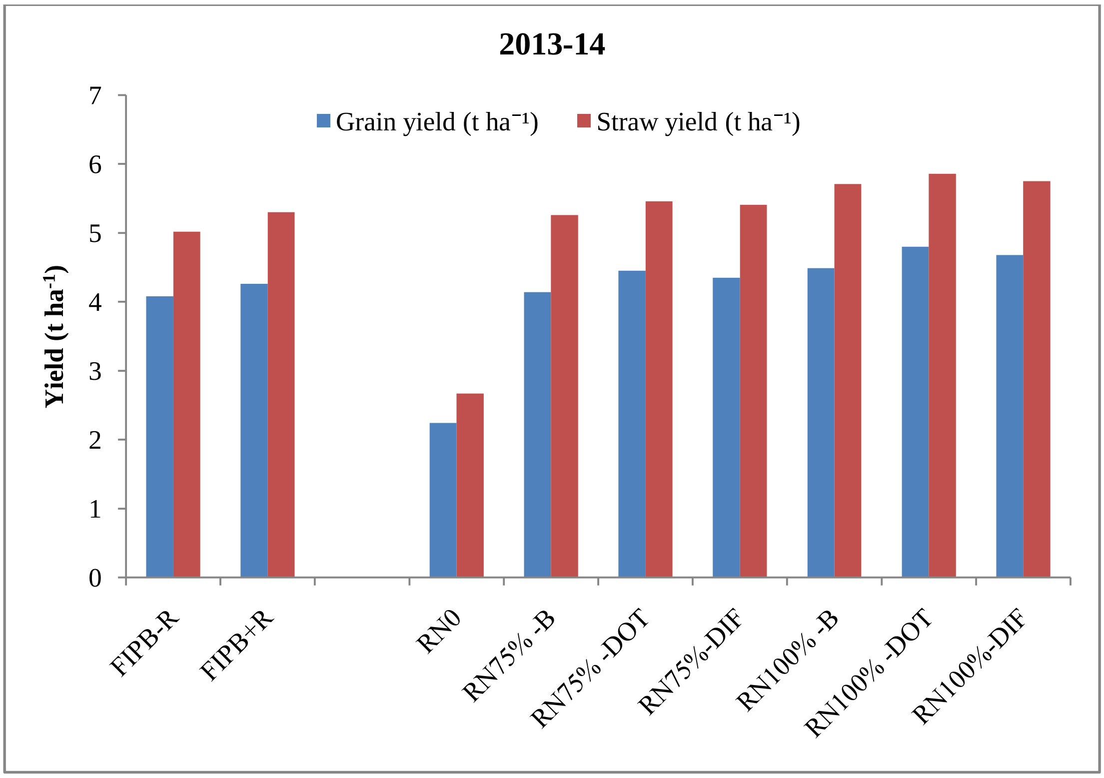
4.2.3Grain and straw yield of wheat

4.2.3.1 Grain yield

Grain yield is function of effective tillers, number of grains per ear and 1000-grain weight etc. The grain yield of wheat crop was significantly influenced due to residue management and different N rates and application methods. The data regarding grain yield presented in Table 40 and Fig.14. Among residue management plots significantly higher grain yield was recorded in the residue retained plots i.e. FIRB+R (4.26 and 4.36 t ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (4.08 and 4.19) during both years, respectively. The higher grain yield under residue retained plots might be due to the effect of maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002). Similarly, Ram *et al* (2010) also reported higher yields under ZT with

Table 40: Effect of residue and N management on grain and straw yield of wheat

Treatments	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2013-14	**2014-15**	**2013-14**	**2014-15**
Residue Management				
FIPB-R	4.08	4.19	5.02	5.12
FIPB+R	4.26	4.36	5.30	5.46
SEm±	**0.013**	**0.024**	**0.029**	**0.039**
LSD (P=0.05)	**0.084**	**0.155**	**0.192**	**0.256**
Nitrogen levels and method of application				
RN_0	2.24	2.28	2.67	2.86
$RN_{75\%}$ -B	4.14	4.29	5.26	5.28
$RN_{75\%}$ -DOT	4.45	4.53	5.46	5.60
$RN_{75\%}$-DIF	4.35	4.37	5.41	5.35
$RN_{100\%}$ -B	4.49	4.65	5.71	5.86
$RN_{100\%}$ -DOT	4.80	4.98	5.86	6.09
$RN_{100\%}$-DIF	4.68	4.83	5.75	5.99
SEm±	**0.091**	**0.074**	**0.142**	**0.113**
LSD (P=0.05)	**0.269**	**0.217**	**0.415**	**0.331**



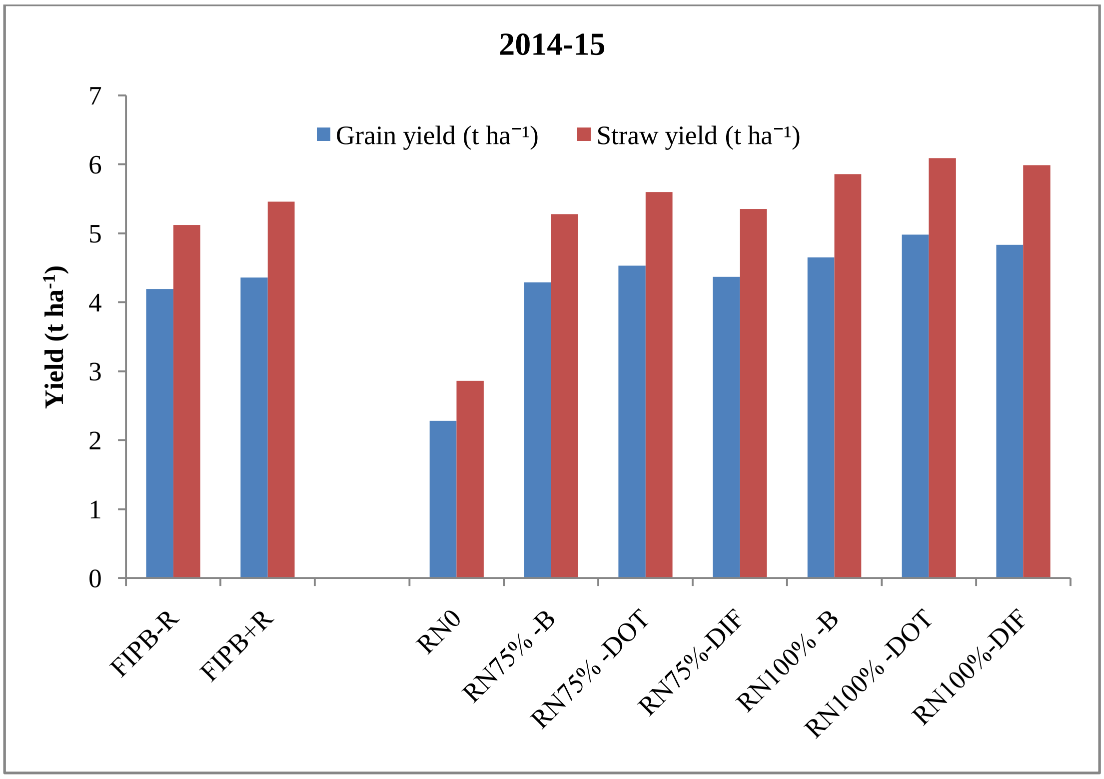


Fig.14: Effect of residue and N management on grain and straw yield of wheat

residue due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture, tillers, grains/ear and 1000-grain weight than no-residue application under ZT and CT practices. Parihar et al (2016) likewise demonstrated the constructive outcomes of PB and residue retention on grain yield of wheat. Wheat grain and straw yields was most astounding in PB plots (4.44 and 6.54 Mg ha^{-1}) compared with ZT (3.90 and 5.91 Mg ha^{-1}) and CT (3.73 and 5.72 Mg ha^{-1}).The significantly higher wheat grain yield were recorded in the PB plots compared with ZT and CT plots, which could be ascribed to the spike density, number of grains per spike and 1000-grain weight.

Nitrogen application method and N rate significantly affected the grain yield of wheat. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher grain yield (4.80 and 4.98 t ha^{-1}) as compared to the control (2.24 and 2.28 t ha^{-1}), $RN_{75\%}$ -DOT (4.45 and 4.53 t ha^{-1}), $RN_{75\%}$-DIF (4.35 and 4.37 t ha^{-1}), $RN_{75\%}$ -B (4.14 and 4.29 t ha^{-1}) and $RN_{100\%}$ -B (4.49 and 4.65 t ha^{-1}) but statically at par with the $RN_{100\%}$-DIF (4.68 and 4.83 t ha $^{-1}$), during both years respectively. However no significant difference was observed between the grain yield of $RN_{75\%}$ -DOT (4.45 and 4.53 t ha^{-1}) and $RN_{100\%}$ -B (4.49 and 4.65 t ha^{-1}), during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application. The higher grain yield was obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE, which ultimately affects the effective tiller count (Hartmann *et al* 2015). Siyal *et al* (2012) also reported that N leaching can be reduced to zero percent by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching. Waddell *et al* (2006) reported that the placement of N fertilizer as compared to surface application through broadcasting results into less ammonia volatilisation and nitrous oxide emission which ultimately increases the NUE. Chen *et al* (2016) reported higher grain yield with band placement of fertilizer as compared to the broadcasting. Kumar *et al* (2013) also reported that placement of N significantly improved the grain and straw yield of wheat over broadcast application of N. The increase with placement of N was 8.1% for grain and 7.4% for straw yield over broadcast.

4.2.3.2 Straw yield

The effect of residue management and, different N levels and method of N application on straw yield of wheat during 2013-14 and 2014-15 are presented in Table 40. A reference to data presented revealed that the residue management bring significant effect on straw yield of wheat. Higher straw yield was recorded under the residue retained plots i.e.

FIRB+R (5.30 and 5.46 t ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (5.02 and 5.12 t ha^{-1}) during both years, respectively. Parihar *et al* (2016) showed the positive effects PB and residue retention on grain and starw yield of wheat. Wheat grain and straw yields were highest in PB plots with residue retention (4.44 and 6.54 Mg ha^{-1}) as compared to CT without residue retention (3.73 and 5.72 Mg ha^{-1}), this might be due to less lodging of wheat crop under PB systems with residue retention. Increase in grain and straw yield of wheat in PB with residue retention may be attributed to the positive effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), improved soil health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009), lesser weed population (Ozpinar 2006, Chauhan *et al* 2007), and improved nutrient use efficiency compared to CT without residue retention (Unger and Jones, 1998).

Nitrogen application method and N rate significantly affected the straw yield of wheat. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher straw yield (5.86 and 56.09 t ha^{-1}) as compared to the control (2.67 and 2.86 t ha^{-1}), $RN_{75\%}$-DOT (5.46 and 5.60 t ha^{-1}), $RN_{75\%}$-DIF (5.41 and 5.35 t ha^{-1}) and $RN_{75\%}$-B (5.26 and 5.28 t ha^{-1}) but statically at par with the $RN_{100\%}$-DIF (5.75 and 5.99 t ha^{-1}) and $RN_{100\%}$-B (5.71 and 5.86 t ha^{-1}), during both years respectively. However no significant difference was observed between the straw yield of $RN_{75\%}$-DOT and $RN_{100\%}$-B, during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application. Kumar *et al* (2013) reported that placement of N fertilizer resulted in significant improvement of various yield attributes over broadcast application of N. This might be ascribed to the view that there was adequate supply of nutrients and metabolites under placement of N for growth and development of each reproductive structure of the plant. Improvement in yield attributes due to placement of N appears to be on account of vigorous growth as reflected by higher accumulation of dry matter at successive growth stages of wheat which ultimately accounts for the higher straw yield. Similar results were obtained by Chen *et al* (2016) and Hartmann *et al* (2015).

4.2.4 Plant analysis

4.2.4.1 Nitrogen content

The effect of residue management and, different N levels and method of N application on nitrogen content of wheat was observed at maximum tillering stage, panicle initiation stage and at maturity during the year 2013-14 and 2014-15 and is presented in Table 41. Nitrogen content was not influenced significantly by residue management treatments at all the crop growth stages. Nitrogen content recorded at maximum tillering stage and at panicle initiation stage was found to be higher under the FIPB+R as compared to the FIPB-R. Similarly, FIPB+R recorded higher nitrogen content in grain (1.82 and 1.74%) and straw (0.45 and 0.47%) as compared to the FIPB-R content in grain (1.76 and 1.70%) and straw (0.43 and 0.45%) but not a significant difference was observed.

Table 41: Effect of residue and N management on N content at different growth stages of wheat

Treatments	Nitrogen content (%)							
	At maximum tillering Stage		At panicle initiation Stage		At Maturity			
					Grain		Straw	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Residue Management								
FIPB-R	2.91	2.70	1.45	1.42	1.76	1.70	0.43	0.45
FIPB+R	2.94	2.78	1.46	1.43	1.82	1.74	0.45	0.47
SEm±	**0.011**	**0.038**	**0.024**	**0.104**	**0.086**	**0.033**	**0.016**	**0.028**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0 (Control)	2.56	2.41	0.96	1.01	1.48	1.45	0.34	0.33
$RN_{75\%}$ -B	2.80	2.59	1.43	1.35	1.67	1.55	0.39	0.43
$RN_{75\%}$ -DOT	2.98	2.72	1.48	1.48	1.72	1.70	0.45	0.47
$RN_{75\%}$-DIF	2.91	2.63	1.44	1.42	1.62	1.67	0.42	0.45
$RN_{100\%}$ -B	3.06	2.93	1.59	1.59	1.98	1.82	0.48	0.51
$RN_{100\%}$ -DOT	3.14	2.96	1.67	1.59	2.09	1.95	0.51	0.52
$RN_{100\%}$-DIF	3.00	2.94	1.60	1.52	1.98	1.89	0.47	0.49
SEm±	**0.061**	**0.131**	**0.087**	**0.095**	**0.084**	**0.067**	**0.029**	**0.038**
LSD (P=0.05)	**0.180**	**0.386**	**0.255**	**0.280**	**0.248**	**0.196**	**0.085**	**0.112**

However the N levels and method of application had significant effect on N content at all the observations i.e. at maximum tillering stage, at panicle imitation stage and at maturity in grain and straw. At maximum tillering stage, it was observed that with the addition of plant nutrients to crop, there was increase in the N content of the wheat crop as compared to control. Higher nitrogen content was observed under the top placement of fertilizer both for the $RN_{75\%}$ and $RN_{100\%}$ as compared to the broadcasted. The $RN_{100\%}$-DOT results into significantly higher N content in grain as compared to the $RN_{75\%}$ -DOT, which was significantly at par with the $RN_{100\%}$-DIF and $RN_{100\%}$-B during the second year. However in straw the method of N application does not bring any significant difference in N content. Ahmad *et al* (2015) reported significant improvement in the nitrogen content of wheat in grain and straw with increase in the nitrogen level up to 120 kg N ha^{-1}. Malhi *et al* (1999) reported that in the placement of N fertilizer on the top of bed as compared to broadcasting can reduce N loss via ammonia volatilization and improve N uptake by plants.

4.2.4.2 Nitrogen uptake

The N uptake by wheat crop at different growth stages was not significantly influenced due to residue management but significantly influenced by different N rates and application methods. The data regarding N uptake presented in Table 42. However higher N uptake was recorded under the residue retained plots i.e. FIRB+R as compared to the residue removed plots i.e. FIRB-R during both years at all growth stages. At maximum tillering stage higher N uptake was obtained in FIPB+R (34.51 and 33.59 kg ha^{-1}) which was statistically similar with FIPB-R (33.05 and 31.26 kg ha^{-1}). Similarly, N uptake by grain and straw was higher under the FIPB+R (78.91, 76.82 and 24.20, 26.29 kg ha^{-1}) as compared to the FIPB-R (73.06, 72.63 and 21.94, 23.43 kg ha^{-1}), respectively in both the years but not statistical difference was observed. Bahera *et al* (2007) also reported maximum N uptake under ZT with residue retention, which might be due to addition of nutrients through residue, better root growth, leading to more extraction of nutrient from soil, lower weed infestation and better performance of crop, improved physical environment favourable for better microbial activity that might helped in mineralization resulting better availability of nutrients (macro and micro) to crops and thus increased the uptake under these treatments.

However the N levels and method of application had significant effect on N uptake at all the observations i.e. at maximum tillering stage, at panicle initation stage and at maturity in grain and straw. At maximum tillering stage among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher N uptake (42.88 kg ha^{-1}) as compared to the all other treatments during the first year, but in the second year N uptake under $RN_{100\%}$-DOT (41.10 kg ha^{-1}) was significantly higher than the control (13.59 kg ha^{-1}), $RN_{75\%}$ -DOT (32.95 kg ha^{-1}), $RN_{75\%}$-DIF (30.19 kg ha^{-1}) and $RN_{75\%}$ -B (30.00 kg ha^{-1}), but statically at par with the $RN_{100\%}$-DIF (39.15 kg ha $^{-1}$) and $RN_{100\%}$ -B (38.64 kg ha^{-1}). Similarly at panicle

Table 42: Effect of residue and N management on N uptake at different growth stages of wheat

Nitrogen uptake (kg ha^{-1})								
Treatments	**At maximum tillering Stage**		**At panicle initiation Stage**		**At Maturity**			
					Grain		**Straw**	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Residue Management								
FIPB-R	33.05	31.26	91.52	91.31	73.06	72.63	21.94	23.43
FIPB+R	34.51	33.59	95.98	93.06	78.91	76.82	24.20	26.29
SEm±	**0.463**	**0.545**	**1.394**	**6.109**	**3.341**	**1.320**	**0.716**	**1.500**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0 (Control)	14.93	13.59	31.02	33.79	32.89	33.15	9.22	9.39
$RN_{75\%}$ -B	31.27	30.00	87.45	84.36	68.89	66.76	20.72	23.01
$RN_{75\%}$ -DOT	35.55	32.95	94.17	96.12	76.51	76.85	24.51	26.66
$RN_{75\%}$-DIF	33.33	30.913	90.47	90.36	70.72	73.38	22.77	23.90
$RN_{100\%}$ -B	39.42	38.64	114.21	113.92	89.27	84.52	27.37	30.10
$RN_{100\%}$ -DOT	42.88	41.70	122.83	117.28	100.59	97.33	29.76	31.70
$RN_{100\%}$-DIF	39.10	39.15	115.82	109.45	93.03	91.09	27.12	29.24
SEm±	**0.907**	**1.645**	**6.099**	**6.481**	**3.980**	**3.399**	**1.609**	**2.280**
LSD (P=0.05)	**2.664**	**4.829**	**17.908**	**19.029**	**11.687**	**9.981**	**4.725**	**6.695**

initiation stage higher N uptake was observed under the top placement of fertilizer as compared to furrow application and broadcasting. At maturity stage the $RN_{100\%}$-DOT results into significantly higher N uptake in grain (100.59 and 97.33 kg ha^{-1}) as compared to the $RN_{75\%}$ -DOT (76.51 and 76.85 t ha^{-1}), which was significantly at par with the $RN_{100\%}$-B during the second year. Similarly, N uptake by straw was significantly higher under the $RN_{100\%}$-DOT as compared to the $RN_{75\%}$ -DOT which is statistically at par with the $RN_{100\%}$-B and $RN_{100\%}$-DIF during both the years. The higher N uptake was obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the N uptake by crop plant and NUE (Hartmann *et al* 2015). Siyal *et al* (2012) also reported that N leaching can be reduced to zero percent by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching.

4.2.5 Nitrogen use efficiency (NUE)

The ability of crops to use the applied N depends on the uptake and utilization efficiency. Residue management and, different N levels and method of N application brought significant differences in the NUE by the wheat. The data regarding NUE presented in Table 43**.** In the first year no significant difference was recorded under the residue retained plots i.e. FIRB+R and residue removed plots i.e. FIRB-R. However in the second year of crop significantly higher NUE was recorded under the residue retained plots i.e. FIRB+R (45.39 kg kg^{-1}**)** residue removed plots i.e. FIRB-R (43.61 kg kg^{-1}**).** Increase in NUE with residue retention may be attributed to the positive effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), improved soil health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009), lesser weed population (Ozpinar 2006, Chauhan *et al* 2007), and improved nutrient use efficiency compared to CT without residue retention (Unger and Jones, 1998). Parihar *et al* (2016) also showed the positive effects of PB and residue retention on NUE of wheat.

Nitrogen application method and N rate significantly affected the NUE of wheat. Among the different N levels and application methods $RN_{75\%}$ -DOT results into significantly higher NUE (49.47 and 50.25 kg kg^{-1}) as compared to the $RN_{75\%}$ -B (45.99 and 47.73 kg kg^{-1}), $RN_{100\%}$ -DOT (40.04 and 41.47 kg kg^{-1}), $RN_{100\%}$-DIF (38.98 and 40.23 kg kg^{-1}) and $RN_{100\%}$ -B (37.45 and 38.76 kg kg^{-1}), but statistically at par with the $RN_{75\%}$-DIF (48.35 and 48.55 kg kg^{-1}) during both years, respectively. However among the 100% recommended fertilizer rate significantly higher NUE was observed under the $RN_{100\%}$ -DOT which was significantly at par with the $RN_{100\%}$-DIF and significantly higher than the $RN_{100\%}$ -B. The higher NUE obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer

Table 43: Effect of residue and N management on nitrogen use efficiency of wheat

NUE (kg kg^{-1})		
Treatments	**2013-14**	**2014-15**
Residue Management		
FIPB-R	42.72	43.61
FIPB+R	44.04	45.39
SEm±	**0.239**	**0.127**
LSD (P=0.05)	**NS**	**0.702**
Nitrogen levels and method of application		
RN_0	-	-
$RN_{75\%}$ -B	45.99	47.73
$RN_{75\%}$ -DOT	49.47	50.25
$RN_{75\%}$-DIF	48.35	48.55
$RN_{100\%}$ -B	37.45	38.76
$RN_{100\%}$ -DOT	40.04	41.47
$RN_{100\%}$-DIF	38.98	40.23
SEm±	**0.890**	**0.702**
LSD (P=0.05)	**2.543**	**2.085**

zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the N uptake by crop plant and NUE (Hartmann *et al* 2015). Nitrogen use efficiency is greater when the yield response to N is high. Therefore, this efficiency is generally high with low N rates and decreases in accordance with the rate increase of applied N (Gauer *et al* 1992, Parodi 2003). Similar results were obtained by Sinebo *et al* (2004) and Rahman *et al* (2000).

4.2.6 Growth attributes of maize

4.2.6.1Plant Height

The effect of residue management and, different nitrogen levels and method of application on plant height of wheat was observed at knee height stage, tasseling stage, silking stage and at maturity during the year 2014 and 2015 and is presented in Table 44. Plant height an index of growth and development representing the infrastructure build-up over a period of time, is dependent on genetic constitution of a particular cultivar and may also vary due to different agronomic manipulations which may alter the soil or above ground conditions for the better growth of crop plants. Plant height was not influenced significantly by tillage and residue management treatments at all the crop growth stages. Plant height increased almost quadratically with increasing plant age and maximum height was attained at harvest. Although, an increase of more than four folds was noticed between knee height stage and tasseling stage, but the residue management could not bring any significant change in plant height of maize at all growth stages. Plant height recorded at knee height stage was found to be lower in FIPB-R (39.46 and 43.32 cm) as compared to the FIPB+R (40.73 and 45.27 cm) during both the years. At the tasseling and silking stage, significantly higher plant height was recorded under the residue retained plots as compared to residue removed plots. Plant height increases linearly with the advancement of crop age and reaches to its maximum value at maturity stage with higher value under the FIPB+R (214.09 and 221.12) as compared to the FIPB+R (207.95 and 214.21 cm). This increase in plant height was mainly due to the fact that incorporating plant residues into agricultural soils can also sustain organic carbon content, readily available C and N, improve soil physical properties, enhance biological activities and increase nutrient availability which ultimately affects the crop growth parameters (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu *et al* 2011). Govaerts *et al* (2005) also reported that permanent bed planting along with rotation and residue retention had the advantages in growth parameters of maize.

Nitrogen application method and N rate significantly affected plant height of wheat at knee height stage, tasseling stage, silking satge and at maturity stage. It was observed that with the addition of plant nutrients to crop, there was increase in the plant height of the maize crop as compared to control. In both years, at knee height stage and at tasseling stage the $RN_{100\%}$ -POT resulted in significantly taller plants as compared to $RN_{100\%}$ -B and was statistically at par with the $RN_{100\%}$-PIF. However at silking and maturity stage the plant height recorded under the $RN_{100\%}$-PIF was significantly lower than the $RN_{100\%}$ -POT. The plant height recorded under the $RN_{75\%}$ -POT was statistically at par with nitrogen level $RN_{100\%}$ -B and significantly higher than the $RN_{75\%}$ -B at all growth stages of maize. At harvest stage the tallest plants was observed under the treatment $RN_{100\%}$ -POT (233.00 and 240.17 cm) which was significantly higher than the $RN_{100\%}$ -B (222.50 and 226 cm) and $RN_{100\%}$-PIF (224.17 and 231.50 cm) in both the years, respectively. The higher plant height under the top placement was might be ascribed to the view that there was adequate supply of nutrients and metabolities under top placement of N for growth and development of each reproductive structure of the plant (Kumar *et al* 2013. Similar advantages of placement of N have been reported by Hassan *et al* (2013) in maize crop. The improvement in plant height with increase in nitrogen might be attributed to the fact that nitrogen is an integral part of proteins, the building blocks of plant and it also helps in maintaining higher auxin level which might have resulted in better plant height (Singh *et al* 2000). Similar results were reported by Kumar (2009) and Paradkar and Sharma (1993).

Table 44: Effect of residue and N management on plant height of maize

Plant height (cm)								
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**		**At maturity**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management								
FIPB-R	39.46	43.32	186.11	191.45	200.57	208.64	207.95	214.21
FIPB+R	40.73	45.27	191.75	195.21	206.00	215.57	214.09	221.12
SEm±	**0.255**	**0.495**	**1.910**	**2.079**	**1.669**	**1.402**	**2.431**	**1.200**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	30.28	32.83	145.83	149.83	160.00	162.67	164.83	168.50
$RN_{75\%}$ -B	38.02	43.00	184.18	189.33	197.50	210.08	202.50	215.00
$RN_{75\%}$ -POT	41.05	44.97	193.85	199.08	207.83	217.00	216.33	223.67
$RN_{75\%}$-PIF	39.70	43.73	187.17	194.08	199.67	212.00	210.83	218.83
$RN_{100\%}$ -B	42.32	45.88	201.83	204.25	213.67	220.92	222.50	226.00
$RN_{100\%}$ -POT	45.35	50.33	207.17	210.75	226.33	235.67	233.00	240.17
$RN_{100\%}$-PIF	43.93	49.10	202.50	206.00	218.00	226.42	224.17	231.50
SEm±	**0.593**	**0.702**	**1.596**	**1.761**	**2.604**	**1.510**	**2.433**	**1.433**
LSD (P=0.05)	**1.741**	**2.062**	**4.685**	**5.171**	**7.647**	**4.434**	**7.144**	**4.208**

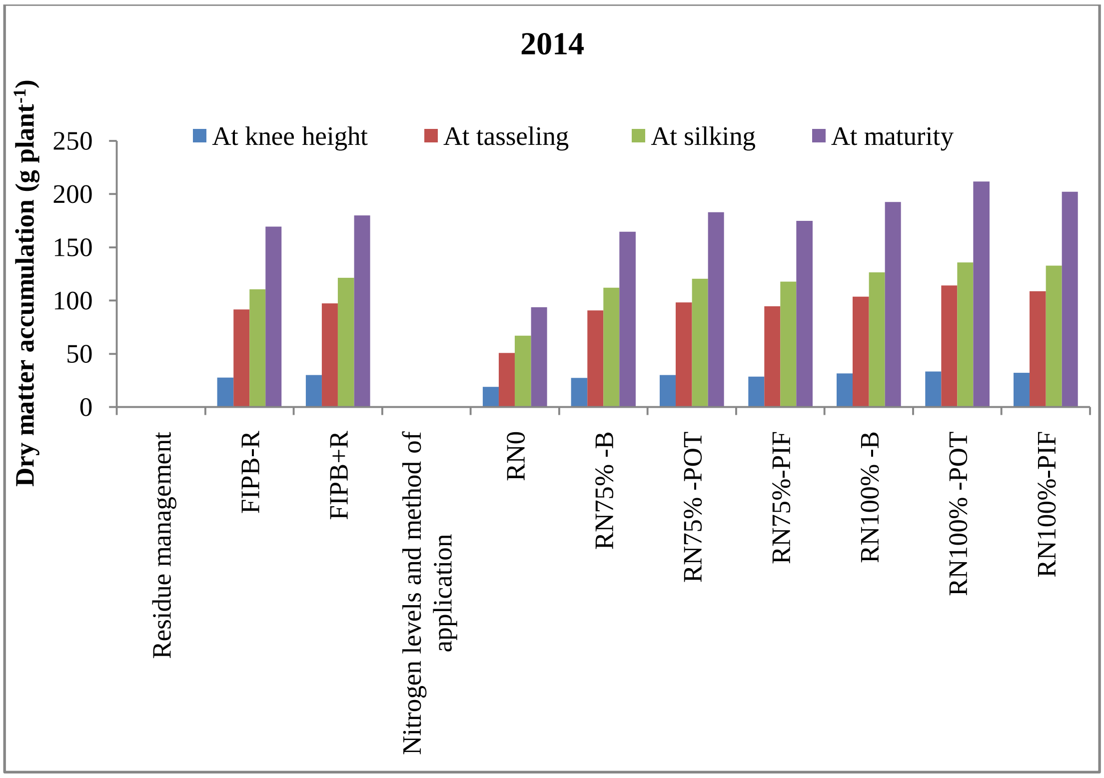
4.2.6.2 Dry matter accumulation

Dry matter accumulation is an important feature showing the growth and metabolic efficiency of plants which ultimately affect the yield of crop. Optimum accumulation of dry matter followed by adequate partitioning of assimilates to the sink leads to higher grain yield. The biological efficiency of any crop species could be reflected in the amount of dry matter it produces. The data with respect to dry matter accumulation are reported in Table 45 and Fig.15. Values of dry matter accumulation increased progressively with the advancement of crop age and maximum values were recorded at harvest stage of crop. Residue management brought significant change in accumulation of dry matter of maize at different growth stages. In both years, residue management caused significant variation in dry matter accumulation at different growth stages of maize. Dry matter accumulation recorded at knee height stage was found significantly higher under FIPB+R (29.92 and 31.20 g $plant^{-1}$) as compared to the FIPB-R (28.73 and 31.20 g $plant^{-1}$) during both the years. The treatment FIPB+R maintained its superiority on the basis of dry matter accumulation at tasseling and silking stage by recording significantly higher dry matter accumulation over FIPB-R during the two years of study. Similarly, at harvest stage significantly higher dry matter accumulation was found in FIPB+R (179.96 and 189.28 g $plant^{-1}$) as compared to the FIPB-R (169.45 and175.17 g $plant^{-1}$) respectively during both the years. The higher dry matter accumulation under the residue retained treatments was mainly due to the fact of better root growth (Aggarwal *et al,* 2006), which might helped in better soil moisture extraction during dry periods and maintained the plant vigour. Secondly, residue retention also helps in to increased minimum soil temperature and soil moisture content in the upper portion of the soil, which provided an ideal environment for early germination and vigorous growth of the plant particularly at the initial stage of crop growth (Mahajan *et al*, 2007). Similar results were also reported by Hassan *et al* (2005), Talukder *et al* (2004) and Jat *et al* (2013).

Nitrogen application method and N rate significantly affected dry matter accumulation of wheat at different growth stages of maize. Among the different N levels the application of N at the rate of $RN_{100\%}$, irrespective of the method of application results into significantly higher dry matter accumulation as compared $RN_{75\%}$ and control at all growth stages. Among the different treatments $RN_{100\%}$ -POT recorded significantly higher dry matter accumulation as compared to the all other treatments except $RN_{100\%}$-PIF which was statistically at par with $RN_{100\%}$ -POT at all growth stages during both years of study. In both years, at maturity stage the $RN_{100\%}$ -POT (211.87 and 216.89 g $plant^{-1}$) resulted in significantly higher dry matter accumulation as compared to $RN_{100\%}$ -B (192.58 and 200.07 g $plant^{-1}$) and was statistically at par with the $RN_{100\%}$-PIF (202.33 and 208.54 g $plant^{-1}$). Similarly in the N level of $RN_{75\%}$ significantly higher dry matter accumulation was recorded under the top placement of fertilizer as compared to the broadcasting. However at all growth

Table 45: Effect of residue and N management on dry matter accumulation of maize

Dry matter accumulation (g plant^{-1})								
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**		**At maturity**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management								
FIPB-R	27.77	28.73	91.65	98.16	110.66	115.84	169.45	175.17
FIPB+R	29.92	31.20	97.24	106.44	121.44	123.11	179.96	189.28
SEm±	**0.253**	**0.348**	**0.895**	**1.257**	**0.848**	**0.968**	**1.205**	**1.085**
LSD (P=0.05)	**1.540**	**2.12**	**5.439**	**7.654**	**5.151**	**5.911**	**7.301**	**6.577**
Nitrogen levels and method of application								
RN_0	18.87	20.17	50.65	50.58	67.11	65.25	93.60	99.82
$RN_{75\%}$ -B	27.45	28.52	90.78	98.15	112.08	116.49	164.59	174.85
$RN_{75\%}$ -POT	30.00	31.12	98.39	108.83	120.39	125.24	183.13	192.76
$RN_{75\%}$-PIF	28.45	29.73	94.62	103.74	117.68	121.74	174.82	182.65
$RN_{100\%}$ -B	31.44	32.04	103.59	113.74	126.46	131.04	192.58	200.07
$RN_{100\%}$ -POT	33.40	34.86	114.22	123.17	135.76	141.09	211.87	216.89
$RN_{100\%}$-PIF	32.30	33.32	108.87	118.52	132.87	135.46	202.33	208.54
SEm±	**0.558**	**0.502**	**1.841**	**1.718**	**2.287**	**2.173**	**3.471**	**3.043**
LSD (P=0.05)	**1.630**	**1.464**	**5.374**	**5.013**	**6.676**	**6.341**	**10.132**	**8.883**



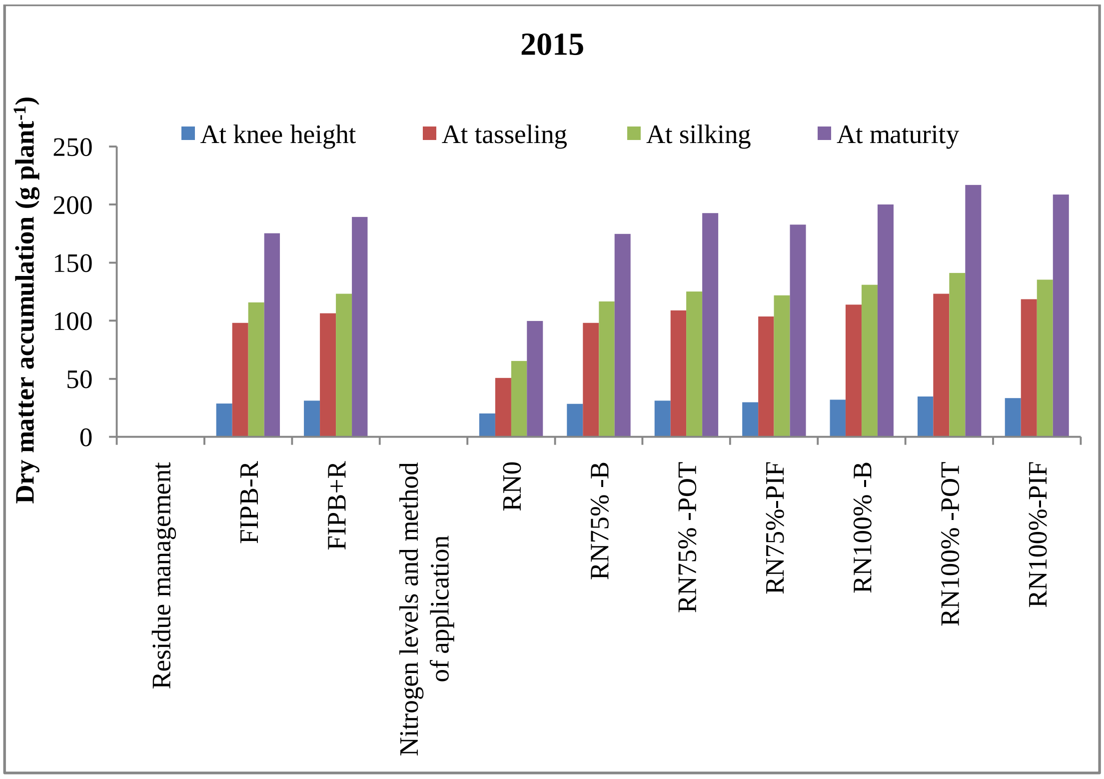


Fig.15: Effect of residue and N management on dry matter accumulation of maize

stages dry matter accumulation recorded under the $RN_{75\%}$ -POT was found to be significantly at par with the $RN_{100\%}$ -B during both years of study. The higher dry matter accumulation under the top placement was might be ascribed to the view that there was adequate supply of nutrients and metabolities under top placement of N for growth and development of each reproductive structure of the plant (Kumar *et al* 2013). Secondly, in the placement of N fertilizer on the top of bed as compared to broadcasting can reduce N loss via ammonia volatilization and improve NUE of plants (Malhi *et al* 1999). Significantly higher amount of dry matter accumulated with increase in N-level was due to the cumulative effect of higher plant height and higher LAI under higher N-level as compared to the lower N-level as also reported by Bangarwa *et al* (1988). Terman *et al* (1977) also observed that application of nitrogen increased plant height by increasing length and number of internodes and the increase in leaf number and size would result in more and larger photosynthetic apparatus by increasing total leaf area and leaf area index of the crop consequently influencing assimilates production, which has direct bearing on dry matter production per plant and per unit area.

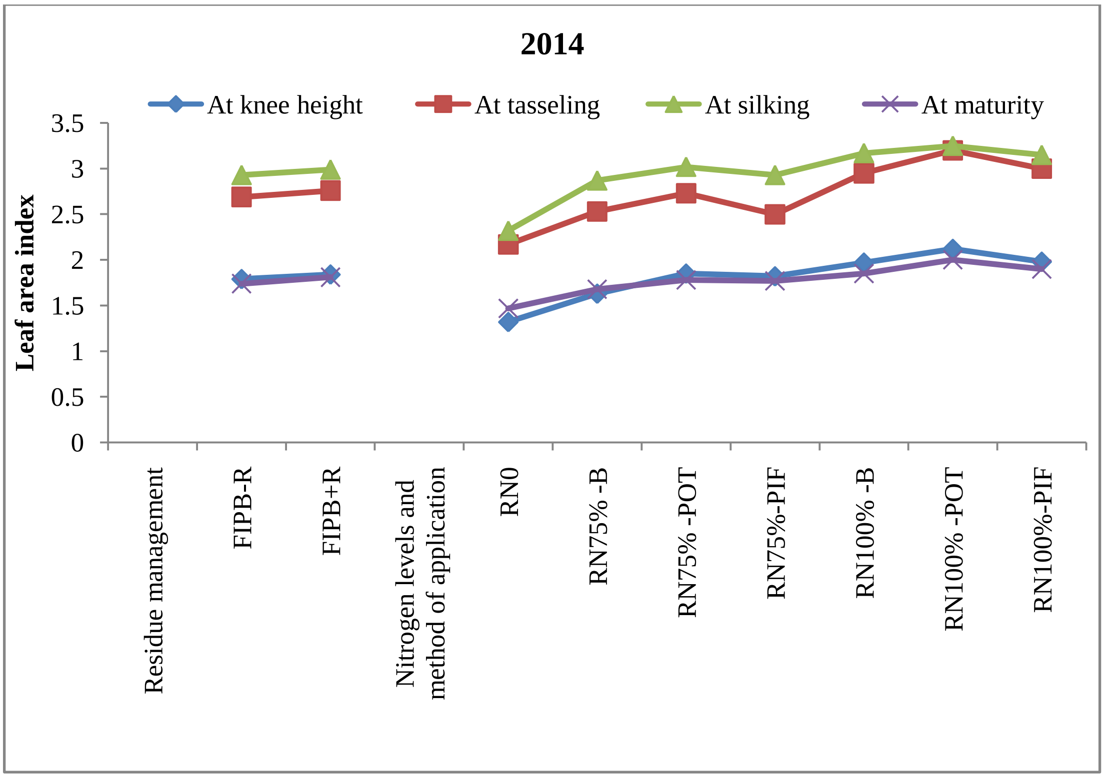
4.2.6.3Leaf area index

It is a dimensionless variable and was first defined as the total one-sided area of photosynthetic tissue per unit ground surface area (Watson, 1947) which expresses the photosynthetic potential of a crop at its particular growth stage. Leaf area index (LAI) is good index of crop growth and is a major character influencing the assimilating capacity of the crop. Higher the LAI means more interception of photosynthetically active radiation which is the source of energy during the process of photosynthesis. So, higher the LAI better is the crop growth, resulting in higher yield. The data on LAI recorded at various growth stages have been presented in Table 46 and Fig.16. Leaf area index increased with the advancement of crop age up to silking stage and it declined thereafter when crop advanced towards maturity due to senescence of lower leaves. After giving fast look at the data it was observed that LAI was not influenced significantly due to residue management at all the growth stages of maize. However the higher LAI was reordered at knee height stage under FIPB+R (1.84 and 1.87) as compared to the FIPB-R (1.79 and 1.80) during both the years of study, respectively. Leaf area index increases linearly with the advancement of crop age and reaches to its maximum value at silking stage with significantly higher value under the FIPB+R as compared to the FIPB-R during both years. The more LAI under the residue retained might be due to fact that residue retention generally increases soil organic carbon content (Saharawat *et al* 2010) and improves soil physical health (Naresh *et al* 2012) which ultimately affects the crop growth parameters.

Nitrogen is a primary nutrient required for better development of leaves. LAI (Table 46) in general showed increasing trend with increase in N level. The nitrogen levels had significant effect on leaf area index at various growth stages. Among the different N levels

Table 46: Effect of residue and N management on leaf area index of maize

LAI								
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**		**At maturity**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management								
FIPB-R	1.79	1.80	2.69	2.73	2.93	3.08	1.74	1.81
FIPB+R	1.84	1.87	2.76	2.88	2.99	3.11	1.81	1.88
SEm±	**0.029**	**0.050**	**0.018**	**0.045**	**0.021**	**0.026**	**0.077**	**0.049**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	1.32	1.35	2.17	2.21	2.32	2.35	1.47	1.40
$RN_{75\%}$ -B	1.63	1.67	2.53	2.62	2.87	2.98	1.68	1.78
$RN_{75\%}$ -POT	1.85	1.92	2.73	2.90	3.02	3.12	1.78	1.88
$RN_{75\%}$-PIF	1.82	1.82	2.50	2.73	2.93	3.17	1.77	1.88
$RN_{100\%}$ -B	1.97	2.02	2.95	3.02	3.17	3.32	1.85	1.95
$RN_{100\%}$ -POT	2.12	2.13	3.20	3.15	3.25	3.45	2.00	2.03
$RN_{100\%}$-PIF	1.98	1.95	3.00	3.05	3.15	3.28	1.90	1.98
SEm±	**0.083**	**0.062**	**0.069**	**0.066**	**0.068**	**0.077**	**0.081**	**0.079**
LSD (P=0.05)	**0.243**	**0.183**	**0.202**	**0.195**	**0.193**	**0.227**	**0.237**	**0.233**



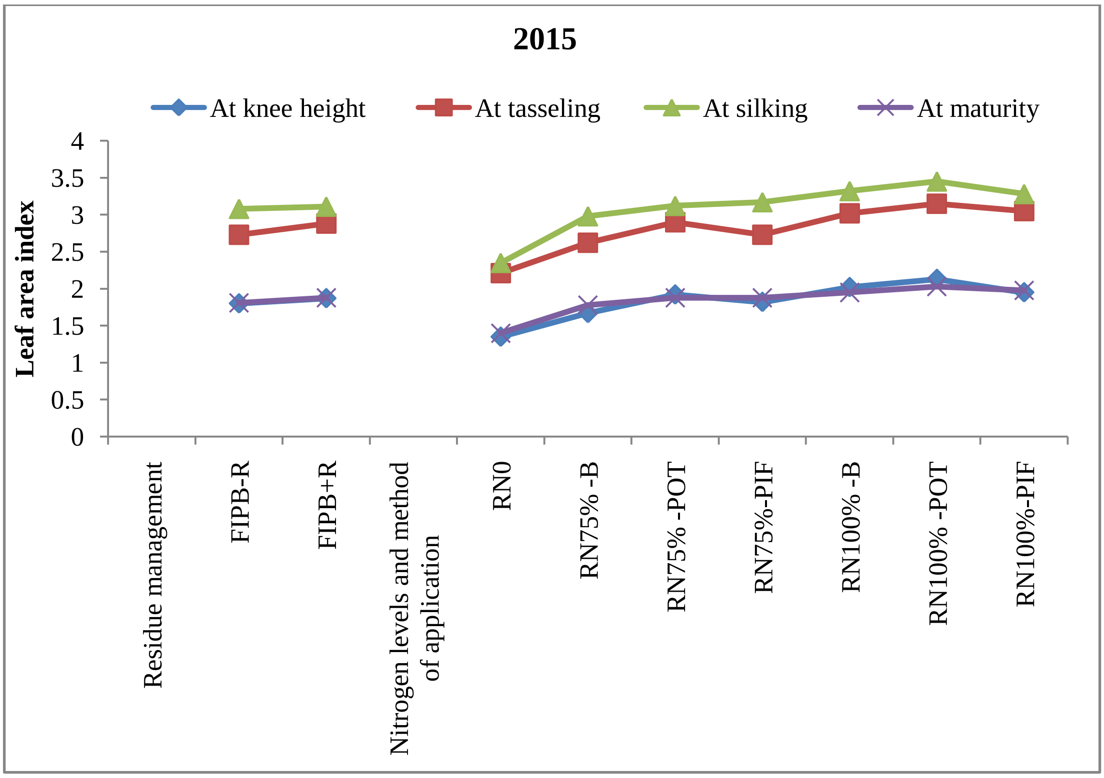


Fig.16: Effect of residue and N management on leaf area index of maize

and application methods $RN_{100\%}$-POT results into significantly higher LAI as compared all other treatments at all growth stages. At knee height and tasseling stage significantly higher LAI was recorded under the $RN_{100\%}$-POT as compared to the control, $RN_{75\%}$ -POT, $RN_{75\%}$-PIF and $RN_{75\%}$ -B but statically at par with the $RN_{100\%}$ -B and $RN_{100\%}$-PIF, during both years of study. However the LAI recorded under $RN_{75\%}$ -POT was significantly at par with the $RN_{100\%}$ -B and $RN_{100\%}$-PIF at all growth stages during both years. Hartmann *et al* (2015) reported that the placement of fertilizer at the top of the bed results into the higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE, which ultimately affects the various growth parameters of crop. Secondly, the positive effect of band placement of N on leaf area index could also be attributed to increased nitrogen supply, which might have promoted synthesis of new leaves led to higher LAI (Chatterjee, 2010). These results are supported by the findings of Ahmad *et al* (2002) and Hassan *et al* (2010) who stated that in maize more LAI was produced with band placement of nitrogen application than broadcast method.

4.2.7Yield attributes of maize

4.2.7.1 Number of cobs per plant

The cob bearing capacity is one of the most important crop yield components. The data regarding the number of cobs $plant^{-1}$ are presented in Table 47. More or less it is a genetic character of the cultivar but some improvement can be expected due to agronomic manipulations. Number of cobs per plant was not significantly influenced by residue management treatments. However, number of cobs per plant was found to be lower in FIPB-R (0.980 and 0.996) as compared to the FIPB+R (1.008 and 1.014) during both the years, respectively. This increase in number of cobs was mainly due to the fact that incorporating plant residues into agricultural soils can also sustain organic carbon content, readily available C and N, improve soil physical properties, enhance biological activities and increase nutrient availability which ultimately affects the crop growth parameters (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu *et al* 2011).

Nitrogen application method and N rate significantly affected the number of cobs per plant. It was observed that with the addition of plant nutrients to crop, there was increase in the number of cobs per plant as compared to control. In both years, $RN_{100\%}$ -POT resulted in significantly higher number of cobs per plant as compared to control, $RN_{75\%}$ -POT, $RN_{75\%}$-PIF and $RN_{75\%}$ -B, but statically at par with the $RN_{100\%}$-PIF and $RN_{100\%}$ -B in both years. The higher number of cobs per plant under the top placement was might be ascribed to the view that there was adequate supply of nutrients and metabolities under top placement of N for growth and development of each reproductive structure of the plant (Kumar *et al* 2013). Similar advantages of placement of N have been reported by Hassan *et al* (2013) and Chatterjee (2010) in maize crop.

4.2.7.2 Cob length

Cob length may serve as reliable criteria to access crop yield as it is an indicator of yield because increase in cob length will influence the number of grains cob^{-1}. A reference to data in Table 47 revealed that the residue management brought significant effect on cob length. Significantly higher cob length was found under the residue retained plots i.e. FIRB+R (16.71 and 17.55 cm) as compared to the residue removed plots i.e. FIRB-R (15.99 and 16.67) during both years, respectively. The retention of residue under permanent bed treatment resulted higher values of cob length than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002). Govaerts *et al* (2005) and Talukder *et al* (2004) also reported the increased cob length under permanent bed planting along with rotation and residue retention as compared to conventional tillage with residue removal.

Cob length was significantly affected by N application method and rate. Among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher spike length as compared to the control, $RN_{75\%}$ -POT, $RN_{75\%}$-PIF and $RN_{75\%}$ -B, but statically at par with the $RN_{100\%}$-PIF and $RN_{100\%}$ -B in both years. However, the cob length recorded under $RN_{75\%}$ -POT was significantly at par with the $RN_{100\%}$ -B in the second year of study. Siyal *et al* (2012) reported that N leaching can be reduced to zero percent by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching. Hassan *et al* (2013) reported that placement of N fertilizer resulted in significant improvement of various yield attributes of maize over broadcast application of N.

4.2.7.31000-grain weight

The data on 1000-grain weight have been presented in Table 47. The grain weight indicates the nature and extent of grain development. It is a function of various production factors that influence grain development and filling patterns. 1000-grain weight was not significantly influenced by residue management treatments. However, 1000-grain weight was found to be lower in FIPB-R (245.52 and 253.29 g) as compared to the FIPB+R (251.71 and 262.33 g) during both the years, respectively. This increase was mainly due to the fact that incorporating plant residues into agricultural soils can also sustain organic carbon content, readily available C and N, improve soil physical properties, enhance biological activities and increase nutrient availability which ultimately affects the crop growth parameters (Hadas *et al* 2004, Cayuela *et al* 2009, Murungu *et al* 2011). Govaerts *et al* (2005) also reported that permanent bed planting along with rotation and residue retention had the advantages in growth parameters of maize.

Table 47: Effect of residue and N management on yield attributes of maize

Treatments	No of cobs plant^{-1}		Cob length (cm)		1000-grain weight (g)		Shelling (%)	
	2014	2015	2014	2014	2015	2015	2014	2015
Residue management								
FIPB-R	0.980	0.996	15.99	67.96	72.75	16.67	245.52	253.29
FIPB+R	1.008	1.014	16.71	69.61	73.73	17.55	251.71	262.33
SEm±	**0.021**	**0.013**	**0.072**	**0.267**	**0.103**	**0.047**	**1.145**	**2.016**
LSD (P=0.05)	**NS**	**NS**	**0.471**	**1.74**	**0.677**	**0.306**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0 (Control)	0.870	0.886	13.88	64.31	66.85	14.33	218.67	225.83
$RN_{75\%}$ -B	0.929	0.935	15.86	67.45	72.89	16.96	244.33	252.50
$RN_{75\%}$ -POT	0.996	0.992	16.81	69.12	73.59	17.52	250.67	261.17
$RN_{75\%}$-PIF	0.981	0.984	16.29	67.95	73.33	17.30	248.33	257.67
$RN_{100\%}$ -B	1.017	1.034	17.00	70.06	74.61	17.62	254.67	265.83
$RN_{100\%}$ -POT	1.116	1.126	17.41	71.06	75.93	18.24	266.67	273.00
$RN_{100\%}$-PIF	1.051	1.078	17.21	71.48	75.46	17.82	257.00	268.67
SEm±	**0.025**	**0.026**	**0.145**	**0.595**	**0.275**	**0.219**	**2.940**	**2.416**
LSD (P=0.05)	**0.074**	**0.076**	**0.424**	**1.75**	**0.807**	**0.644**	**8.633**	**7.093**

Nitrogen application method and N rate significantly affected the 1000 grain weight of maize. Among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher 1000 grain weight (266.67 and 273.00 g) as compared to the control (218.67 and 225.83 g), $RN_{75\%}$ -POT (250.67 and 261.17 g), $RN_{75\%}$-PIF (248.33 and 257.67 g), $RN_{75\%}$ -B (244.33 and 252.50 g) but statistically at par with the $RN_{100\%}$-PIF (257.00 and 268.67 g) and $RN_{100\%}$-B (254.67 and 265.83 g) during both years, respectively. However the 1000-grain weight recorded under the $RN_{75\%}$ -DOT (250.67 and 261.17 g) was significantly at par with the $RN_{100\%}$-PIF (257.00 and 268.67 g) and $RN_{100\%}$-B (254.67 and 265.83 g) during both years, respectively. Increase in 1000-grain weight in top placement of nitrogen was due to better physiological response of crop to enhance plant growth due to more availability and uptake of nitrogen around the grain filling period of the crop. Similar results were reported by Ahmad *et al* (2002).

4.2.7.4Shelling percentage

The data presented in Table 47 reveal that shelling percentage influenced significantly by irrigation method and residue management treatments. The FIPB+R (69.61 and 72.75 %) resulted in significantly higher shelling percentage as compared to the FIPB-R (67.96 and 73.73 %), during the two years of study. The higher shelling percentage under the FIPB+R treatment as compared to the FIPB-R treatment might be due to the higher cob length with positive effect of residue retention in easy access of resources like moisture and nutrient by maize (Kumar and Bangarwa, 1997). Secondly, the retention of residue under permanent bed treatment resulted higher values of shelling percentage than no residue, this might be due to maintaining optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues (Gursoy *et al* 2010, Astatke *et al* 2002).

Shelling percentage was significantly affected by N application method and rate. Among the different N levels and application methods in the first year significantly higher shelling percentage was obtained under the $RN_{100\%}$-PIF as compared to the control, $RN_{75\%}$ -POT and $RN_{75\%}$ -PIF, but statistically at par with the$RN_{100\%}$-POT and $RN_{100\%}$ -B. However in the second year significantly higher shelling percentage was obtained under the $RN_{100\%}$-POT as compared to the control, $RN_{75\%}$ -POT and $RN_{75\%}$ -PIF, but statistically at par with the$RN_{100\%}$-PIF and $RN_{100\%}$ -B. Higher shelling percentage in top placement of fertilizer was in accordance with higher cob length as compared to broadcast, which might be due to reduced N leaching to zero percent and more uptake by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching (Siyal *et al*, 2012). Hussaini *et al*

(2002) and, Shivay and Singh (2000) also reported the increased shelling percentage with increased N-levels.

4.2.8Grain and straw yield of maize

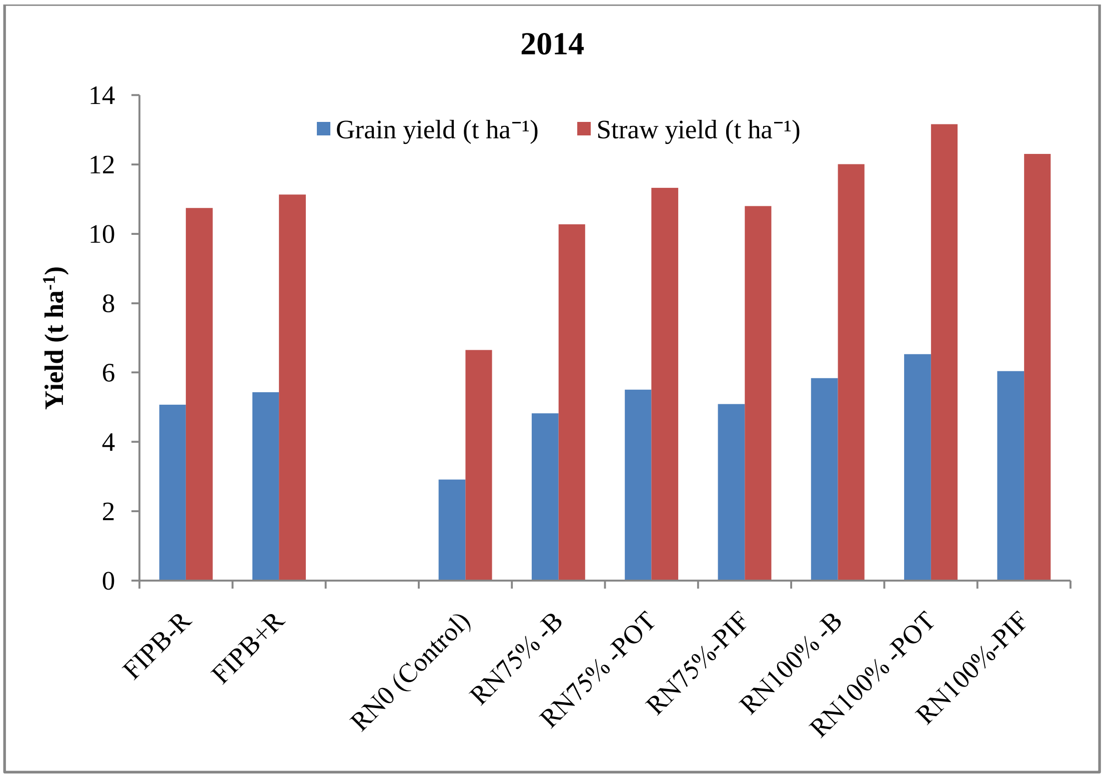
4.2.8.1 Grain yield

Grain yield is function of cob length, no of cobs plant^{-1} and 1000-grain weight etc. The grain yield of maize crop was significantly influenced due to residue management and different N rates and application methods. The data regarding grain yield presented in Table 48 and Fig.17. Among residue management plots significantly higher grain yield was recorded in the residue retained plots i.e. FIRB+R (5.43 and 5.80 t ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (5.07 and 5.35 t ha^{-1}) during both years, respectively. The significantly higher yield of maize under FIPB+R in comparison to FIPB-R was may also attributed to increase in cob length and 1000-grain weight which was enhanced by optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues. Parihar *et al* (2016) also showed the positive effects of PB and residue retention on grain yield of maize. Naresh *et al* (2012) reported that PB with residue retention increased yield by 11-17 percent in maize and 12-15% in wheat as compared to conventional practices. The crop residues retained as surface mulch would have helped in regulating the soil temperature and moisture. Lafond (1999) reported that surface residues in a no-till system helped to buffer soil temperature and that, during winter, soil temperature (at 5 cm depth) with residue removal and conventional tillage was on average 0.29 °C lower than that with no tillage and surface retained residues. Sepat and Rana (2013) also reported that zero till-raised bed with crop residue retention and conventional till -raised bed with crop residue incorporation recorded 25% higher yield and yield attributes in maize as compared to conventional till-flat without residue retention.

Grain yield of maize is a function of yield attributes which are favorably influenced by nitrogen application (Singh *et al* 2000). Nitrogen application method and N rate significantly affected the grain yield of maize. Among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher grain yield (6.53 and 6.73 t ha^{-1}) as compared to the control (2.91 and 3.22 t ha^{-1}), $RN_{75\%}$ -POT (5.51 and 5.84 t ha^{-1}), $RN_{75\%}$-PIF (5.09 and 5.45 t ha^{-1}), $RN_{75\%}$ -B (4.82 and 5.12 t ha^{-1}) and $RN_{100\%}$ -B (5.84 and 6.12 t ha^{-1}) during both years respectively. However no significant difference was observed between the grain yield of $RN_{75\%}$ -POT (5.51 and 5.84 t ha^{-1}) and $RN_{100\%}$ -B (5.84 and 6.12 t ha^{-1}), during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application. The higher grain yield was obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to

Table 48: Effect of residue and N management on grain and stover yield of maize

Treatments	Grain Yield (t ha^{-1})		Stover yield (t ha^{-1})	
	2014	**2015**	**2014**	**2015**
Residue management				
FIPB-R	5.07	5.35	10.74	11.15
FIPB+R	5.43	5.80	11.13	11.99
SEm±	**0.022**	**0.071**	**0.042**	**0.110**
LSD (P=0.05)	**0.141**	**0.462**	**0.278**	**0.722**
Nitrogen levels and method of application				
RN_0 (Control)	2.91	3.22	6.65	7.34
$RN_{75\%}$ -B	4.82	5.12	10.27	10.73
$RN_{75\%}$ -POT	5.51	5.84	11.33	11.95
$RN_{75\%}$-PIF	5.09	5.45	10.80	11.34
$RN_{100\%}$ -B	5.84	6.12	12.01	12.61
$RN_{100\%}$ -POT	6.53	6.73	13.16	13.55
$RN_{100\%}$-PIF	6.04	6.54	12.30	13.41
SEm±	**0.123**	**0.109**	**0.271**	**0.232**
LSD (P=0.05)	**0.486**	**0.320**	**0.795**	**0.682**



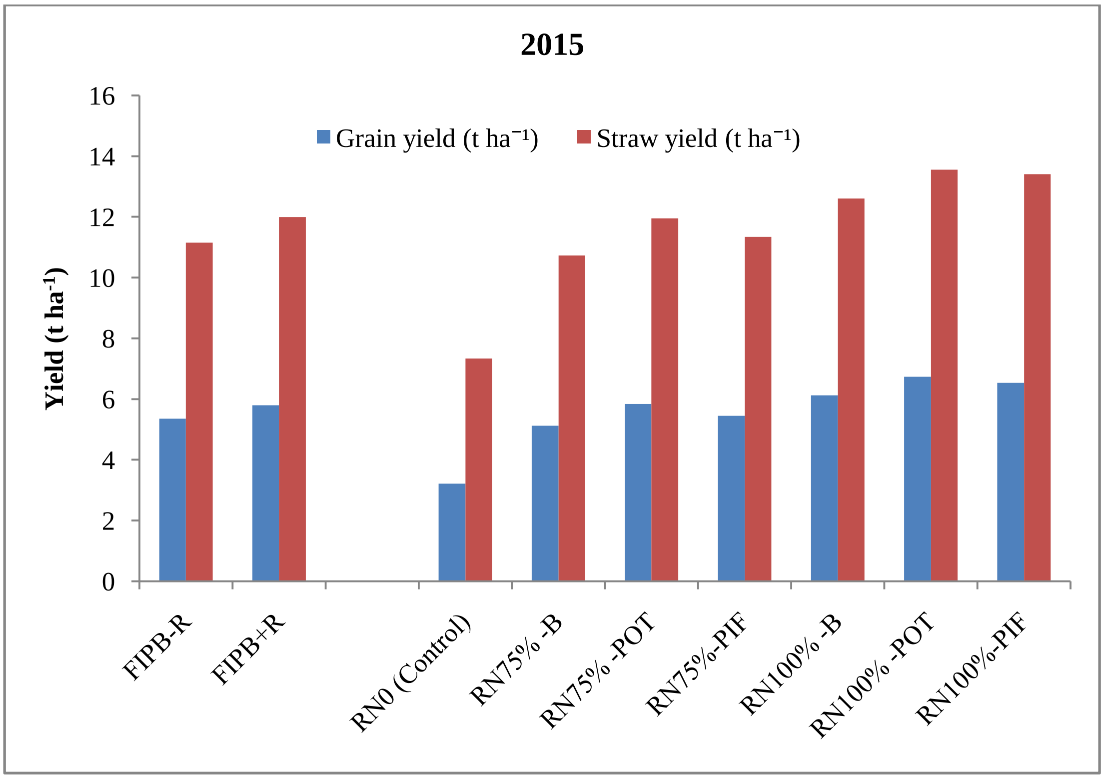


Fig.17: Effect of residue and N management on grain and stover yield of maize

the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE, which ultimately affects the grain yield (Hartmann *et al* 2015). Hassan *et al* (2013) reported that band placement of nitrogen produced a grain yield of 6.49 and 5.60 t ha^{-1} whereas nitrogen applied broadcast produced 5.78 and 4.95 t ha^{-1} during 2006 and 2007, respectively. The increase in grain yield of maize by band placement was probably due to more N uptake and its continuous supply to maize plants near plant roots throughout the growing period and improved all physiological characteristics of the plant that led to better yield attributes and grain yield.

4.2.8.2Stover yield

The effect of residue management and, different N levels and method of N application on straw yield of maize during 2014 and 2015 are presented in Table 48. A reference to data presented revealed that the residue management brought significant effect on stover yield of maize. Higher stover yield was recorded under the residue retained plots i.e. FIRB+R (11.13 and 11.99 t ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (10.74 and 11.15 t ha^{-1}) during both years, respectively. Maize grain and straw yields were highest in residue retention as compared to without residue retention, this might be due to less lodging of maize crop under PB systems with residue retention. Increase in grain and straw yield of maize in PB with residue retention may be attributed to the positive effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), improved soil health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009), lesser weed population (Ozpinar 2006, Chauhan *et al* 2007), and improved nutrient use efficiency compared to CT without residue retention (Unger and Jones, 1998). Parihar *et al* (2016) also showed the positive effects PB and residue retention on grain and starw yield of maize. Girma *et al* (2012) reported that zero-tillage with residue retention led to higher labile C formation in soil, which improves acquisition of nutrients to the plant and finally reflected in higher grain and stover yield. Parihar *et al* (2016) also showed the positive effects PB and residue retention on grain and starw yield of maize.

Nitrogen application method and N rate significantly affected the stover yield of maize. Among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher straw yield (13.16 and 13.55 t ha^{-1}) as compared to the control (6.65 and 7.34 t ha^{-1}), $RN_{75\%}$ -POT (11.33 and 11.95 t ha^{-1}), $RN_{75\%}$-PIF (10.80 and 11.34 t ha^{-1}) and $RN_{75\%}$ -B (10.27 and 10.73 t ha^{-1}). However no significant difference was observed between the straw yield of $RN_{75\%}$ -POT and $RN_{100\%}$ -B, during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application. These results are in agreement with the findings of Ahmad *et al* (2002) who found more grain and straw yield of maize with band placement of nitrogen over broadcast. This might be ascribed to the view that there was adequate supply of nutrients and metabolites under top placement of N for growth and development of each reproductive structure of the plant. Improvement in yield attributes due to placement of N appears to be on account of vigorous growth as reflected by higher accumulation of dry matter at successive growth stages of maize which ultimately accounts for the higher straw yield.

4.2.9 Plant analysis

4.2.9.1 Nitrogen content

The effect of residue management and, different N levels and method of N application on nitrogen content of wheat was observed at knee height stage, tasseling stage, silking stage and at maturity stage during the year 2014 and 2015 and is presented in Table 49 and Table 50. Nitrogen content was not influenced significantly by residue management treatments at all the crop growth stages. Nitrogen content recorded at knee height stage was found to be higher in FIPB+R (1.56 and 1.69 %) as compared to FIPB-R (1.47 and 1.55 %) during both the years. Similarly, FIPB+R recorded higher nitrogen content at tasseling and silking stage as compared to the FIPB-R over all other treatments but not a significant difference was observed. Similarly, nitrogen content in grain, straw and cob cores was higher under the residue retained treatments as compared to the residue removed treatments but not a significant difference was observed. Restriction of tillage under PB along with residue retention improves the structure of soil, especially micro-aggregates, which are active site of holding the labile C for longer periods (Jha *et al*, 2012). This led to higher labile C formation in soil, which improves acquisition of nutrients to the plant and finally reflected in higher growth and growth attributes (Girma *et al*, 2012).

However the N levels and method of application had significant effect on N content at all the growth stages of maize. At maximum tillering stage, it was observed that with the addition of plant nutrients to crop, there was increase in the N content of the maize crop as compared to control. Higher nitrogen content was observed under the top placement of fertilizer both for the $RN_{75\%}$ and $RN_{100\%}$ as compared to the broadcasted. The $RN_{100\%}$-POT results into significantly higher N content in grain as compared to the $RN_{75\%}$ -POT, which was significantly at par with the $RN_{100\%}$-DIF and $RN_{100\%}$-B during the second year. Increase in N content with increase in rate might be attributed to enhanced N uptake by maize followed by partitioning of more assimilates to plant. Similar results were obtained by Hassan *et al* (2010) and Saeed (2010).

Table 49: Effect of residue and N management on nitrogen content at different growth stages of maize

Nitrogen content (%)						
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management						
FIPB-R	1.47	1.55	1.47	1.49	1.30	1.37
FIPB+R	1.56	1.69	1.51	1.53	1.34	1.42
SEm±	**0.039**	**0.092**	**0.028**	**0.051**	**0.016**	**0.050**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application						
RN_0 (Control)	1.17	1.23	1.25	1.27	1.01	1.19
$RN_{75\%}$ -B	1.41	1.42	1.37	1.45	1.23	1.33
$RN_{75\%}$ -POT	1.58	1.69	1.55	1.54	1.41	1.43
$RN_{75\%}$-PIF	1.49	1.56	1.47	1.49	1.31	1.37
$RN_{100\%}$ -B	1.62	1.76	1.56	1.56	1.41	1.42
$RN_{100\%}$ -POT	1.73	1.85	1.61	1.65	1.48	1.53
$RN_{100\%}$-PIF	1.62	1.81	1.59	1.61	1.39	1.46
SEm±	**0.052**	**0.108**	**0.066**	**0.073**	**0.039**	**0.068**
LSD (P=0.05)	**0.153**	**0.318**	**0.193**	**0.215**	**0.116**	**0.199**

Table 50: Effect of residue and N management on nitrogen content in grain, stover and cob cores at maturity stage of maize

Treatments	Nitrogen content (%)					
	Grain		Stover		Cob cores	
	2014	2015	2014	2015	2014	2015
Residue management						
FIPB-R	1.29	1.31	0.59	0.61	0.42	0.54
FIPB+R	1.32	1.37	0.62	0.63	0.47	0.58
SEm±	**0.025**	**0.060**	**0.014**	**0.019**	**0.025**	**0.012**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application						
RN_0 (Control)	1.09	1.15	0.43	0.45	0.33	0.39
$RN_{75\%}$ -B	1.25	1.31	0.51	0.54	0.39	0.50
$RN_{75\%}$ -POT	1.35	1.38	0.65	0.64	0.45	0.60
$RN_{75\%}$-PIF	1.27	1.30	0.56	0.58	0.41	0.57
$RN_{100\%}$ -B	1.35	1.37	0.67	0.67	0.48	0.61
$RN_{100\%}$ -POT	1.42	1.49	0.74	0.73	0.53	0.67
$RN_{100\%}$-PIF	1.39	1.39	0.67	0.71	0.51	0.62
SEm±	**0.055**	**0.057**	**0.042**	**0.038**	**0.021**	**0.029**
LSD (P=0.05)	**0.162**	**0.168**	**0.122**	**0.112**	**0.062**	**0.085**

4.2.9.2 Nitrogen uptake

The N uptake by maize crop at different growth stages was not significantly influenced due to residue management but significantly influenced by different N rates and application methods. The data regarding N uptake presented in Table 51 and Table 52. However higher N uptake was recorded under the residue retained plots i.e. FIRB+R as compared to the residue removed plots i.e. FIRB-R during both years at all growth stages. Among the different treatments at knee height stage higher N uptake was obtained inFIPB+R (35.34 and 39.89 kg ha^{-1}) as compared to the FIPB-R (30.74 and 33.50 kg ha^{-1}) during both years of study. Similarly at tasseling and silking stage higher N uptake was recorded under the FIPB+R as compared to the FIPB-R during both years of study. A perusal of data reveal that on quantitative basis nitrogen uptake followed the trend grain > stover > cob cores during both the years. Similarly In grain, starw and cob cores significantly higher nitrogen uptake was observed under FIPB+R as compared to FIPB-R during both years of study. Bahera *et al* (2007) also reported maximum N uptake under ZT with residue retention, which might be due to addition of nutrients through residue, better root growth, leading to more extraction of nutrient from soil, lower weed infestation and better performance of crop, improved physical environment favourable for better microbial activity that might helped in mineralization resulting better availability of nutrients (macro and micro) to crops and thus increased the uptake under these treatments.

However the N levels and method of application had significant effect on N uptake at all the observations i.e. at knee height stage, tasseling stage, silking stage and at maturity in grain, straw and cob cores. At knee height stage among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher N uptake (42.96 and 48.19 kg ha^{-1}) as compared to control (16.26 kg ha^{-1} and 18.46), $RN_{75\%}$ -POT (35.22 and 39.10 kg ha^{-1}), $RN_{75\%}$-PIF (31.41 and 34.42 kg ha^{-1}) and $RN_{75\%}$ -B (28.71 and 30.07 kg ha^{-1}), but statically at par with the $RN_{100\%}$-PIF (37.85 and 48.19 kg ha^{-1}) during both years respectively. Similarly at tasseling and silking stage higher N uptake was observed under the top placement of fertilizer as compared to furrow application and broadcasting. Maximum N uptake in grain and stover was with the $RN_{100\%}$-POT(92.99, 100.62 and 75.74, 81.27 kg ha^{-1}), which was statistically at par with $RN_{100\%}$-PIF(83.95, 91.14 and 64.64, 76.93 kg ha^{-1}) but significantly higher than control (31.82, 37.16 and 20.86, 24.36 kg ha^{-1}), $RN_{75\%}$ -POT (74.17, 81.28 and 56.35, 60.92 kg ha^{-1}), $RN_{75\%}$-PIF (64.44,71.02 and 45.82,52.93 kg ha^{-1}) and $RN_{75\%}$ -B (60.46, 67.46 and 39.43 and 45.79 kg ha^{-1}) and $RN_{100\%}$-B (78.89, 84.20 and 61.45, 68.23 kg ha^{-1}) , respectively during both years of study. Similarly, the maximum N uptake in cob cores was observed under $RN_{100\%}$-DOTwhich was statistically at par with that recorded under $RN_{100\%}$-PIF and $RN_{100\%}$-B but significantly higher than observed under control, $RN_{75\%}$-PIF and $RN_{75\%}$ -B. Higher N uptake achieved in maize with top placement of nitrogen was due to better availability of N and its

Table 51: Effect of residue and N management on nitrogen uptake at different growth satges of of maize

Nitrogen uptake (kg ha^{-1})						
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management						
FIPB-R	30.74	33.50	101.22	110.82	108.112	119.36
FIPB+R	35.34	39.89	110.08	121.77	123.071	130.14
SEm±	**1.210**	**2.593**	**3.853**	**5.006**	**2.533**	**5.455**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application						
RN_0 (Control)	16.26	18.46	46.64	48.03	49.97	57.57
$RN_{75\%}$ -B	28.71	30.07	92.26	105.39	102.19	114.38
$RN_{75\%}$ -POT	35.22	39.10	113.09	124.66	125.25	133.02
$RN_{75\%}$-PIF	31.41	34.42	103.58	115.26	113.75	123.58
$RN_{100\%}$ -B	37.85	41.84	119.40	130.30	131.64	137.58
$RN_{100\%}$ -POT	42.96	48.19	136.69	150.13	149.08	160.41
$RN_{100\%}$-PIF	38.89	44.77	127.90	140.28	137.26	146.69
SEm±	**1.454**	**3.052**	**5.143**	**5.390**	**4.383**	**5.895**
LSD (P=0.05)	**4.270**	**8.961**	**15.101**	**15.826**	**12.871**	**17.308**

Table 52: Effect of residue and N management on nitrogen uptake in grain, stover and cob cores at maturity stage of maize

Nitrogen uptake (kg ha^{-1})						
Treatments	**Grain**		**Stover**		**Cob cores**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management						
FIPB-R	66.08	71.38	49.94	55.22	11.22	12.64
FIPB+R	72.99	80.88	54.14	62.05	12.15	13.86
SEm±	**1.325**	**2.439**	**1.203**	**1.504**	**0.761**	**0.213**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application						
RN_0 (Control)	31.82	37.16	20.86	24.36	6.02	7.14
$RN_{75\%}$ -B	60.46	67.46	39.43	45.79	10.17	11.28
$RN_{75\%}$ -POT	74.17	81.28	56.35	60.92	12.36	14.58
$RN_{75\%}$-PIF	64.44	71.02	45.82	52.93	10.79	13.35
$RN_{100\%}$ -B	78.89	84.20	61.45	68.23	13.38	14.89
$RN_{100\%}$ -POT	92.99	100.62	75.74	81.27	15.58	16.58
$RN_{100\%}$-PIF	83.95	91.14	64.64	76.93	13.50	14.96
SEm±	**3.335**	**3.850**	**4.181**	**3.539**	**0.746**	**0.811**
LSD (P=0.05)	**9.791**	**11.306**	**12.277**	**10.392**	**2.191**	**2.381**

uptake which ultimately accelerated the crop growth rate of the crop plants throughout the growing period (Hassan *et al*, 2013). The significant increase in nitrogen accumulation in response to increasing N rates could be credited; to additional nutrients availability and to elevated N concentration in particular, to speedy growth and development of roots and shoots, to improved microbial activity and thus to increasing soil N mineralization making available more soil N to plants (Niaz *et al*, 2015). Quaye *et al* (2010) and Saeed (2010) also reported that uptake was increased with increased nitrogen levels. Similar effects of nitrogen levels on nitrogen uptake were also observed by Kumar and Ahlawat (2006) in which nitrogen uptake was increased with increased nitrogen levels. Also Jing *et al* (2009) reported that the increase in nitrogen uptake at 300 kg N ha^{-1} over control, 75, 150 and 225 kg Nha^{-1}.

4.2.10 Nitrogen use efficiency (NUE)

The ability of crops to use the applied N depends on the uptake and utilization efficiency. Residue management and, different N levels and method of N application brought significant differences in the NUE by the maize. The data regarding NUE presented in Table 53**.** Significantly higher NUE was recorded under the residue retained plots i.e. FIRB+R (56.04 and 59.74 kg kg^{-1}**)** residue removed plots i.e. FIRB-R (52.23 and 54.89 kg kg^{-1}**).**

Table 53: Effect of residue and N management on nitrogen use efficiency of maize

NUE (kg kg^{-1})		
Treatments	**2014**	**2015**
Residue Management		
FIPB-R	52.23	54.89
FIPB+R	56.04	59.74
SEm±	**0.944**	**1.125**
LSD (P=0.05)	**1.394**	**4.9125**
Nitrogen levels and method of application		
RN_0	**-**	**-**
$RN_{75\%}$ -B	53.56	56.93
$RN_{75\%}$ -DOT	61.23	64.85
$RN_{75\%}$-DIF	56.57	60.53
$RN_{100\%}$ -B	48.70	50.99
$RN_{100\%}$ -DOT	56.45	56.06
$RN_{100\%}$-DIF	53.10	54.53
SEm±	**4.336**	**6.700**
LSD (P=0.05)	**2.508**	**3.118**

Increase in NUE with residue retention may be attributed to the positive effects of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al* 2010), improved soil health (Jat *et al* 2013, Singh *et al* 2016), better water regimes (Govaerts *et al* 2009), lesser weed population (Ozpinar 2006, Chauhan *et al* 2007), and improved nutrient use efficiency compared to CT without residue retention (Unger and Jones, 1998). Parihar *et al* (2016) also showed the positive effects of PB and residue retention on NUE of maize.

Nitrogen application method and N rate significantly affected the NUE of wheat. Among the different N levels and application methods $RN_{75\%}$-DOT results into significantly higher NUE (61.23 and 64.85 kg kg^{-1}) as compared to the $RN_{75\%}$-B (53.56 and 56.93 kg kg^{-1}), $RN_{100\%}$-DOT (56.45 and 56.06 kg kg^{-1}), $RN_{100\%}$-DIF (53.10 and 54.53 kg kg^{-1}) and $RN_{100\%}$-B (48.70 and 50.99 kg kg^{-1}), during both years, respectively. However among the 100% recommended fertilizer rate significantly higher NUE was observed under the $RN_{100\%}$-DOT as compared to the $RN_{100\%}$-DIF and $RN_{100\%}$-B. The higher NUE obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the N uptake by crop plant and NUE (Hartmann *et al* 2015). Nitrogen use efficiency is greater when the yield response to N is high. Therefore, this efficiency is generally high with low N rates and decreases in accordance with the rate increase of applied N (Gauer *et al* 1992, Parodi 2003). Similar results were obtained by Sinebo *et al* (2004) and Rahman *et al* (2000).

4.2.11 Soil analysis

4.2.11.1 Soil pH

The data on soil pH after the harvest of wheat and maize crop in the second year at different depths i.e. 0-7.5, 7.5-15, 15-30 and 30-45 cm along with statistical analysis was presented in Table 54. The perusal of data shows that soil pH was not influenced significantly due to residue management treatments after the harvest of wheat and maize in the second year. It might be due to buffering capacity of soil, which offered resistant against change in pH. However the soil pH increased with soil depth. The soil pH ranged from 8.62-8.67, 8.77-8.80, 8.90-8.92 and 8.99-9.06 at soil depth 0-7.5, 7.515, 15-30 and 30-45 cm, respectively after the harvest of wheat crop during 2014-15 and 8.52-8.57, 8.68-8.73, 8.73-8.80 and 8.83-8.86 at soil depth 0-7.5, 7.5-15, 15-30 and 30-45 cm, respectively after the harvest of maize crop during 2015 under different residue management treatments. . However as compared to the initial soil pH (8.6), slightly lower pH was recorded for FIPB+R at the end of experiment under the uppermost layer (0-7.5) which might be due to the acidifying processes attributing to mineralization of organic matter, nitrification of applied N fertilizer and root exudation. A decrease of pH is among the short-term chances of soil properties which can result during decomposition of crop residues due to production of organic acids and microbial respiration (Hulugalle and Weaver 2005). These findings were in conformity with Malhi *et al* (2011). Rasmussen (1999) reported residue management technique is often shown to have no effect on soil pH (Rasmussen, 1999), though soil pH has been reported to be lower in

Table 54: Effect of residue and N management on soil pH after the harvest of wheat and maize in the second year of the experiment

	pH							
Treatments	0-7.5		7.5-15		15-30		30-45	
	After wheat	After maize	After wheat	After maize	After wheat	After maize	After wheat	After maize
Residue management								
FIPB-R	8.67	8.57	8.80	8.73	8.92	8.80	9.06	8.86
FIPB+R	8.62	8.52	8.77	8.68	8.90	8.73	8.99	8.83
SEm±	**0.069**	**0.029**	**0.025**	**0.037**	**0.010**	**0.037**	**0.010**	**0.030**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	8.66	8.49	8.73	8.70	8.85	8.71	8.96	8.77
$RN_{75\%}$ -B	8.65	8.53	8.76	8.70	8.90	8.78	9.01	8.92
$RN_{75\%}$ -POT	8.67	8.62	8.85	8.75	8.97	8.75	9.11	8.86
$RN_{75\%}$-PIF	8.70	8.60	8.89	8.70	8.97	8.77	9.04	8.76
$RN_{100\%}$ -B	8.64	8.51	8.74	8.66	8.96	8.74	9.06	8.90
$RN_{100\%}$ -POT	8.61	8.55	8.76	8.72	8.87	8.82	9.02	8.83
$RN_{100\%}$-PIF	8.59	8.54	8.79	8.73	8.87	8.78	9.04	8.86
SEm±	**0.047**	**0.078**	**0.061**	**0.066**	**0.070**	**0.086**	**0.059**	**0.078**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

no-till systems compared to CT (Rahman *et al* 2008). The lower pH in ZT was attributed to accumulation of organic matter in the upper few centimetres under ZT soil (Rhoton, 2000) causing increases in the concentration of electrolytes and reduction in pH (Rahman *et al* 2008). However, the nitrogen levels had not showed any significant influenced on the soil pH. However, the nitrogen levels had not showed any significant influenced on the soil pH.

4.2.11.2Electrical Conductivity (dS m^{-1})

The data on soil electrical conductivity (EC) after the harvest of wheat and maize crop in the second year at different depths i.e. 0-7.5, 7.5-15, 15-30 and 30-45 cm along with statistical analysis was presented in Table 55. The perusal of data shows that EC of the soil was not influenced significantly due to irrigation and residue management treatments after the harvest of wheat and maize in the second year. However the soil EC decreased with soil depth. The EC of the soil ranged from 0.195-197, 0.171-0.176, 0.147-0.156 and 0.125-0.130 dS m^{-1} at soil depth 0-7.5, 7.515, 15-30 and 30-45 cm, respectively after the harvest of wheat crop during 2014-15 and 0.184-0.189, 0.160-0.166, 0.138-0.144 and 0.125-0.130 dS m^{-1}at soil depth 0-7.5, 7.5-15, 15-30 and 30-45 cm, respectively after the harvest of maize crop during 2015 under different residue management treatments.

The data presented in Table 55 reveals that EC of the soil was influenced significantly upto the 15-30 cm soil depth with increase in the N level and also with the method of N application. Significantly higher EC was recorded under the $RN_{100\%}$ -POTat different soil depths as compared to the control after the harvest of wheat and maize in the second year. However the soil EC recorded under the $RN_{100\%}$ -POTat different soil depths was statistically at par with that recorded under $RN_{75\%}$ -B, $RN_{75\%}$ -POT, $RN_{75\%}$-PIF, $RN_{100\%}$ -B and $RN_{100\%}$-PIF. The increase in the EC with increase in the N levels might because of the fertilizer salts were not mixed into the soil; salts may also move to the surface during evaporation and then accumulate when not remixed by tillage (Veenstra *et al*, 2006).

4.2.11.3Soil organic carbon (mg/kg)

Soil organic carbon (SOC) was affected significantly due to residue management treatments at 0-7.5 and 7.5-15 cm soil depth and did not influenced at lower layer of soil profile (Table 56). The data revealed that crop residues application significantly increased the SOC under FIPB+R by 3.88%, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. Similarly the SOC observed under the FIPB+R at the 7.5-15 cm depth was statistically higher as compared to the FIPB-R after the harvest of wheat and maize in the second year of the experiment. The increase in the SOC under the FIPB+R was may be due to application of crop residues in this treatment which decomposed and added the organic matter to the soil. Govaerts *et al* (2007) reported that permanent raised beds with full residue retention increased soil organic matter content 1.4 times in the 0-5 cm layer compared to conventionally tilled raised beds with straw

Table 55: Effect of residue and N management on soil EC after the harvest of wheat and maize in the second year of the experiment

Treatments	EC (dS m^{-1})							
	0-7.5		7.5-15		15-30		30-45	
	After wheat	After maize	After wheat	After maize	After wheat	After maize	After wheat	After maize
Residue management								
FIPB-R	0.195	0.184	0.171	0.160	0.148	0.138	0.121	0.125
FIPB+R	0.197	0.189	0.176	0.166	0.156	0.145	0.129	0.130
SEm±	**0.006**	**0.002**	**0.006**	**0.002**	**0.002**	**0.005**	**0.002**	**0.002**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	0.185	0.169	0.166	0.153	0.158	0.135	0.120	0.124
$RN_{75\%}$ -B	0.192	0.191	0.168	0.166	0.147	0.142	0.127	0.127
$RN_{75\%}$ -POT	0.197	0.196	0.176	0.160	0.151	0.143	0.126	0.128
$RN_{75\%}$-PIF	0.193	0.180	0.171	0.164	0.147	0.140	0.122	0.131
$RN_{100\%}$ -B	0.196	0.187	0.177	0.173	0.149	0.142	0.121	0.125
$RN_{100\%}$ -POT	0.207	0.195	0.174	0.165	0.150	0.141	0.125	0.127
$RN_{100\%}$-PIF	0.203	0.184	0.183	0.163	0.162	0.146	0.134	0.126
SEm±	**0.007**	**0.006**	**0.005**	**0.006**	**0.006**	**0.005**	**0.005**	**0.006**
LSD (P=0.05)	**0.019**	**0.017**	**0.014**	**0.018**	**NS**	**NS**	**NS**	**NS**

Table 56: Effect of residue and N management on soil OC after the harvest of wheat and maize in the second year of the experiment

OC (g kg^{-1})								
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After wheat	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**
Residue management								
FIPB-R	5.53	5.67	4.82	4.99	3.40	3.69	1.97	1.99
FIPB+R	5.79	5.89	5.04	5.29	3.53	3.81	2.07	2.04
SEm±	**0.042**	**0.024**	**0.024**	**0.044**	**0.117**	**0.023**	**0.047**	**0.031**
LSD (P=0.05)	**0.252**	**0.147**	**0.148**	**2.66**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	5.61	5.71	4.93	4.99	3.33	3.70	1.96	1.97
$RN_{75\%}$ -B	5.62	5.74	4.79	4.99	3.38	3.74	1.98	1.98
$RN_{75\%}$ -POT	5.71	5.76	4.84	5.03	3.30	3.71	1.99	2.01
$RN_{75\%}$-PIF	5.70	5.86	4.91	5.23	3.55	3.78	2.03	2.01
$RN_{100\%}$ -B	5.66	5.72	5.02	5.10	3.54	3.78	2.12	1.99
$RN_{100\%}$ -POT	5.75	5.94	4.96	5.45	3.53	3.71	2.07	2.11
$RN_{100\%}$-PIF	5.63	5.71	5.06	5.16	3.63	3.86	2.01	2.05
SEm±	**0.084**	**0.092**	**0.116**	**0.162**	**0.120**	**0.100**	**0.057**	**0.087**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

incorporated and it increased significantly with increasing amounts of residue retained on the soil surface in the permanent raised beds. Similar findings were also reported by Sarkar and Kar (2011). Secondly within CA systems, both repeated application of residues as well as reduced mineralisation of these through reduced soil disturbance contributed to superior SOC status as compared to the CT systems.

The effect of different N levels and method of N application was observed to be non-significant after the harvest of wheat and maize in the second year of the experiment. Statistically similar results were reported at different levels of N and different method of N application at different depths of soil.

4.2.11.4Ammonical-N (mg kg^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to Ammonical-N (NH_4^+-N) in soil after harvest of wheat and maize crop in the second year. Ammonical-N was affected significantly due to residue management treatments at 0-7.5 and 7.5-15, cm soil depth (Table 57). The data revealed that crop residues application significantly increased the NH_4^+-N under FIPB+R by 6.25% over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. Although the chemical fertilizer sources have immediate effect and supply of ammonical nitrogen to soil but on long term basis, the treatments in which continuous application of residue i.e. organic sources have higher ammonical nitrogen content in soils which may be due to slow release of ammonical nitrogen from organic sources (crop residue) and more availability to the soil as compared to chemical fertilizer sources which have immediate more availability but on long term basis its available decreases in the soil. More ammonical nitrogen in combined application of organic along with inorganic fertilizers may be due to continuous release of nitrogen from the organic sources whereas in chemical treatments the supply of ammonical nitrogen to the plant was for a short period but in excess amounts as reported by Hao and Chang (2002).

The data regarding NH_4^+-N presented in Table 57 reveals that NH_4^+-N under different soil depths increased significantly and consistently with increase in the N level and change in method of application. Significantly higher NH_4^+-N was recorded under the $RN_{100\%}$ -POT at different soil depths as compared to the control after the harvest of wheat and maize in the second year. The higher NH_4^+-N content was obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE, (Hartmann *et al* 2015).

4.2.11.5 Nitrate-N (mg kg^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to Nitrate-N (NO_3^--N) in soil after harvest of wheat and maize

Table 57: Effect of residue and N management on ammonical-N content in soil after the harvest of wheat and maize in the second year of the experiment

NH_4^+-N (mg kg^{-1})								
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After wheat	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**
Residue management								
FIPB-R	17.92	19.53	15.17	17.43	12.92	13.81	10.50	11.17
FIPB+R	19.17	20.75	16.92	18.78	14.33	14.44	11.58	12.11
SEm±	**0.408**	**0.286**	**0.510**	**0.715**	**0.514**	**0.227**	**0.664**	**0.166**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	13.42	13.02	10.79	11.48	8.46	9.14	6.71	7.59
$RN_{75\%}$ -B	17.50	19.64	15.17	16.64	12.83	13.42	10.21	11.09
$RN_{75\%}$ -POT	19.83	20.90	16.92	17.70	14.58	15.17	11.08	12.06
$RN_{75\%}$-PIF	19.25	20.42	15.75	18.47	13.71	14.78	11.38	11.67
$RN_{100\%}$ -B	18.67	21.98	17.21	19.64	14.29	15.07	12.54	12.73
$RN_{100\%}$ -POT	20.12	22.75	18.96	20.16	16.63	16.14	13.13	13.42
$RN_{100\%}$-PIF	21.00	22.27	17.50	22.17	14.88	15.17	12.25	12.93
SEm±	**0.777**	**0.718**	**0.936**	**0.827**	**0.787**	**0.673**	**0.622**	**0.710**
LSD (P=0.05)	**2.267**	**2.095**	**2.733**	**2.415**	**2.298**	**1.963**	**4.071**	**2.073**

Table 58: Effect of residue and N management on nitrate-N content in soil after the harvest of wheat and maize in the second year of the experiment

Treatments	NO_3^--N (mg kg^{-1})							
	0-7.5		7.5-15		15-30		30-45	
	After wheat	After maize	After wheat	After maize	After wheat	After maize	After wheat	After maize
Residue management								
FIPB-R	14.50	15.95	12.75	14.45	11.25	12.78	9.92	10.53
FIPB+R	16.31	17.17	14.66	15.42	13.42	14.08	10.50	11.03
SEm±	**0.336**	**0.300**	**0.588**	**0.199**	**0.358**	**0.199**	**0.212**	**0.180**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	11.67	12.45	10.21	11.09	7.29	8.66	7.29	7.20
$RN_{75\%}$ -B	14.29	16.14	12.54	14.20	11.96	13.23	9.63	10.31
$RN_{75\%}$ -POT	15.75	17.50	14.29	15.75	13.41	14.39	10.20	10.99
$RN_{75\%}$-PIF	14.88	16.53	14.00	14.98	12.25	13.42	10.79	10.70
$RN_{100\%}$ -B	16.33	17.14	14.28	15.76	12.54	14.59	10.50	11.96
$RN_{100\%}$ -POT	18.04	18.86	15.46	16.82	14.88	15.17	11.67	12.25
$RN_{100\%}$-PIF	16.88	17.26	15.17	15.95	14.00	14.59	11.38	12.06
SEm±	**0.115**	**0.737**	**0.873**	**0.740**	**0.867**	**0.516**	**0.646**	**0.713**
LSD (P=0.05)	**3.253**	**2.151**	**2.549**	**2.161**	**2.530**	**1.507**	**1.885**	**NS**

crop in the second year. Nitrate-N was affected significantly due to residue management treatments at 0-7.5 and 7.5-15, cm soil depth (Table 58). The data revealed that crop residues application significantly increased the NO_3^--N under FIPB+R by 7.64% over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. Although the chemical fertilizer sources have immediate effect and supply of nitrate nitrogen to soil but on long term basis, the treatments in which continuous application of residue i.e. organic sources have higher ammonical nitrogen content in soils which may be due to slow release of nitrate nitrogen from organic sources (crop residue) and more availability to the soil as compared to chemical fertilizer sources which have immediate more availability but on long term basis its available decreases in the soil. More nitrate nitrogen in combined application of organic along with inorganic fertilizers may be due to continuous release of nitrogen from the organic sources whereas in chemical treatments the supply of nitrate nitrogen to the plant was for a short period but in excess amounts as reported by Hao and Chang (2002).

The data regarding NO_3^--N presented in Table 58 reveals that NO_3^--N under different soil depths increased significantly and consistently with increase in the N level and change in method of application.Significantly higher NO_3^--N was recorded under the $RN_{100\%}$ -POTat different soil depths as compared to the control after the harvest of wheat and maize in the second year. The higher NH_4^+-N content was obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due to the effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE (Hartmann *et al* 2015).

4.2.11.6 Soil P (kg ha^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to Soil P in soil after harvest of wheat and maize crop in the second year. Soil P was affected significantly due to residue management treatments at 0-7.5 and 7.5-15, cm soil depth (Table 59). The data revealed that crop residues application significantly increased the Soil K content under FIPB+R by 5.31% over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. The increase in the SOC under the FIPB+R was may be due to application of crop residues in this treatment which decomposed and added the organic matter to the soil. The effect of different N levels and method of N application was observed to be non-significant after the harvest of wheat and maize in the second year of the experiment. Statistically similar results were reported at different levels of N and different method of N application at different depths of soil.

Table 59: Effect of residue and N management on Soil P content in soil after the harvest of wheat and maize in the second year of the experiment

Soil P (kg ha^{-1})								
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After wheat	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**
Residue management								
FIPB-R	35.05	36.73	27.20	28.13	23.73	24.52	16.80	17.87
FIPB+R	37.32	38.67	28.00	31.33	25.20	25.72	17.40	18.5
SEm±	**0.899**	**0.618**	**0.327**	**0.589**	**0.984**	**0.566**	**0.510**	**0.313**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	35.48	36.40	26.13	28.93	22.88	22.88	16.80	18.20
$RN_{75\%}$ -B	35.93	35.93	28.48	29.40	25.20	25.20	15.40	17.40
$RN_{75\%}$ -POT	35.48	36.88	26.60	28.48	23.33	24.28	16.80	17.98
$RN_{75\%}$-PIF	35.00	38.50	27.08	30.33	24.73	26.13	17.28	18.43
$RN_{100\%}$ -B	37.80	37.58	27.53	29.88	24.28	25.68	17.50	17.98
$RN_{100\%}$ -POT	37.33	39.20	28.48	31.28	25.20	26.13	17.98	18.43
$RN_{100\%}$-PIF	36.40	39.43	28.93	29.88	25.68	25.68	17.98	18.90
SEm±	**1.364**	**1.931**	**1.000**	**1.154**	**1.118**	**1.288**	**0.922**	**1.401**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 60: Effect of residue and N management on Soil K content in soil after the harvest of wheat and maize in the second year of the experiment

Soil K (kg ha^{-1})								
Treatments	**0-7.5**		**7.5-15**		**15-30**		**30-45**	
	After wheat	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**	**After wheat**	**After maize**
Residue management								
FIPB-R	209.58	219.47	152.27	162.67	128.80	137.60	79.20	81.33
FIPB+R	231.97	238.93	167.20	176.53	138.40	142.40	88.80	92.29
SEm±	**0.336**	**0.300**	**0.588**	**0.199**	**0.358**	**0.199**	**0.212**	**0.180**
LSD (P=0.05)	**20.489**	**3.036**	**11.979**	**13.527**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0	216.37	225.87	156.80	166.13	132.53	138.13	80.27	81.20
$RN_{75\%}$ -B	218.40	224.93	155.87	168.93	127.87	139.07	81.20	84.00
$RN_{75\%}$ -POT	220.27	224.93	157.73	167.07	136.27	137.20	85.87	88.73
$RN_{75\%}$-PIF	219.33	229.60	163.33	171.73	132.53	141.87	79.33	83.07
$RN_{100\%}$ -B	221.20	227.73	155.87	167.07	134.40	139.07	87.73	93.33
$RN_{100\%}$ -POT	228.67	235.20	168.00	176.40	140.00	140.93	83.06	86.80
$RN_{100\%}$-PIF	221.20	236.13	160.53	169.87	131.60	143.73	90.53	90.53
SEm±	**0.115**	**0.737**	**0.873**	**0.740**	**0.867**	**0.516**	**0.646**	**0.713**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.2.11.7 Soil K (kg ha^{-1})

It was observed during the study that there were significant differences among the different treatments in relation to Soil K in soil after harvest of wheat and maize crop in the second year. Soil P was affected significantly due to residue management treatments at 0-7.5 and 7.5-15, cm soil depth (Table 60). The data revealed that crop residues application significantly increased the Soil K content under FIPB+R by 8.87% over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment. The increase in the SOC under the FIPB+R was may be due to application of crop residues in this treatment which decomposed and added the organic matter to the soil. The effect of different N levels and method of N application was observed to be non-significant after the harvest of wheat and maize in the second year of the experiment. Statistically similar results were reported at different levels of N and different method of N application at different depths of soil.

4.3 EXPERIMENT-III

The experiment was conducted in a split plot design design entitled as "Decomposition rate and nutrient dynamics of crop residue as affected by depth of placement". Crop residues are an important source of plant nutrients and are the primary source of organic matter (as C constitutes more than 40% of the total dry biomass), are available in large quantities, and are not being fully utilized. Although the effects of placement on decomposition of different residues under field conditions other than maize and moongbean are known, information is lacking in the maize-wheat-moongbean system, a world’s most important cropping system. The various interaction effects were not significant for various parameters. Hence, to avoid repetition have not been discussed under the individual parameters. Only the effects of main treatments and sub treatments have been discussed.

4.3.1 Residue decomposition

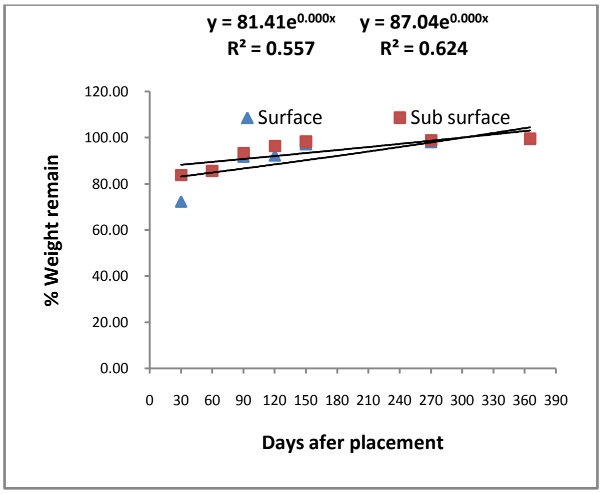
A rapid decrease in the weight was observed during the initial time in both the residues (Table 61). However this decrease was not significantly different between two types of residues mainly because of same residue quality. After 60 days of placement of bags, $MT_{50\%}$ had lost 27.07% of its initial mass and $ML_{50\%}$ had lost 31.28% of its initial irrespective of the method of placement. Nearly 50% of the initial weight was lost from the bags after 120 days of placement of bags and, at the end of the decomposition cycle $MT_{50\%}$ had lost 93.50% of its initial mass and $ML_{50\%}$ had lost 94.78% of its initial irrespective of the method of placement (Fig 18 and 19). Decomposition was significantly affected by method of placement as surface placed residue lost about 11.59% of initial mass after the 30 DAP, where as sub-surface placed residue lost about 30.78% of initial mass irrespective of type of residue. Throughout the decomposition cycle, the percent decrease in weight was significantly higher from the sub-surface placed residue as compared to surface placed residue. In surface placed residue, the 50% of the initial weight lost after the 150 DAP, whereas in sub-surface placed residue the 50% of the initial weight lost after the 90 DAP. At the end of the decomposition cycle (365 DAP), the percent weight remaining was of the order 8.31% and 3.14% of surface placed and sub-surface palced respectively.

Table 61: Periodic weight remains in $MT_{50\%}$ and $ML_{50\%}$residues as affected by method of placement

Weight (g)							
Treatments	**Days after placement**						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue							
MR $T_{50\%}$	39.568[a]	36.463[a]	29.948[a]	25.922[a]	17.650[a]	7.510[a]	3.250[a]
MR $L_{50\%}$	39.246[a]	34.359[a]	26.906[a]	21.473[a]	15.202[a]	4.404[a]	2.611[a]
SEm±	**0.658**	**0.309**	**0.569**	**1.350**	**0.609**	**0.429**	**0.378**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Method of placement							
SP	44.205[a]	40.698[a]	32.157[a]	27.408[a]	21.193[a]	7.917[a]	4.158[a]
SSP	34.610[b]	30.123[b]	24.698[b]	19.987[b]	11.658[b]	3.998[b]	1.705[b]
SEm±	**0.658**	**0.833**	**0.569**	**1.350**	**0.609**	**0.429**	**0.378**
LSD (p = 0.05)	**2.322**	**2.940**	**2.008**	**4.762**	**2.149**	**1.513**	**1.334**

Means with same letter are not significantly different

Similarly, in wheat and moongbean residues rapid decrease of litter mass at the beginning decomposition for all treatment irrespective of method of placemecnt was observed (Table 62). After 30 days of placement of bags, $M_{100\%}$ had lost 57.60% of its initial mass, while $WT_{75\%}$, $WL_{25\%}$ and $WL_{25\%}+M_{100\%}$ had lost 38.41%, 30.79% and 46.11% respectively (Fig.20&21). At the end of the decomposition cycle all the residues had lost about 93-95% of their initial mass. Moongbean residue decompose more rapidly than the other residue at the early stage of decomposition, but the percentages of residue weight left trended to constant after an initial period of rapid decomposition (Fig.22&23). The initial more weight loss of moongbean residue was mainly due to the high total N contents of the legume residues compared to the other non-legumes legume residues. Increased residue decomposition with greater inherent litter N has been also observed in other studies (Cornwell *et al* 2008, Hobbie *et al* 2012). It has been reported that N availability may control the decomposition of plant residues, particularly those with low N content such as cereals, when the N requirements of the soil decomposers are not met by the residue or soil N contents (Vahdat *et al* 2011). The



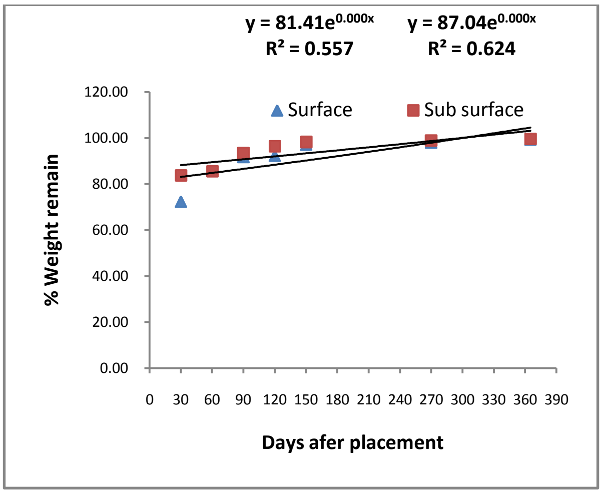
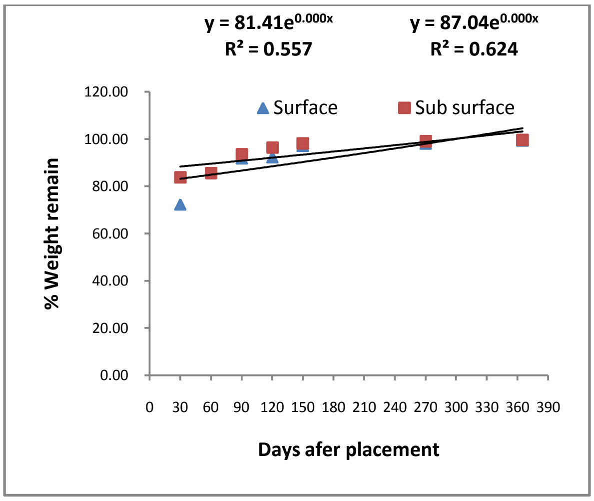


Fig 18&19: Percent weight remaining of $MT_{50\%}$ and $ML_{50\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement



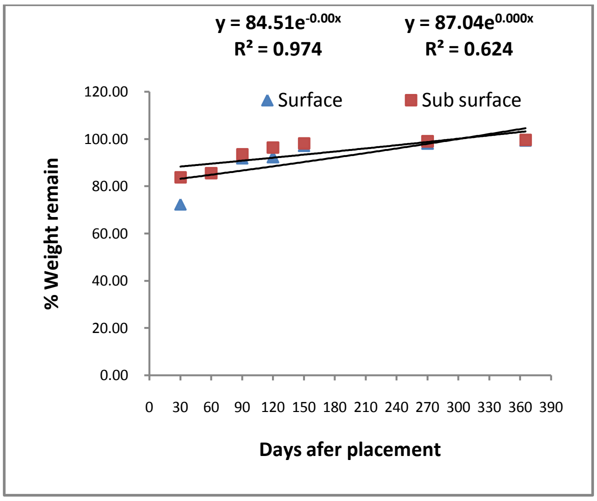
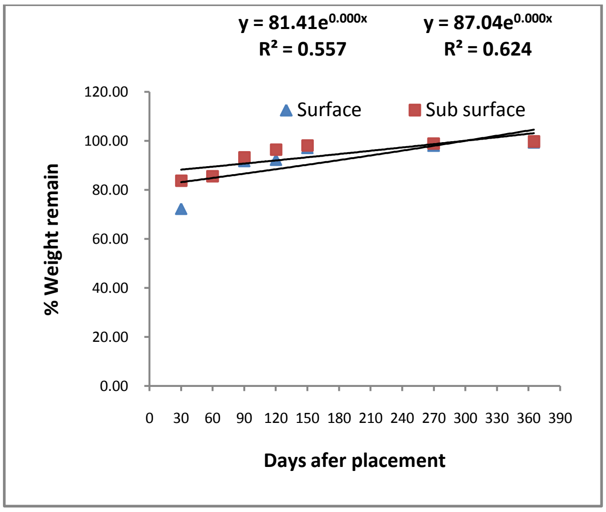


Fig 20&21: Percent weight remaining of $WT_{75\%}$ and $WL_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement



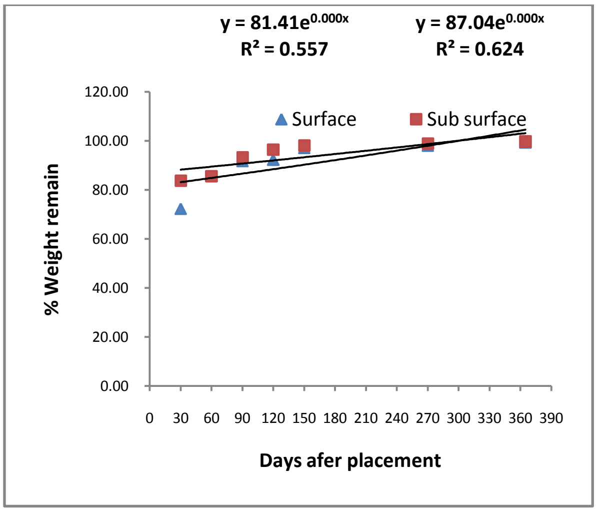


Fig 22&23: Percent weight remaining of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

decomposition of the surface and subsurface placed residue observed in this study are quite similar to the ones reported by other authors. Decomposition was significantly affected by method of residue placement as sub-surface placed residue lost 74.63% of initial weight after the 150 DAP, where as surface placed residue lost about 82.99% of initial mass irrespective of type of residue.

Table 62: Periodic weight remains in different residues as affected by method of placement

Weight (g)							
Treatments	**Days after placement**						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue							
Wheat Res $T_{75\%}$	30.793[b]	24.935[a]	17.607[bc]	14.402[b]	10.015[bc]	6.725[b]	2.550[b]
Wheat Res $L_{25\%}$	34.603[a]	26.997[a]	20.543[a]	16.582[a]	12.123[a]	8.842[a]	3.497[a]
Mung $Res_{100\%}$	21.202[d]	19.010[c]	16.445[c]	12.820[c]	9.165[c]	5.960[b]	2.540[b]
$MR_{100\%}$+$WRL_{25\%}$	26.943[c]	22.337[b]	18.617[b]	16.395[a]	11.073[ab]	7.413[ab]	2.923[ab]
SEm±	**0.720**	**0.747**	**0.614**	**0.497**	**0.762**	**0.546**	**0.239**
LSD (p = 0.05)	**2.205**	**2.287**	**1.879**	**1.522**	**1.651**	**1.674**	**0.731**
Method of placement							
SP	31.792[a]	26.811[a]	21.150[a]	17.566[a]	12.685[a]	8.630[a]	3.792[a]
SSP	24.979[b]	19.828[b]	15.456[b]	12.533[b]	8.503[b]	5.840[b]	1.963[b]
SEm±	**0.509**	**0.528**	**0.434**	**0.352**	**0.539**	**0.386**	**0.169**
LSD (p = 0.05)	**1.559**	**1.617**	**1.329**	**1.077**	**1.167**	**1.183**	**0.517**

Means with same letter are not significantly different

The initial phase of decomposition is characterized by rapid loss of hydrosoluble compounds, high microbial activity, availability of limiting elements such as N and P (leaching/release of nutrients), whereas in late stages carbon loss has been related to elements required to decompose recalcitrant components such as lignin that accumulate in the remaining litter (Gusewell and Gessner 2009, Berg *et al*, 2010, Hobbie *et al* 2012, Loranger *et al* 2002 and Nyberg *et al* 2002). Nevertheless, our findings of weight loss were comparable to the findings of Ngatia *et al* (2014), who reported 50-65% weight loss of savanna grasses in East Africa in a study period of the 20 weeks. The findings were also comparable to 36–55% Cynodon dactylon (L.) Pers. (Bermuda grass) organic matter loss reported by Liu *et al* (2011) within 18 weeks of study period in Florida. Decomposition rates of sub-surface placed residues faster than those of surface placed residues as a result of greater soil–residue contact, a more favourable and stable microenvironment, particularly soil moisture regime, and increased availability of exogenous N for decomposition by microorganisms (Cogle *et al*, 1987, Schomberg *et al*, 1994). Decomposition rates for many different residue types have consistently been 2-4 times faster in sub-surface placed than in surface-placed (Beare *et al* 2002, Ghidey and Alberts 1993, Varco *et al* 1993).

4.3.2Nutrient change pattern during residue decomposition

Nitrogen and K contents were significantly affected both by type of residue as well as method of placement (Table 63& 64). After 30 DAP of bags the percent residue N increased by 19.23% and 13.96% in MT50% and ML50%, respectively. In maize residues after 90 days of placement, the N content was increased by fifty per cent of its initial content irrespective of method of placement. However no significant difference was observed at the end of season, which might be due to the fact that whole of the organic carbon at the end of was lost from the residue with 365 days of placement. The percent residue N increased by 5.4% in surface placed residue and 28% in sub-surface placed residue by 30 DAP, irrespective of type of residue. The increase in N concentration was greater in sub-surface placed residues than placed at surface due to more loss of organic C in the former. For example, at the end of 150 DAP, N concentration was 106.6% in surface placed residue as compared to 64% in sub-surface placed residue.

Table 63: Periodic N content in $MT_{50\%}$ and $ML_{50\%}$ residues as affected by method of placement

Nitrogen (%)							
Treatments	**Days after placement**						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue							
MR $T_{50\%}$	0.620[a]	0.640[a]	0.783[a]	0.830[a]	0.947[a]	1.033[a]	1.157[a]
MR $L_{50\%}$	0.547[b]	0.580[b]	0.720[b]	0.767[b]	0.933[a]	0.997[a]	1.117[a]
SEm±	**0.011**	**0.012**	**0.018**	**0.014**	**0.037**	**0.042**	**0.084**
LSD (p = 0.05)	**0.037**	**0.042**	**0.064**	**0.049**	**NS**	**NS**	**NS**
Method of placement							
SP	0.527[b]	0.540[b]	0.697[b]	0.737[b]	0.820[b]	1.050[a]	1.163[a]
SSP	0.640[a]	0.697[a]	0.807[a]	0.860[a]	1.033[a]	0.980[a]	1.110[a]
SEm±	**0.011**	**0.012**	**0.018**	**0.014**	**0.037**	**0.042**	**0.084**
LSD (p = 0.05)	**0.037**	**0.042**	**0.064**	**0.049**	**0.131**	**NS**	**NS**

Means with same letter are not significantly different

Table 64: Periodic K content in $MT_{50\%}$ and $ML_{50\%}$residues as affected by method of placement

Potassium (%)							
Treatments	**Days after placement**						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue							
MR $T_{50\%}$	0.404^{b}	0.346^{b}	0.279^{b}	0.250^{b}	0.221^{a}	0.192^{a}	0.158^{a}
MR $L_{50\%}$	0.488^{a}	0.408^{a}	0.338^{a}	0.288^{a}	0.246^{a}	0.183^{a}	0.154^{a}
SEm±	**0.017**	**0.015**	**0.016**	**0.010**	**0.011**	**0.010**	**0.011**
LSD (p = 0.05)	**0.061**	**0.051**	**0.055**	**0.037**	**NS**	**NS**	**NS**
Method of placement							
SP	0.521^{a}	0.450^{a}	0.383^{a}	0.321^{a}	0.279^{a}	0.204^{a}	0.167^{a}
SSP	0.371^{b}	0.304^{b}	0.233^{b}	0.217^{b}	0.188^{b}	0.171^{a}	0.146^{a}
SEm±	**0.017**	**0.015**	**0.016**	**0.010**	**0.011**	**0.010**	**0.011**
LSD (p = 0.05)	**0.061**	**0.051**	**0.055**	**0.037**	**0.038**	**NS**	**NS**

Means with same letter are not significantly different

Similarly in wheat and moongbean residues statistical analysis showed that there were highly significant differences between the different residues in relative N depending upon the initial N concentration. The percent residue N increased by 202.5%, 258.4%, 109.3% and 141.7% in $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ residues respectively over the initial content irrespective of method of placement at the end of the decomposition cycle (Table 65). Irrespective of type of residue increase in percent N was significantly different in surface and sub surface placed residue, as increase percent N content was more in subsurface placed residue as compared to surface placed residue due to greater loss of organic C in the former.

The increase in litter N over the study period was in accordance with the findings of several previous studies (Dubeux *et al* 2006, Hamadi *et al* 2000 and Liu *et al* 2011), which reported increased nitrogen masses over the study period. Apart from greater release of carbon (though not measured directly) which is evident from large mass loss, increase in N concentration in the residue may also be attributed due to faster leaching of other non-nitrogenous compounds (Ghidey and Alberts 1993).

However the method of placement and type of residue showed no significant effect on P content in maize residues (Table 66). Like N, P content also increased continuously and was 85-90% higher than its initial P content in surface and sub-surface placed residue.

Table 65: Periodic N content in different residuesas affected by method of placement

Nitrogen (%)							
Treatments	Days after placement						
	30	60	90	120	150	270	365
Type of residue							
Wheat Res $T_{75\%}$	0.480[c]	0.557[c]	0.680[c]	0.733[c]	0.827[c]	0.975[c]	1.210[c]
Wheat Res $L_{25\%}$	0.377[d]	0.427[d]	0.543[d]	0.687[c]	0.773[c]	0.977[c]	1.147[c]
Mung $Res_{100\%}$	1.523[a]	1.607[a]	1.727[a]	1.850[a]	2.087[a]	2.177[a]	2.260[a]
$MR_{100\%}$+$WRL_{25\%}$	0.787[b]	0.870[b]	0.993[b]	1.127[b]	1.337[b]	1.460[b]	1.547[b]
SEm±	**0.027**	**0.014**	**0.025**	**0.039**	**0.042**	**0.045**	**0.046**
LSD (p = 0.05)	**0.083**	**0.043**	**0.077**	**0.120**	**0.128**	**0.138**	**0.142**
Method of placement							
SP	0.737[b]	0.808 [b]	0.935 [b]	1.050 [b]	1.197[a]	1.375[a]	1.500[a]
SSP	0.847[a]	0.922 [a]	1.037 [a]	1.148 [a]	1.315 [a]	1.419 [a]	1.582 [a]
SEm±	**0.019**	**0.010**	**0.018**	**0.028**	**0.030**	**0.032**	**0.033**
LSD (p = 0.05)	**0.059**	**0.031**	**0.055**	**0.085**	**0.090**	**NS**	**NS**

Means with same letter are not significantly different

Table 66: Periodic P content in $MT_{50\%}$ and $ML_{50\%}$residuesas affected by method of placement

Phosphorus (%)							
Treatments	Days after placement						
	30	60	90	120	150	270	365
Type of residue							
MR $T_{50\%}$	0.065[a]	0.061[a]	0.081[b]	0.076[a]	0.083[a]	0.094[a]	0.136[a]
MR $L_{50\%}$	0.078[a]	0.068[a]	0.092[a]	0.085[a]	0.081[a]	0.094[a]	0.109[a]
SEm±	**0.005**	**0.005**	**0.005**	**0.010**	**0.005**	**0.007**	**0.009**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Method of placement							
SP	0.069[a]	0.057[a]	0.083[a]	0.074[a]	0.081[a]	0.089[a]	0.123[a]
SSP	0.074[a]	0.071[a]	0.090[a]	0.087[a]	0.083[a]	0.099[a]	0.122[a]
SEm±	**0.005**	**0.005**	**0.005**	**0.010**	**0.005**	**0.007**	**0.009**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means with same letter are not significantly different

Table 67: Periodic P content in different residuesas affected by method of placement

Phosphorus (%)							
Treatments	**Days after placement**						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue							
Wheat Res $T_{75\%}$	0.091^{c}	0.101^{b}	0.105^{c}	0.112^{b}	0.121^{b}	0.138^{c}	0.161^{b}
Wheat Res $L_{25\%}$	0.080^{d}	0.089^{c}	0.094^{d}	0.103^{b}	0.112^{b}	0.126^{d}	0.146^{c}
Mung $Res_{100\%}$	0.122^{a}	0.131^{a}	0.176^{a}	0.200^{a}	0.233^{a}	0.254^{a}	0.269^{a}
$MR_{100\%}$+$WRL_{25\%}$	0.115^{b}	0.125^{a}	0.160^{b}	0.191^{a}	0.223^{a}	0.237^{b}	0.259^{a}
SEm±	**0.002**	**0.002**	**0.003**	**0.004**	**0.004**	**0.004**	**0.003**
LSD (p = 0.05)	**0.005**	**0.006**	**0.010**	**0.013**	**0.012**	**0.012**	**0.011**
Method of placement							
SP	0.101^{a}	0.111^{a}	0.134^{a}	0.124^{a}	0.168^{a}	0.187^{a}	0.209^{a}
SSP	0.103^{a}	0.112^{a}	0.133^{a}	0.132^{a}	0.177^{a}	0.190^{a}	0.208^{a}
SEm±	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.003**	**0.002**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Means with same letter are not significantly different

Table 68: Periodic Kcontent in different residuesas affected by method of placement

Potassium (%)							
Treatments	**Days after placement**						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue							
Wheat Res $T_{75\%}$	0.471^{ab}	0.367^{abc}	0.254^{bc}	0.229^{ab}	0.204^{d}	0.133^{b}	0.108^{c}
Wheat Res $L_{25\%}$	0.392^{b}	0.296^{c}	0.254^{c}	0.225^{ab}	0.175^{bc}	0.146^{b}	0.096^{c}
Mung $Res_{100\%}$	0.479^{a}	0.421^{a}	0.350^{a}	0.271^{b}	0.163^{cd}	0.108^{b}	0.092^{c}
$MR_{100\%}$+$WRL_{25\%}$	0.392^{b}	0.333^{bc}	0.263^{bc}	0.200^{b}	0.138^{d}	0.117^{b}	0.083^{c}
SEm±	**0.025**	**0.015**	**0.018**	**0.016**	**0.013**	**0.013**	**0.007**
LSD (p = 0.05)	**0.076**	**0.047**	**0.054**	**0.049**	**0.041**	**NS**	**NS**
Method of placement							
SP	0.465^{a}	0.402^{a}	0.308^{a}	0.273^{a}	0.200^{a}	0.127^{a}	0.100
SSP	0.402^{b}	0.306^{b}	0.252^{b}	0.190^{b}	0.140^{b}	0.125^{a}	0.090
SEm±	**0.018**	**0.011**	**0.012**	**0.011**	**0.010**	**0.009**	**0.005**
LSD (p = 0.05)	**0.054**	**0.034**	**0.038**	**0.035**	**0.027**	**NS**	**NS**

Means with same letter are not significantly different

Similarly in wheat and moongbean residues, the P content was increasing linearly with time and statistical analysis showed that, there were significant differences in P content at each sampling time in all type of residue irrespective of method of placement (Table 67). The percent residue P increased by 83.0%, 94.7%, 128.0% and 131.3% in $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ residues respectively over the initial content irrespective of method of placement at the end of the decomposition cycle (365 DAP). Tian *et al* (1992) reported an increase of P concentration in rice residue during the initial period of decomposition. Many studies showed accumulation of P as well as N during decomposition (Staaf and Berg 1982, O'Connell 1988). In some cases, P accumulation was faster than N during decay of forest debris (Lambert *et al*, 1980) indicating that the dependence of decomposer activity for phosphorus. In another study O'Connell (2004) showed that, there was four-fold increase in the amount of P in mesh bags after five years of decomposition.

The change in K in the residue was significantly affected by method of placement as well as type of residue. In maize residues, K in residue decreased markedly from initial level to 70-80% after 150 days of placement irrespective of placement method. However in wheat an moongbean residues, there were also significant differences between the different residues with respect to percent K remaining in litter at each sampling time, with greatest decrease in $WL_{25\%}$ with 74.3% decrease followed by $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ with 66.4 and 65.2% respectively after 30 days of placement irrespective of method of placement (Table 68). The pattern of decrease in K content can be clearly divided into two stages. In the first stage (30 DAP) there was a rapid decrease in potassium content and was found to be almost 50% of initial content (Table 4). During the second stage (60 DAP onwards), it was observed that K content decreased steadily and decrease in K content was 80-85% after 365 days of placement in both type of residue irrespective of method of placement. The high loss of initial K is mainly because k is not a structural element, it is susceptible to high initial loss by leaching, Staaf (1980). Other workers have reported that, higher leaching losses of K from residues since K is not embedded to the tissues of plants (Berg 1984, Saini 1989 and Reddy and Venkataiah 1989). The slow release of K observed here in the second stage might be due to the little change in soil exchangeable cation contents, supported by the studies of (Lupwayi and Haque, 1998 and Ahlam, 2004).

4.3.2 Release of nutrients during residue decomposition

Type of residue and method of placement had a strong influence on N releasing behaviour. In surface placed residue total N release from $MT_{50\%}$ residue by 60 DAP was about 2.73 kg N ha^{-1} (11.78% of initial) and 6.08 kg N ha^{-1} (17.88% of initial) from ML50% (Fig 24 & 26). The higher N release from $ML_{50\%}$ as compared to $MT_{50\%}$ was may be due to the more weight lost in former at each sampling time. In both type of residue the amount of N release from the sub surface placed residue was higher than the surface

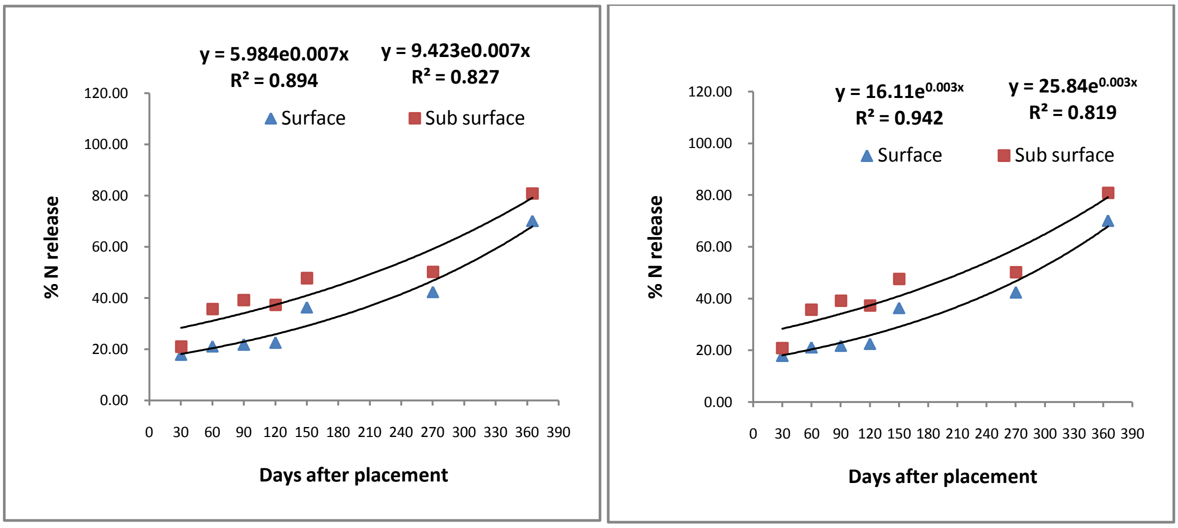


Fig 24&25: Nitrogen release during decomposition of $MT_{50\%}$ and $ML_{50\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

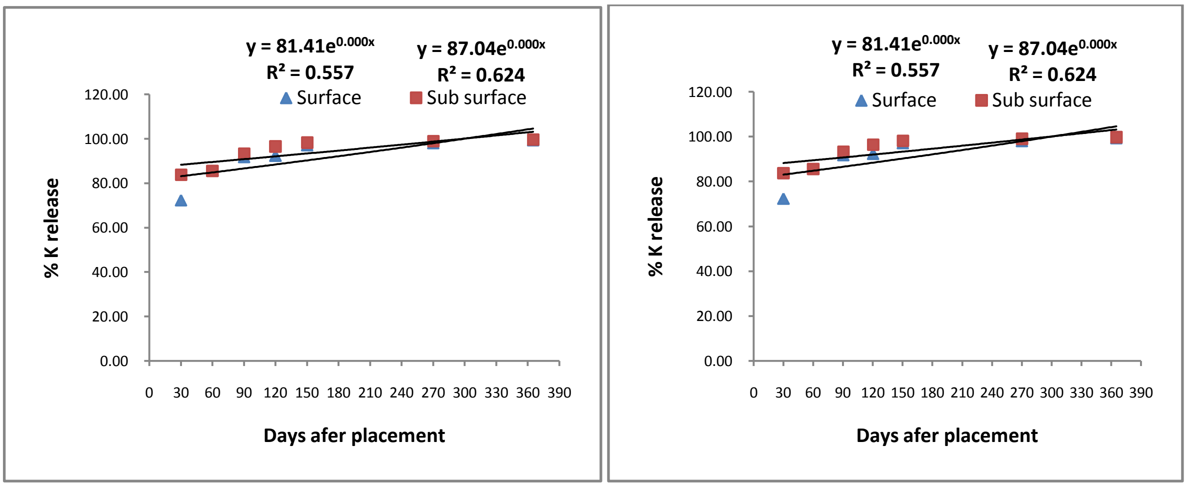


Fig 26&27 Potassium release during decomposition of $MT_{50\%}$ and $ML_{50\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

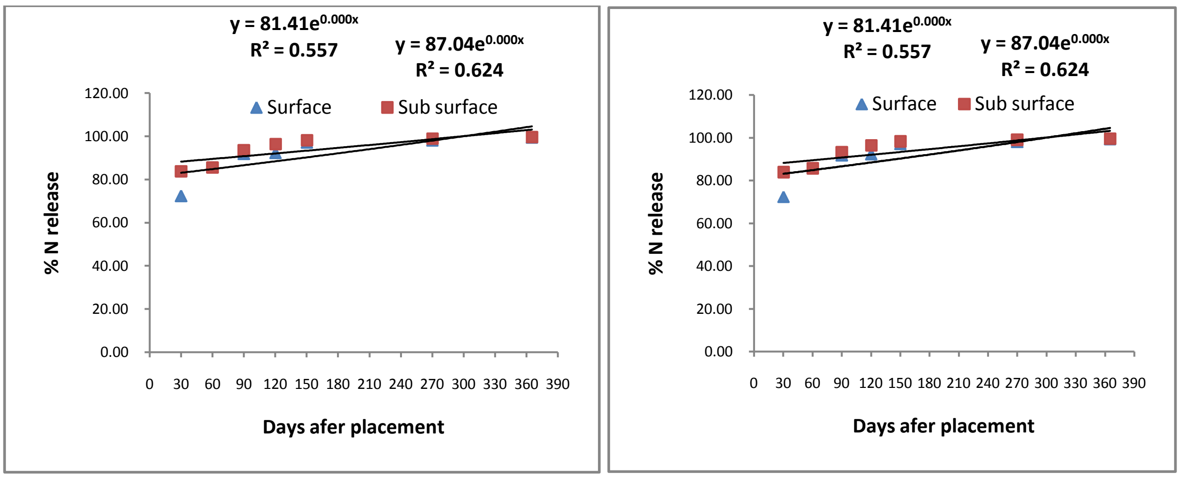


Fig 28&29: Nitrogen release during decomposition of $WT_{75\%}$ and $WL_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

placed residue, as in $MT_{50\%}$ residue by 120 DAP N release increased to 7.86 kg N ha^{-1} (33.93% of initial) from sub surface placed residue in comparison to 3.40 kg N ha^{-1} (14.67% of initial) in surface placed residue. Similarly in $ML_{50\%}$ residue by 120 DAP N release increased to 13.35 kg N ha^{-1} (39.26% of initial) from sub surface placed residue in comparison to 7.45 kg N ha^{-1} (21.92% of initial) in surface placed residue (Fig 26). At the end of decomposition period the total amount of N release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 21.6 kg N ha^{-1} (91.76% of initial) and 31.66 kg N ha^{-1} (93.12% of initial) respectively.

Similarly in wheat and moongbean residues, N release was high in the initial 120 days of decomposition. In surface placed residue after 120 days of placement DAP the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ release 5.79 kg N ha^{-1}, 1.82 kg N ha^{-1}, 18.08 kg N ha^{-1} and 6.78 kg N ha^{-1} (37.99%, 22.61%, 52.31% and 37.95% of initial) respectively (Fig 28,31, 17 & 20). In all type of residue the amount of N released from the sub surface placed residue was higher than the surface placed residue, as in $WL_{75\%}$ residue by 150 DAP, N release increased to 9.52 kg N ha^{-1} (62.44% of initial) from sub surface placed residue in comparison to 8.40 kg N ha^{-1} (55.09% of initial) in surface placed residue (Fig 28). At the end of decomposition period in sub surface placed the total amount of N released from the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ was about 13.71 kg N ha^{-1}, 6.53 kg N ha^{-1}, 32.02 kg N ha^{-1} and 16.07 kg N ha^{-1} (89.95%, 80.96%, 92.64% and 89.95% of initial) respectively. The amount of N released followed the order $MB_{100\%}$ > $WL_{25\%}$+ $MB_{100\%}$ > $WT_{75\%}$ >$WL_{25\%}$ through out the decomposition period, which is mainly due the high initial N concentration of the $MB_{100\%}$.

The highly significant positive correlation between net N mineralization and the residue N content confirms the previous results (Nourbakhsh and Dick 2005, Vahdat *et al* 2011, Abbasi *et al* 2015), indicating that residue N concentration can be considered a better tool to predict mineralization of added organic residues compared to the C=N ratio. As indicated in a previous study (Trinsoutrot *et al* 2000), the net accumulation (whether positive or negative) of mineral N in soil during decomposition of organic residues is directly related to the residue N content. Kumar and Goh, (2003) also reported net nitrogen mineralization (% of added N) from different organic materials during 110 days of incubation was in the range of 35% in *Triticum aestivum* (wheat) residues to 81% in *Trifoliumrepens* (white clover) residues. The results indicated that there was no period of N immobilization through out the decomposition period for the two types of residues. This was clearly observed as % N remaining in each sampling did not exceed 100%. Since N application after maximum tiller stage has less effect on the grain yield of wheat, the additional amount of N released after boot stage may not be absorbed by growing wheat and remains unutilized. Both residue N (and also other chemical composition parameters such as lignin, cellulose and phenol contents), residue load and timely release of N are critical factors for residue to be considered a reliable source of N for crop production (Clement *et al*, 1995). If both the recycling of N in the soil microbial biomass and possible losses of N mineralized (i.e., leaching, denitrification, and volatilization) are considered, the average total N content of maize residue is not enough to significantly reduce the N fertilizer rate applied to wheat and the following maize crop over a short-term. Possible management alternatives that need to be evaluated are adjusting residue incorporation and N fertilizer application times to improve the synchronicity between maize residue decomposition and wheat N uptake.

During the initial period of decomposition (by 90 DAP), P was immobilized against net mineralization. The higher P release from $ML_{50\%}$ as compared to $MT_{50\%}$ was may be due to the more weight lost in former at each sampling time. In maize residue the amount of P release from the sub surface placed residue was higher than the surface placed residue, as in $MT_{50\%}$ residue by 270 DAP, P release increased to 1.44 kg P ha^{-1} (73.68% of initial) from sub surface placed residue in comparison to 1.25 kg P ha^{-1} (63.59% of initial) in surface placed residue. Similarly in $ML_{50\%}$ residue by 270 DAP, P release increased to 2.75 kg P ha^{-1} (88.27% of initial) from sub surface placed residue in comparison to 2.37 kg P ha^{-1} (76.07% of initial) in surface placed residue. At the end of decomposition period the total amount of P release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 1.62 kg P ha^{-1} (82.77% of initial) and 2.91 kg P ha^{-1} (93.40% of initial) respectively.

During the first 60 DAP about 30-50% of initial P was released from different wheat and moongbean residues irrespective of method of placement. By 60 DAP, the amount of P released followed the order $MB_{100\%}$ > $WL_{25\%}$+ $MB_{100\%}$ > $WT_{75\%}$ >$WL_{25\%}$ which was mainly due the fast decomposition in moongbean residues (Fig 29,32,35&38). The percentages of P released trended to constant after an initial period of rapid increase. As expected P release was lower from surface placed residue than the sub surface placed residue throught out the decomposition period. In all type of residue the amount of P release from the sub surface placed residue was higher than the surface placed residue, as in $WT_{75\%}$ residue by 120 DAP, P release increased to 2.45 kg P ha^{-1} (73.04% of initial) from sub surface placed residue in comparison to 1.75 kg P ha^{-1} (52.34% of initial) in surface placed residue (Fig 29). At the end of decomposition period in sub surface placed residue the total amount of P released from the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ was about 3.16 kg P ha^{-1}, 1.70 kg P ha^{-1}, 3.48 kg P ha^{-1} and 2.84 kg P ha^{-1} (94.38%, 89.76%, 92.05% and 90.71% of initial) respectively. The release of P and K depends on the nutrient concentration of the organic matter and the C-to-nutrient ratio (Nygaard Sorensen & Thorup-Kristensen 2011). Lupwayi *et al* (2007) found that the percentages of residue P released were positively correlated with P concentration. As the P mineralization starts by

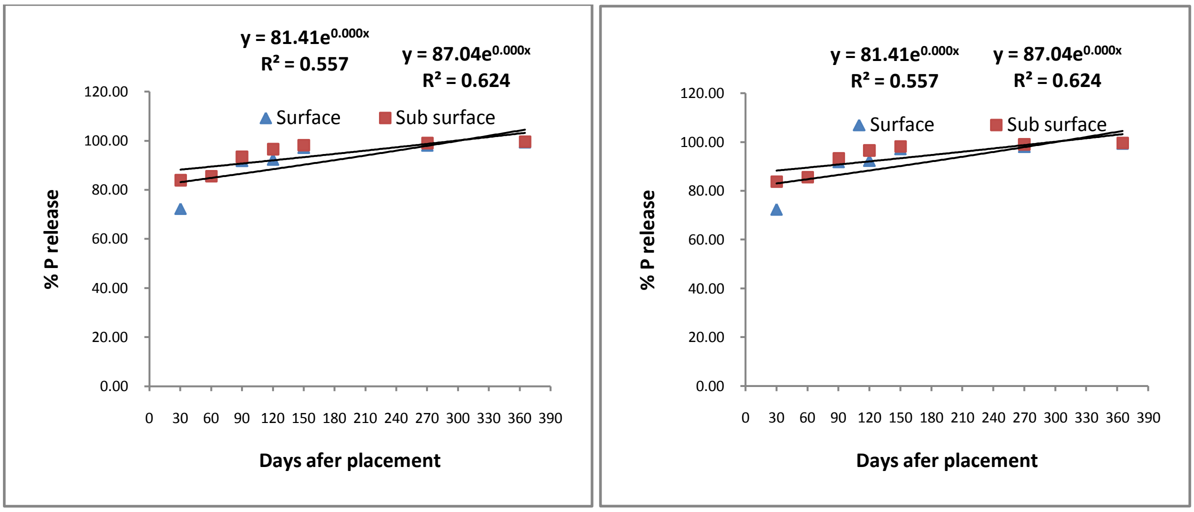


Fig 30&31: Phosphorus release during decomposition of $WT_{75\%}$ and $WT_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

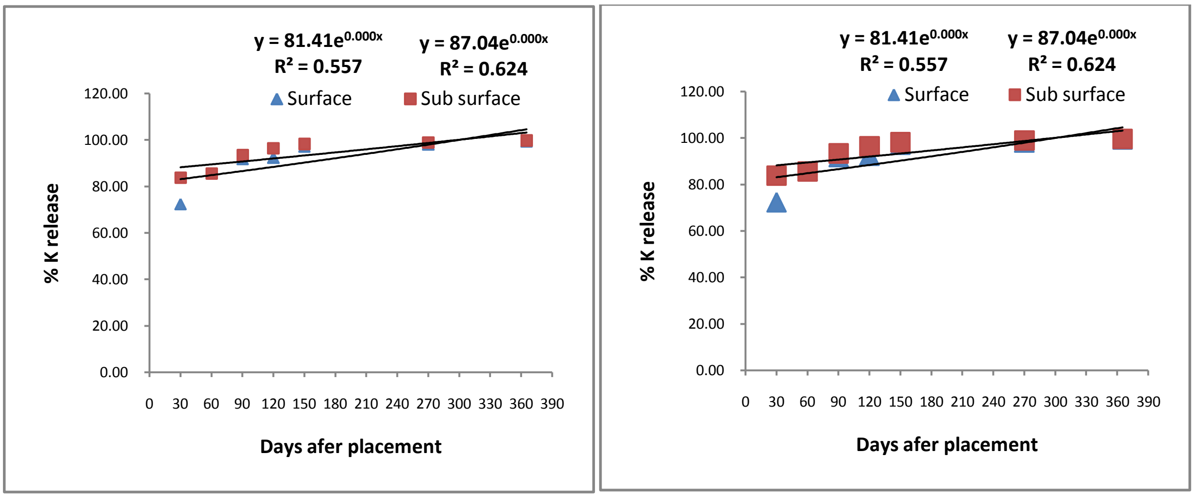


Fig 32&33: Potassium release during decomposition of $WT_{75\%}$ and $WT_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

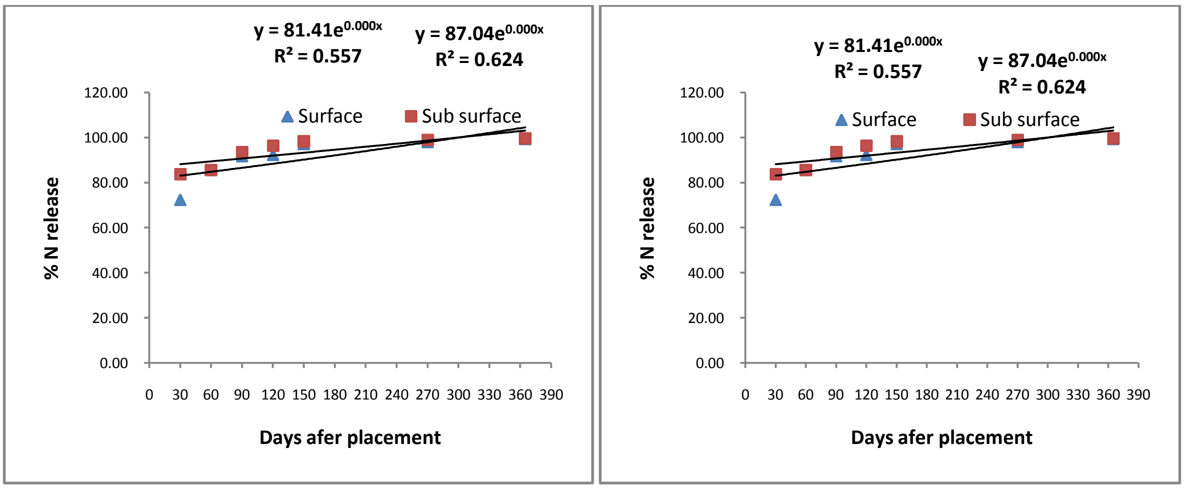


Fig 34&35: Nitrogen release during decomposition of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

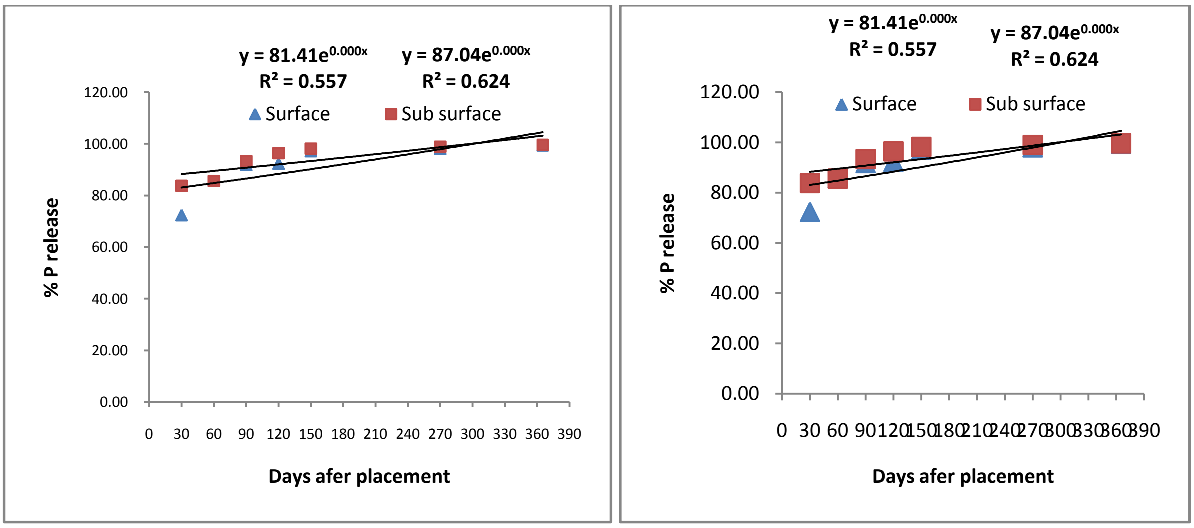


Fig 36&37: Phosphorus release during decomposition of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

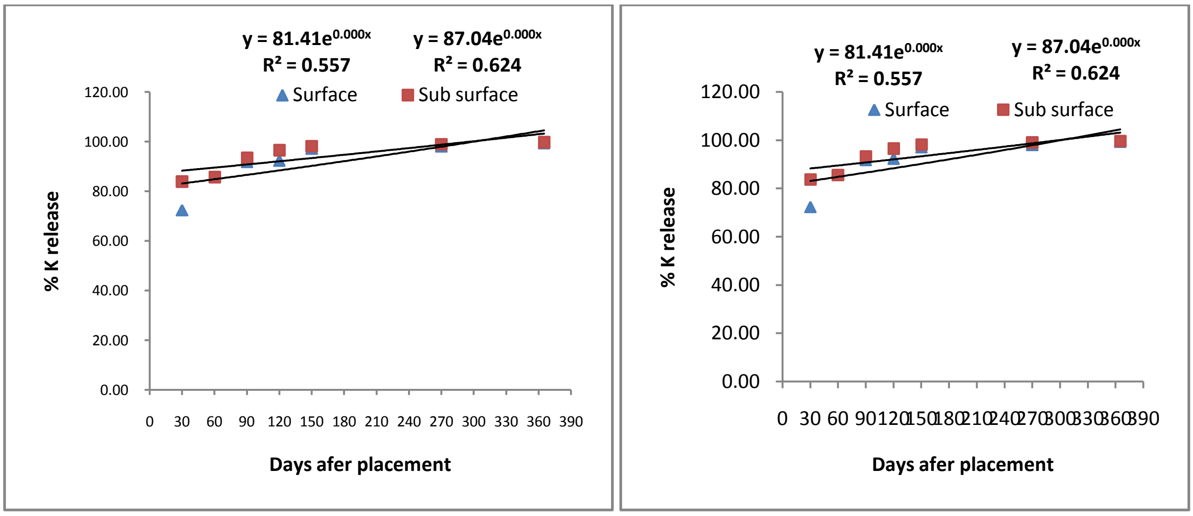


Fig 38&39: Potassium release during decomposition of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

120 DAP of maize residue, so residue P may not significantly contribute to the nutrition of the wheat crop and may incorporated into the soil as a organic P forms. Gupta *et al* (2007) reported that crop residual recycling increased soil P supply to wheat after 4 year in rice–wheat system. Studies by McLaughlin *et al* (1988) however, indicated that crop residue P may not significantly contribute to the nutrition of the subsequent crop over short-term, but becomes incorporated into organic P forms.

The results showed that large percentage of K release from the maize residue occurs by 30 DAP. At initial period of decomposition i.e upto 90 DAP irrespective of type of residue about 65-75% of K was released from surface placed residue and about 80-85% was released from sub surface placed residue. At the end of decomposition period the total amount of K release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 46.22 kg K ha^{-1} (98.78% of initial) and 56.12 kg K ha^{-1} (99.02% of initial) respectively (Fig 25 & 27) similar to the study of Lupwayi *et al* (2006), where 92–99% of the K in green manure and 65–95% of the K in the other residues was released. Similarly in wheat and moongbean residues, rapid K release was observed and most of the K (70-90%) from different residues was released by 30 DAP irrespective of method of placement. In sub surface placed residue after 30 days of placement, $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ release 25.97 kg N ha^{-1}, 32.39 kg N ha^{-1}, 40.98 kg N ha^{-1} and 26.74 kg N ha^{-1} (82.46%, 84.29%, 89.87% and 85.13% of initial K content) respectively (Fig 30,33, 36 & 39). At the end of decomposition cycle i.e by 360 DAP both in surface and sub surface placed residue most (99%) of the K (31-45 kg K ha-1) was released from the different type of residues. Similar trend was reported by (Ventura *et al* 2010) and Tagliavini *et al* (2007) who concluded that high release of litter K occurred from the early stage of litter decomposition, which was attributed to the fact that K was not bound to organic matter. As K is not associated with structural components of plants (Marschner 1995), its release from crop residues will depend less on microbiological decomposition of the residues than N or P release. Thus, the extent and rate of K release from crop residues is usually greater than residue decomposition and N or P release (Lupwayi *et al* 2006). Approximately 93% of the potassium present in plant residues after mechanized harvest becomes bioavailable after 12 months, which largely contributes to improvement of crop productivity (Flores *et al* 2014). Potassium does not remain incorporated in the straw with the carbon chain. Consequently, after senescence or harvest of the plants, this nutrient is quickly released to the soil solution and is readily bioavailable to plants (Prado, 2008).

CHAPTER V

SUMMARY

Extraction of groundwater throughout the years to meet the rich water necessity of flooded rice has brought about serious in ground water level (Sharma et al 2012, Humphreys et al 2010) and likely results into low availability of water for future generation, which results into the socio-economic instability (Jat *et al* 2013). Rice-Wheat system is not only crucial for the nation's sustenance security but rather in the meantime likewise ensure sustainability of natural resources and crop production in dull zones. Therefore, to overcome these issues, replacement of rice with crops requiring less water crops like maize etc. is imperative. (Jat *et al* 2015). Maize has a considerable lower prerequisite of water than rice and along these lines can improve the profitability of the system and sustain health of the soil (Meelu *et al*, 1979). In the later past in view of the falling water table and increasing cost of extraction of water for rice combined with high yielding cultivars of maize, the acreage under maize-wheat system has been increasing day by day in India.

At present, annual crop water requirement for the state is estimated at 4.53 m ha-m, against the current availability of only 3.26 m ha-m, thereby indicating a deficit of about 1.27 m ha-m of water (Minhas *et al* 2010). Substitution of rice with maize in rice-wheat system which require less water and identification of effective and efficient strategies for substitute tillage systems will promote sustainable systems of cropping in the IGP. The modern methods of irrigation such as sprinkler and drip giving better water management practices under water scarcity are highly advocated for water saving in crop production (Pereira *et al* 2002, Zaman *et al* 2001, Zeng *et al* 2009). The efficiency of water use and yield of crops which are drip irrigated can be improved by reducing the water losses below the root zone through leaching under restricted water application (El-Hendawy *et al* 2008). Using drip irrigation method, savings in water usage and yield increases as reported by Tiwari *et al* 2003, Yuan *et al* 2003 and Dhawan 2002. The drip fertigation technology apparently increased the uptake rate of nutrients when compared to surface irrigation (Sampathkumar and Pandian 2011).

Hence, the present study entitled, "Enhancing yield and Nitrogen Use efficiency in maize-wheat system under concervation agriculture" was conducted at BISA Farm, Ladowal, Ludhiana with the following objectives:

(i) To evaluate the effect of residue management, cover crop and rates of N application through fertigation on yield and N use efficiency in maize-wheat system under conservation agriculture.

(ii) To study the effect of different methods of N application, rates of N and straw management on yield and N use efficiency in maize-wheat system under conservation agriculture.

(iii) To determine the effect of methods of placement on decomposition rate and pattern of nutrient release from crop residues and mungbean cover crop.

The soil with sandy loam in texture, medium in organic carbon and low in available nitrogen was used for the experiment. However, available phosphorus and potassium status were medium. The soil pH and electrical conductivity values were within the normal range. The experiment-I was designed in a split plot design with four main treatments and five sub treatments. The main treatments were the combinations from residue management and method of irrigation. i.e. residue removed and residue retained, furrow irrigation and drip irrigation. The sub treatments consist of five levels of N i.e. zero, 50, 75, 100 per cent of recommended N and fifth level of N on the basis of nutrient expert. Each experimental unit was 81 m^2 (4.05 m × 20 m) in gross. Similarly, the experiment-II designed in a split plot design with two main treatments and seven sub treatments with three replications. Two main treatments were the residue management system i.e residue removed and residue retained. The sub treatments were the combination from three levels of nitrogen i.e zero N, 75 and 100 percent of recommended N, and three methods of fertilizer application i.e uniform broadcasting, drilled/placement on top of bed and drilled/placed in furrows. Each experimental unit was 108 m^2 (5.4 m × 20 m) in gross. In experiment-III maize, wheat and moongbean residue used in the experiment was collected from on-going field experiment. The trial was laid out as randomized block design with three replicates of six different type of residues and two methods of placement. The maize residues were placed during the wheat crop cycle after the harvest of maize crop and, wheat and moongbean residues were placed during maize crop cycle after the harvest of wheat and relay moong.

Experiment I: Enhancing nitrogen use efficiency through fertigation in maize-wheat system under conservation agriculture.

Effect of Irrigation and residue management on wheat crop

- Plant height, dry matter accumulation and LAI under different irrigation and residue management treatments differed significantly in the order DIPB+R_{MB} ≥ DIPB+R > DIPB-R> FIPB-R at all growth stages of wheat and maize.
- The yield attributes of wheat and maize were significantly better under the $DIPB_{MB}$+R followed by DIPB+R and the lowest under FIPB-R
- Among the different treatments highest grain yield of wheat and maize was obtained in $DIPB_{MB}$+R was statistically similar with DIPB+R and, statistically higher than the FIPB-R and DIPB-R.

- Similarly among the different treatments highest straw yield of wheat and maize was obtained in $DIPB_{MB}$+R was statistically similar with DIPB+R and, statistically higher than the FIPB-R and DIPB-R.
- The NUE obtained in $DIPB_{MB}$+R was statistically higher than the FIPB-R and DIPB-R, but statistically at par with the DIPB+R in both the crops.
- The WP obtained in $DIPB_{MB}$+R was statistically higher than the FIPB-R and DIPB-R, but statistically at par with the DIPB+R in both the crops.
- Crop residues application and drip irrigation significantly increased the SOC under $DIPB_{MB}$+R and DIPB+R by 6.59% and 5.88%, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment.
- Crop residues application and drip irrigation significantly increased the NH_4^+-N under $DIPB_{MB}$+R and DIPB+R by 10.92 and 10.49 percent, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment
- Significant increase NO_3^--N under $DIPB_{MB}$+R and DIPB+R by 19.46% and 15.76%, respectively over the FIPB-R was observed with the application of crop residues at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment.
- Crop residues application significantly increased the Soil K under $DIPB_{MB}$+R and DIPB+R by 9.24% and 7.27%, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment.

Effect of different N levels

- Plant height, dry matter accumulation and LAI of wheat and maize under different N levels were significantly better under NE than other nitrogen levels. However, the nitrogen level of $RN_{100\%}$ was found to be statistically at par with NE at panicle initiation stage.
- Yield attributes of maize and wheat were significantly better under the nitrogen level of NE than control nitrogen level of $RN_{50\%}$ and nitrogen level of $RN_{75\%}$ but statistically at par with nitrogen level of $RN_{100\%.}$.
- The nitrogen level of NE had significantly higher grain and straw yield of maize and wheat than control, nitrogen level of $RN_{50\%}$ and nitrogen level of $RN_{75\%}$ but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}.
- Fertigation with nitrogen level of $RN_{75\%}$ produced similar yield with nitrogen level $RN_{100\%}$ and thereby saving the 25% of nitrogen fertilizer.
- In grain and straw significantly higher N content was observed in NE than control and $RN_{50\%}$ treatments and was statistically at par with nitrogen level of $RN_{100\%}$ which was statistically at par with nitrogen level of $RN_{75\%}$ during both the years.

- Nitrogen uptake in grain and straw of maize and wheat was also found significantly higher with NE as compared to control and $RN_{50\%}$ during both the years, respectively.
- Significantly higher NUE was obtained with the N level of $RN_{50\%}$ as compared to all other N level.
- The nitrogen level of NE had significantly higher WP than control, nitrogen level of $RN_{50\%}$ and nitrogen level of $RN_{75\%}$ but statistically at par with nitrogen level of $RN_{100\%}$.
- Among the soil properties the NH_4^+-N and NO_3^-N under different soil depths increased significantly and consistently with increase in the N level up to 140 kg N ha^{-1}.

Experiment II: Evaluation of different rates and methods of nitrogen application and straw management for enhancing nitrogen use efficiency in maize-wheat system under conservation agriculture.

Effect of residue management

- Plant height, dry matter accumulation and LAI under different residue management treatments differed significantly in the order FIPB+R > FIPB-R at all growth stages of wheat and maize.
- The yield attributes of wheat and maize were significantly better under the residue retained i.e FIPB+R plots as compared to the residue removed plots i.e. FIPB-R
- Among the residue removed and residue retained plots, significantly higher grain yield of wheat and maize was obtained under the residue retained plots i.e. FIPB+R as compared to residue removed plots i.e. FIPB-R.
- Similarly, among the residue removed and residue retained plots, significantly higher straw yield of wheat and maize was obtained under the residue retained plots i.e. FIPB+R as compared to residue removed plots i.e. FIPB-R.
- The NUE obtained in FIPB+R was statistically higher than the FIPB-R
- Crop residues application significantly increased the SOC under FIPB+R by 3.88%, respectively over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment.
- Crop residues application significantly increased the NH_4^+-N and NO_3^-N under FIPB+R over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment.
- Crop residues application significantly increased the Soil K content under FIPB+R by 8.87% over the FIPB-R at the 0-7.5 cm soil depth after the harvest of maize crop at the end of the experiment.

Effect of different N levels and Method of application

- Among the different N levels the application of N at the rate of $RN_{100\%}$, irrespective of the method of application results into significantly higher plant height, dry matter accumulation and LAI as compared $RN_{75\%}$ and control at all growth stages.
- Plant height, dry matter accumulation and LAI are significantly better under the top placement of fertilizer as compared to broadcasting and furrow placement
- Yield and yield attributes of maize and wheat significantly better under the $RN_{100\%}$-D/POT as compared to all other treatments.
- Among the different N levels and application methods $RN_{100\%}$-D/POT results into significantly higher grain and straw yield of wheat and maize as compared to the control and all other treatments during both years respectively.
- No significant difference was observed between the grain yield of maize and wheat under $RN_{75\%}$ -DOT and $RN_{100\%}$ -B, during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application.
- Higher nitrogen uptake at different growth stages of wheat and maize was observed under the top placement of fertilizer both for the $RN_{75\%}$ and $RN_{100\%}$ as compared to the broadcasted.
- Among the different N levels and application methods $RN_{75\%}$ -D/POT results into significantly higher NUE as compared to all other treatments.

Experiment III: Decomposition rate and nutrient dynamics of crop residue as affected by depth of placement.

Throughout the decomposition cycle, the per cent decrease in weight was significantly higher from the sub-surface placed residue as compared to surface placed residue. In case of maize residue surface placed residue, the 50 per cent of the initial weight lost after the 150 DAP, whereas in sub-surface placed residue the 50 per cent of the initial weight lost after the 90 DAP. At the end of the decomposition cycle (365 DAP), the per cent weight remaining was of the order 8.31 and 3.14 per cent of surface placed and sub-surface placed respectively. However in case of wheat and moong bean residue sub-surface placed residue lost 74.63 per cent of initial weight after the 150 DAP, where as surface placed residue lost about 82.99 per cent of initial mass. At the end of decomposition period the total amount of N release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 21.6 kg N ha^{-1} (91.76% of initial) and 31.66 kg N ha^{-1} (93.12% of initial) respectively. The amount of N released followed the order $MB_{100\%}$ > $WL_{25\%}$+ $MB_{100\%}$ > $WT_{75\%}$ >$WL_{25\%}$ through out the decomposition period, which is mainly due the high initial N concentration of the $MB_{100\%}$. During the initial period of decomposition (by 90 DAP), P was immobilized against net mineralization. At the end of decomposition period the total amount of P release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 1.62 kg P ha^{-1} (82.77% of initial) and 2.91 kg P ha^{-1} (93.40% of initial) respectively. Following 60 DAP about 30-50 per cent of initial P was released from different wheat and moongbean residues irrespective of method of placement. Nitrogen, P and K release was lower from surface placed residue than the sub surface placed residue throught out the decomposition period. At initial period of decomposition i.e upto 90 DAP irrespective of type of residue about 65-75 per cent of K was released from surface placed residue and about 80-85 per cent was released from sub surface placed residue. At the end of decomposition period the total amount of K release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 46.22 kg K ha^{-1} (98.78% of initial) and 56.12 kg K ha^{-1} (99.02% of initial) respectively same as the study of Lupwayi *et al* (2006), where K in green manure (92–99%) and K in the other residues (65–95% of the) was released.

CONCLUSION

Productivity of maize-wheat system was amply influenced by the adoption of drip irrigation along with residue retention under conservation agriculture. Grain yield of wheat and maize was significantly higher under $DIPB_{MB}$+R as compared to DIPB-R which in turn was significantly better than FIPB-R during both the years. In maize the per cent increase in grain yield was 27.05 and 23.40 under $DIPB_{MB}$+R, and 22.13 and 19.80 per cent under DIPB+R over that of FIPB-R during the year 2014 and 2015, respectively. However in wheat there is a approximately 16.09 and 15.22 per cent increase in yield with drip irrigation along with residue retention as compared to furrow irrigation without residue retention in both the years, respectively. The highest system productivity was recorded under $DIPB_{MB}$+R (12.40 and 12.32 Mg ha^{-1}) followed by DIPB+R (9.73 and 9.60 Mg ha^{-1}) over FIPB-R and DIPB-R in both the year of experimentation. Fertigation with nitrogen level of $RN_{75\%}$ produced similar yield with the nitrogen level $RN_{100\%}$ and thereby saving the 25 per cent of the nitrogen fertilizer. The NUE and WP obtained in $DIPB_{MB}$+R was statistically higher than the FIPB-R and DIPB-R, but statistically at par with the DIPB+R in both the crops. Among the residue removed and residue retained plots, significantly higher grain yield of wheat and maize was obtained under the residue retained plots i.e. FIPB+R as compared to residue removed plots i.e. FIPB-R. No significant difference was observed between the grain yield of maize and wheat under $RN_{75\%}$-DOT and $RN_{100\%}$-B, during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application. Throughout the decomposition cycle, the percent decrease in weight was significantly higher from the surface placed residue as compared to subsurface placed residue. Nitrogen, P and K release was lower from surface placed residue than the sub surface placed residue throught out the decomposition period. The study reveals that maize-wheat-moongbean system is more beneficial to the farmers along with drip irrigation and residue retention; however, the effects of these alternative technologies on long-term basis need to be studied under different agro-ecologies.

REFERENCES

Abbasi M K, Tahir M M, Sabir N and Khurshid M (2015) Impact of the addition of different plant residues on nitrogen mineralization–immobilization turnover and carbon content of a soil incubated under laboratory conditions. *Solid Earth* **6:** 197-205.

Abdelraouf R E, S F El Habbasha, M H Taha and K M Refaie (2013) Effect of Irrigation Water Requirements and Fertigation Levels on Growth, Yield and Water Use Efficiency in Wheat. *Middle-East J Sci Res* **16**: 441-50.

Abdullah and Pawar (2013) Production and economics of wheat (*Triticum aestivum* L.) under drip Fertigation. *Int J Sci Res* **4(5):** 1907-09.

Abera G, Wolde-meskel E and Bakken L R (2012) Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents. *Biol Fertil Soils* **48:** 51–66.

Akbar G, Hamilton G, Hussain Z, Yasin M (2007) Problems and potentials ofpermanent raised bed cropping systems in Pakistan. Pak. J. Water Res. 11:11–21.

Almaraz J J, Zhou X, Mabood F, Madramootoo C, Rochette P, Ma B L and Smith D L (2009) Greenhouse gas fluxes associated with soybean production under two tillage systems in south-western Quebec. *Soil Tillage Res* **104**: 134-39.

Alvarez R (2005) A review of nitrogen fertilization and conservation tillage effects on soil C storage. *Soil Use Manage* **21:** 38–52.

Angers D A and Caron J (1998) Plant-induced changes in soil structure: Processes and feedbacks. *Biogeochem* **42:** 55-72.

Anikwe M A N and Ubochi J N (2007) Short-term changes in soil properties under tillage systems and their effect on sweet potato (*Ipomea batatas L*) growth and yield in an Ultisol in South-Eastern Nigeria. *Aust J Soil Res* **45:** 351-58.

Anonymous (2001) Conservation Agriculture in Europe. http.//www.ecaf.org.uk.

Anonymous (2013) *Package of Practices for Crops of Punjab (kharif)*. p 19. Punjab Agricultural University, Ludhiana

Aquino P (1998) The adoption of bed planting of wheat in the Yaqui Valley, Sonora, Mexico. *17a. Mexico DF, CIMMYT.*

Astier M, Maass J M, Etchevers-Barra J D, Pena J J and Gonzalez F D (2006) Short term green manure and tillage management effects on maize yield and soil quality in an Andisol. *Soil Tillage Res* **88:** 153–59.

Aulakh M S and Grant C A (2008) *Integrated Nutrient Management for Sustainable Crop Production*. The Haworth Press, Taylor & Francis Group, New York, pp. 619.

Bakht J, Shafi M, Jan M T and Shah Z (2009) Influence of crop residue management, cropping system and N fertilizer on soil N and C dynamics and sustainable wheat (*Triticum aestivum* L.) production. *Soil Tillage Res* **104**: 233-40.

Baldi E and Toselli, M (2014) Mineralization dynamics of different commercial organic fertilizers from agro-industry organic waste recycling: an incubation experiment. *Plant Soil Environ* **60:** 93–99.

Baldock J A (2007) Composition and cycling of organic carbon in soil. *Soil Bio Biochem* **10: 39-46**.

Bar-Yosef B (1999) Advances in fertigation. *Adv Agron* **65:**2-77.

Beare M H, Wilson P E, Fraser P M, Butler R C (2002) Management effects of barley residue decomposition, nitrogen release, and crop production. *Soil Sci Soc Am J* **66:** 848-56.

Behera U K and Pradhan S (2007) Prformance of very late-sown bread wheat cultivars as influenced by different levels of nitrogen in vertisols of central India. *Ann Agric Res New Series* **28** : 127-31.

Behera U K, Sharma A R and Pandy H N (2007) Sustaining productivity of wheat–soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant Soil* **297**: 185-99.

Bell M C and Raczkowski C W (2008) Soil property indices for assessing short-term changes in soil quality. *Renew Agric Food Sys* **23:**70-79.

Benjamin J G, Porter L K, Duke H R, Ahuja L R and Butters G (1998) Nitrogen movement with furrow irrigation method and fertilizer band placement. *Soil Sci Soc Am J* **62:** 1103-08.

Berg B and McClaugherty C (2003) *'Plant litter: Decomposition, humus formation, carbon Sequestration.'* Springer: Berlin, Gemany.

Berg B, Davey M, De Marco A, Emmett B, Faituri M, Hobbie S, Johansson MB, Liu C, McClaugherty C, Norell L, Rutigliano F, Vesterdal L and De Virzo Santo A (2010) Factors influencing limit values for pine needle litter decomposition: a synthesis for boreal and temperate pine forest systems. *Biogeochem* **100:** 57-73.

Bhandari A L, Ladha J K, Pathak H, Padre A T, Dawe, D and Gupta R K. (2002) Yield and soil nutrient changes in a long-term rice–wheat rotation in India. *Soil Sci Soc Am J* **66:** 162-70.

Bhattacharyya R , Kundu S , Pandey S C , Singh K P and Gupta H S (2008) Tillage and irrigation effects on crop yields and soil properties under rice–wheat system of the Indian Himalayas. *Agricu Water Manage* **95:** 993-1002.

Bhattacharyya R, Das T K, Pramanik P, Ganeshan V, Saad A A and Sharma A R (2013) Impacts of conservation agriculture on soil aggregation and aggregate-associated N under an irrigated agroecosystem of the Indo-Gangetic Plains. *Nutr Cycl Agroecosyst* **96:**185–202.

Biamah E K, Rockstrom J and Okwack G (2000) Conservation tillage for dryland farming: Technological options and experiences in Eastern and Southern Africa. *Regional Land Management Unit, RELMA/Sida, ICRAF, House, Gigiri, Nairobi, Kenya.*

Bijay-Singh, Shan Y H, Johnson-Beebout S E, Yadvinder-Singh, Buresh R J, Donald L S (2008) Crop residue management for lowland rice-based cropping systems in Asia. *Adv Agron Academic Press, pp*. 117–199.

Biswas, M.R. (1984) Agricultural production and environment: a review. *Environ Conse* **11:** 253**-**59.

Blanco-Canqui H and Lal, R (2008) No-tillage and soil-profile carbon sequestration: An on-farm assessment. *Soil Sci Soc Am J* **72**: 693**-**701.

Bozkurt S, Yazar A and Mansuroglu G S (2011) Effects of different drip irrigation levels on yield and some agronomic characteristics of raised bed planted corn. *Afric J Agric Res* **6:** 5291-5300.

Bronick C J and Lal R (2005) Soil structure and management: a review. *Geoderma* **124:** 3–22.

Burgess M S, Mehuys G R and Madramootoo C A (2002) Nitrogen dynamics of decomposing corn residue components under three tillage systems. *Soil Sci Soc Am J* **66:** 1350-58.

Busari M A, Kukal S S, Kaur A, Bhatt R and Dulazi AA (2015) Conservation tillage impacts on soil, crop and the environment. *Int Soil Water Conser Res* **3:** 119-29.

Busari M A, Salako F K, Tuniz C, Zuppi G M, Stenni B, Adetunji M T and Arowolo T A (2013) Estimation of soil water evaporative loss after tillage operation using the stable isotope technique. *Int Agrophys* **27:** 257**-**64.

Campbell C A, Zentner R P (1993) Soil organic matter as influenced by crop rotations and fertilization. *Soil Sci Soc Am J* **57:** 1034-40.

Campos A C, Etchevers J B, Oleschko K L and Hidalgo C M (2013) Soil microbial biomass and nitrogen mineralization rates along an altitudinal gradient on the cofre de perote volcano (Mexico): the importance of landscape position and land use. *Land Degrad Dev* **25:** 581-93.

Carsky R J (1989) *Estimating availability of nitrogen from green manure to subsequent maize crop by using buried bag technique.* Ph.D thesis, Cornell University, Ithaca, NY-USA.

Carter M R (1990) Relative measures of soil bulk-density to characterize compaction in tillage studies on fine sandy loams. *Can J Soil Sci* **70:** 425-33.

Carter M R and Mele P M (1992) Changes in microbial biomass and structural stability at the surface of a duplex soil under direct drilling and stubble retention in north-eastern Victoria. *Aust j Soil Res* **30:** 493-503.

Cayuela, M L, Sinicco T and Mondini V (2009) Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil. *Appl Soil Ecol* **48:** 118-27.

Chauhan B S, Mahajan G, Sardana V, Timsina J and Jat M L (2012) Productivity and Sustainability of the Rice–Wheat Cropping System in the Indo-Gangetic Plains of the Indian subcontinent: Problems, Opportunities, and Strategies. *Adv Agron* **117:** 315-69.

Chen Z, Wang H, Liu X, Liu Y, Goa S and Zhou J (2016) The Effect of N Fertilizer Placement on the Fate of Urea-15N and Yield of Winter Wheat in Southeast China. *Plos One* **11(4):** 1-13.

Christensen B T (1986) Barley residue decomposition under field conditions: Effect of placement and initial nitrogen content on weight loss and nitrogen dynamics. *Soil Biol Biochem* **18:** 523-29.

Clement A, Ladha J K and Chalifour F P (1995) Crop residue effects on nitrogen mineralization, microbial biomass, and rice yield in submerged soils. *Soil Sci Soc Am J* **59:**1595-03.

Connor D J, Timsina J and Humphreys E (2003) Prospects for permanent beds forthe rice–wheat system. In: Improving the Productivity and Sustainability of Rice–Wheat Systems: Issue and Impact. ASA Special Publication 65, WI, USA, pp. 197–210.

Conservation Tillage Information Center (CTIC) M R (2004) National crop residue management survey. *West Lafayette, IN: Conservation Technology Information Center.*

Cookson W R, Beare M H and Wilson P E (1998) Effects of prior crop residue management on microbial properties and crop residue decomposition. *Appl Soil Ecol* **7:**179-88.

Cornwell W K, Cornelissen J H C, Amatangelo K, Dorrepaal E, Eviner VT, Godoy O, Hobbie S E, Hoorens B, Kurokawa H, Pe´rez-Harguindeguy N, Quested H M, Santiago L S, Wardle D A, Wright I J, Aerts R, Allison S D, Van Bodegom P, Brovkin V, Chatain A, Callaghan T V, Dı´az S, Garnier E, Gurvich D E, Kazakou E, Klein J A, Read J, Reich P B, Soudzilovskaia N A, Vaieretti M V and Westoby M (2008) Plant species traits are the predominant control on litter decomposition rates within biomes worldwide. *Ecol Lett* **11:** 1065-71

Corsi S, Friedrich T, Kassam A, Pisante M and de Moraes Sà J C (2012) Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: A literature review. *Integrated Crop Manage* **16:** 101-15.

Curtin D, Selles F, Wang H, Campbell C A and Biederbeck V O (1998) Carbon dioxide emissions an transformation of soil carbon and nitrogen during wheat straw decomposition *Soil Sci Soc Am J* **62:** 1035-41.

Das T K, Bhattacharyya R, Sudhishri S, Sharma A R, Saharawat Y S, Bandyopadhyay K K, Sepat S, Bana R S, Aggarwal P, Sharma R K, Bhatia A, Singh G, Datta S P, Kar A, Singh B, Singh P, Pathak H, Vyas A K and Jat M L (2014) Conservation agriculture in an irrigated cotton–wheat system of the western Indo-Gangetic Plains: Crop and water productivity and economic profitability. *Field Crops Res* **158:** 24–33.

De Vita, P, Di Paolo E, Fecondo G, Di Fonzo N and Pisante M (2007) No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in Southern Italy. *Soil Tillage Res* **92**: 69-78.

Denef K, Six J, Merckx R and Paustian K (2002) Short-term effects of biological and physical forces on aggregate formation in soils with different clay mineralogy. *Plant Soil* **246:** 185-200.

Dhadli H S, Singh G, Yadvinder-Singh and Singh S (2009) Evaluation of different crops on permanent raised beds on Vertic Usto Chrepts in Punjab, India. *In: Abstracts of 4th World Congress on Conservation Agriculture held from February 4–7, 2009 at New Delhi India*, pp. 111.

Dhawan B D (2002) Technological Change in Indian Irrigated Agriculture: A Study of Water Saving Methods. Commonwealth Publishers, New Delhi.

Dhillon B S, Thind H S, Malhi N S, Sharma R K (1998) Effect of excess water stress on grain yield and other traits of maize hybrids. *Crop Improv* **25:** 209-14.

Dick P P (1992) A review: long-term effects of agricultural systems on soil biochemical and microbial parameters. *Agric Ecosyst Env* **40:** 25-36.

Dinnes D L, Karlen D L, Jaynes D B, Kaspar T C, Hatfield J L, Colvin T S and Cambardella C A (2002) Nitrogen management strategies to reduce nitrate leaching in tile-drainded midwestern soil. *Agron J* **94**: 153-71.

Doran J W (1980) Soil microbial and biochemical changes associated with reduced tillage. *Soil Sci Soc America J* **44:** 765-71.

Doran J W and Smith M S (1987) Organic matter management and utilization of soil and fertilizer nutrients. In: Follett *et al*. (ed), *Soil Fertility and Organic Matter as Critical Components of Production Systems*. Pp. 53-72. SSSA Spec. Pub. 9. SSSA, Madison, WI.

Douglas C L J and Rickman R W (1992) Estimating crop residue decomposition from air temperature, initial nitrogen content, and residue placement. *Soil Sci Soc Am J* **56**: 272-78.

Drinkwater L E, Wagoner, P and Sarrantonio, M (1998) Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* **396**: 262–65.

Du Preez C C, Steyn J T and Kotze E (2001) Long-term effects of wheat residue management on some fertility indicators of a semi-arid Plinthosol. *Soil Tillage Res* **63:** 25–33.

Dubeux J C B, Sollenberger L E, Interrante S M, Vendramini J M B and Stewart R L (2006) Litter decomposition and mineralization in Bahia grass pastures managed at different intensities. *Crop Sci* **46:** 1305-10.

Duiker S W and Beegle D B (2006) Soil fertility distributions in long-term no-till, chisel/disk and moldboard plow/disk systems. *Soil Tillage Res* **88:** 30–41.

El-Hendawy S E, El-Lattief E A, Ahmed A S and Schmidhalter U (2008) Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. *Agric Water Manage* **95:** 836-44.

Erenstein O and Laxmi V (2008) Zero tillage impacts in India's rice-wheat systems: a review. *Soil Till. Res* **100:** 1-14.

Etana A, Hakansson I, Zagal E and Bucas S (1999) Effects of tillage depth on organic carbon content and physical properties in five Swedish soils. *Soil Tillage Res* **52:** 129–39.

Fabrizzi K P, Garcia F O, Costab J L and Picone L I (2005) Soil water dynamics, physical properties and corn and wheat responses to reduced and no-tillage systems in the southern Pampas of Argentina. *Soil Till Res* **81:** 57-69.

Fanong W, Xuqing W and Sayre K (2004) Comparison of conventional, flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. *Field Crops Res* **87:** 35–42

Fekadu Y and Teshome T (1998) Effect of drip and furrow irrigation and plant spacing on yield of tomato at Dire Dawa, Ethiopia. *Agric Water Manage* **35:** 201–07.

Fischer R A, Santiveri F and Vidal I R (2002) Crop rotation, tillage and crop residue management for wheat and maize in the sub-humid tropical highlands: Maize and system performance. *Field Crops Res* **79:** 123-37.

Flores R A, Mello Prado R, Pancelli M A, Almeida H J, Moda L R, Borges M N, Melo B and Souza Junior J P (2014) Potassium nutrition in the first and second ratoon sugarcane grown in an oxisol by a conservationist system. *Chilean J Agr Res* **74:** 83-88.

Fluegel S M and Johnson J B (2001) The effect of soil nitrogen levels and wheat resistance on the Russian wheat aphid, *Diuraphis noxia* (*Homoptera: Aphididae*). *J Kans Entomol Soc* **74** : 49-55.

Food and Agriculture Organization of United Nations (2005) The importnce of soil organic matter, key to drought-resistance soil and sustained food and production. FAO Soils Bulletin 80.

Food and Agriculture Organization of United Nations (2010) Green manure/cover crops and crop rotation in Conservation Agriculture on small farms. *Integrated Crop Management* **12**: 9.

Foresight (2011) The future of food and farming. *Published by Government Office for Science.*

Fowler R and Rockstrom J (2001) Conservation tillage for sustainable agriculture: An agrarian revolution gathers momentum in Africa. *Soil Tillage Res* **61:** 93-107.

Franzluebbers A J and Hons F M (1996) Soil profile distribution of primary and secondary plant available nutrients under conventional and no tillage. *Soil Tillage Res* **39:** 229–39.

Frederick J R, P J Bauer and W. J. Busscher (2001) Grain yield and yield components of double cropped winter wheat as affected by wheat and previous soybean production practices *Crop Sci* **41**:778-84.

Frey S D, Elliot E T, Paustian K and Peterson G A (2000) Fungal translocation as a mechanism for soil nitrogen inputs to surface residue decomposition in a no-till ecosystem. *Soil Biol Biochem* **32:** 689-98.

Friedrich T and Kassam A H (2009) Adoption of Conservation Agriculture technologies: constraints and opportunities. *Invited paper 4th World Congress on Conservation Agriculture, 4–7 February. New Delhi: ICAR.*

Gal A Vyn T J, Micheli E, Kladivko E J and McFee W W (2007) Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled zone sampling depths. *Soil Tillage Res* **96:** 42–51.

Galantini J A, Landriscini M R, Iglesias J O, Miglierina A M and Rosell R A (2000) The effects of crop rotation and fertilization on wheat productivity in the Pampean semiarid region of Argentina. *Soil Tillage Res* **53:** 137–44.

Gastal F and Lemaire G (2002) Nitrogen uptake and distribution in crops: an agronomical and ecophysiological perspective. *J Exp Bot* **53:** 789-99

Gathala M K, Ladha J K, Saharawat Y S, Kumar V, Kumar V and Sharma P K (2011) Effect of tillage and crop establishment methods on physical properties of a medium-textured soil under a seven-year rice–wheat rotation. *Soil Sci Soc Am J* **75:** 1 851-62.

Ghidey F and Alberts E E (1993) Residue type and placement effects on decomposition: field study and model evaluation. *Trans ASAE* **36:**1611-17.

Ghosh P K and Sharma K C (1996) Direct and residual effect of green manuring on rice-wheat rotation. *Crop research* **211:** 133-36. IRRI. *Annual report* for 1991. Manila, Philippines.

Ghosh P K and Singh N P (1996) Production potential of summer legumes-maize (*Zea mays* L.) sequence under varying levels of nitrogen. *Indian J Agron* **41**: 525-28.

Ghuman B S and Sur H S (2001) Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate. *Soil Tillage Res* **58**: 1-10

Gill M A (1999) Promotion of Resource Conservation Tillage Technologies in South Asia - *An Overview of Rice-Wheat Consortium Activities in the Indo-Gangetic Plains* (Directorate General Agriculture – Water Management, Lahore, Pakistan).

Girma A, Wolde-meskelb E and Bakkena L R (2012) Effect of organic residue amendments and soil moisture on N mineralization, maize (Zea mays L.) dry biomass and nutrient concentration. Archives Agron Soil Sci **59**: 1263-277.

Gomez K A and A A Gomez (1984) Statistical Procedures for Agriculture Research. 2nd Ed. John Wiley and Sons. New York.

Govaerts B, Sayre K D and Deckers J (2005) Stable high yields with zero tillage and permanent bed planting. *Field Crops Res* **94:** 33-42

Govaerts B, Sayre K D, Ceballos-Ramirez J M, Luna- Guido M L, Limon-Ortega A, Deckers J and Dendooven L (2006) Conventionally tilled and permanent raised beds with different crop residue management: effects on soil C and N dynamics. *Plant Soil* **280:**143-55

Govaerts B, Sayre K D, Goudeseune B, De Corte P, Lichter K, Dendooven L and Deckers J (2008) Conservation agriculture as a sustainable option for the central Mexican highlands. *Soil Tillage Res* **103:** 222–30.

Govaerts B, Sayre K D, Litcher K, Dendooven L and Deckers J (2007) Influence of permanent raised bed planting and residue management on physical and chemical soil quality in rain fed maize/wheat systems. *Plant Soil* **291:**39-55.

Govaerts, B., Sayre, K.D., Goudeseune, B., De Corte, P., Lichter, K., Dendooven, L. and Deckers, J. 2009. Conservation agriculture as a sustainable option for the central Mexican highlands. *Soil Tillage Res* **103**, 222-230.

Griffin T, Liebman M and Jemisoon J (2000) Cover crops for sweet corn production in a short-season environment. *Agron J* **92:**144-51.

Gupta R K and Sayre K (2007) Conservation Agriculture in South Asia. *J Agri Sci Cambridge* **145:** 207-14.

Gupta R K, Jat M L and Sharma S K (2005). Resource conserving technologies for water savings and enhancing productivity. *In Proceedings of the National Symposium on Efficient Water Management for Eco-friendly Sustainable and Profitable Agriculture.* pp. 181-82, New Delhi.

Gupta R, Kienzler K, Martius C, Mirzabaev A, Oweis T, de Pauw E, Qadir M, Shideed K, Sommer R, Thomas R, Sayre K, Carli C, Saparov A, Bekenov M, Sanginov S, Nepesov M and Ikramov R (2009) Research Prospectus: A Vision for Sustainable Land Management Research in Central Asia. ICARDA Central Asia and Caucasus Program. *Sustainable Agriculture in Central Asia and the Caucasus Series No.1*. CGIAR-PFU, Tashkent, Uzbekistan.

Gupta, M., Bali, A.S., Sharma, S. and Dixit, A.K. 2007a. Potential role and influence of zero tillage technology on energy saving in rice (*Oryze sativa*)–wheat (*Triticum aestivum*) system. *Indian J Agric Sci* **77**(10): 657-59.

Gursoy S, Sessiz A and Malhi S S (2010) Short-term effects of tillage and residue management following cotton on grain yield and quality of wheat. *Field Crops Res* **119:** 260-68.

Gusewell S and Gessner M O (2009) N: P ratios influence litter decomposition and colonization by fungi and bacteria in microcosms. *Funct Ecol* **23:** 211-19.

Gwenzi W, Gotosa J, Chakanetsa S and Mutema Z (2009) Effects of tillage systems on soil organic carbon dynamics, structural stability and crop yields in irrigated wheat (*Triticum aestivum* L.)-cotton (*Gosspium hirsutum* L.) rotation in semi-arid Zimbabwe. *Nutr Cycl Agroecosyst* **83:** 211-21.

Habtegebrial K, Singh BR and Haile M (2007) Impact of tillage and nitrogen fertilization on yield, nitrogen use efficiency of tef (Eragrostis tef (Zucc.) Trotter) and soil properties. *Soil Tillage Res* **94:** 55-63

Hadas A, Kautsky L, Goek M and Kara E E (2004) Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover. *Soil Biol Biochem* **36:** 255-66.

Hamadi Z, Steinberger Y, Kutiel P, Lavee H and Barness G (2000) Decomposition of Avena sterilis litter under arid conditions. *J Arid Environ* **46:** 281-93.

Hanson B R, Schwankl L J, Schulbach K Fand Pettygrove G S (1997) A comparison of furrow, surface drip and subsurface drip irrigation on lettuce yield and applied water. *Agric Water Manage* **33:** 139–57.

Hargrove W L (1990) Role of conservation tillage in sustainable agriculture. In: Mueller J P and Wagger M G (Eds) Proceedings of the 1990 Southern Region Conservation Tillage Conference, North Carolina State University Special Bulletin 90-1. North Carolina State University, Raleigh, North Carolina, pp. 28–32.

Harris B L and Krishna J H (1989) Furrow diking to conserve moisture. *J Soil Water Cons* **44:** 271–73

Hartmann T E, Yue S, Schulz R, He X, Chen X, Zhang F, et al (2015) Yield and N use efficiency of a maize–wheat cropping system as affected by different fertilizer management strategies in a farmer's field of the North China Plain. *Field Crop Res* **174:** 30–39.

Hassan I, Hussain Z and Akbar G (2005) Effect of permanent raised beds on water productivity for irrigated maize–wheat cropping system. In: Roth C H et al (Eds.) *Evaluation and Performance of Permanent Raised Bed Cropping Systems in Asia, Australia and Mexico.* ACIAR Proceedings, vol. 121. ACIAR, Griffith, Australia, pp. 59–65.

Hassan I, Hussain Z and Akbar G (2005) Effect of permanent raised beds on water productivity for irrigated maize–wheat cropping system. In: Roth C H, Fischer R A and Meisner C A (Eds.) *Evaluation and performance of permanent raised bed cropping systems in Asia, Australia and Mexico.* ACIAR Proceeding No. 121

Hassanli A M, Ebrahimizadeh M A and Beecham S (2009) The effects of irrigation methods with effluent and irrigation scheduling on water use efficiency and corn yields in an arid region. *Agric Water Manage* **96:** 93-99.

Heal O W, Anderson J M and Swift M J (1997) Plant residue quality and decomposition: An historical overview. In: Cadisch G and Giller K E (Eds.) *Driven by nature: plant Residue Quality and Decomposition.* CAB Int, Cambridge, pp 3–30.

Hiloidhari M, Das D and Baruah, D C (2014) Bioenergy potential from crop residue biomass in India. *Renewable Sustainable Energy Reviews* **32**: 504–12.

Hira G S, Jalota S K and Arora V K (2004) *Efficient Management of Water Resources for Sustainable Cropping in Punjab*. Research Bulletin. Department of Soils, Punjab Agricultural University, Ludhiana, 20 pp.

Hirel B, Le Gouis J, Ney B and Gallais A (2007) The challenge of improving nitrogen use efficiency in crop plants: Towards a more central role for genetic variability and quantitative genetics within integrated approaches. *J Exp Bot* **58:** 2369–87

Hobbie S E, Eddy W C, Buyarski C R, Adair E C, Ogdahl M L and Weisenhorn P (2012) Response of decomposing litter and its microbial community to multiple forms of nitrogen enrichment. *Ecol Monogr* **82:** 389-405

Hoflich G, Tauschke M, Kuhn G, Werner K, Frielinghaus M and Hohn W (1999) Influence of long-term conservation tillage on soil and rhizosphere organisms. *Biol Fert Soils* **29:** 81–86.

Honeycutt C W and Potaro L J (1990) Field evaluation of heat units for predicting crop residue carbon and nitrogen mineralization. *Plant Soil* **125:** 213–20.

Hossain, M A and Maniruzzaman A.F.M (1992) Response of rainfed wheat (Triticum aestiuum) to method of sowing placement. Indian J. Agron. **37**: 710-715.

Hueso-González P, Martínez-Murillo J F and Ruiz-Sinoga, J D (2014) The impact of organic amendments on forest soil properties under Mediterranean climatic conditions. *Land Degrad Dev* **25:** 604-12.

Humphreys E, Kukal S S, Christen E W, Hira G S, Singh B, Yadav S and Sharma R K (2010) Halting the groundwater decline in North-West India—which crop technologies will be winners? *Adv Agron* **109:** 155–217.

Humphreys E, Kukal S S, Kaur A, Thaman S, Yadav S, Singh Y, Singh B, Timsina J, Dhillon S S, Prashar A and Smith D J (2008a) Permanent beds for riceewheat in Punjab, India. Part 2. Water balance and soil water dynamics. In: Humphreys E and Roth C H (Eds.) *Permanent Beds and Rice-residue Management for Rice-wheat Systems in Indo-Gangetic Plains.* Ludhiana, India: PAU, ACIAR Proceedings No. 127.

Itnal C J and Palled Y B (2001) Studies on inter cropping of sunhemp green manuring in hybrid maize. *Karnataka J Agric Sci* **14**: 586-96.

Jacobs A, Rauber R and Ludwig B (2009) Impact of reduced tillage on carbon and nitrogen storage of two Haplic Luvisols after 40 years. *Soil Till Res* **102:** 158-64.

Jantalia C P, Resck D V S, Alves B J R, Zotarelli L, Urquiaga S and Boddey R M (2007) Tillage effect on Carbon stocks of a clayey Oxisol under a soybean-based crop rotation in the Brazilian Cerrado region. *Soil Tillage Res* **95:** 97–109.

Janzen H H, Beauchemin K A, Bruinsma Y, Cambell C A, Desjardins R L, Ellert B L and Smith E G (2003) The fate of nitrogen in agroecosystems: An illustration using Canadian estimates. *Nut Cycl Agroecosys* **67:** 85–102.

Jat H S, Gurbachan Singh, Ranbir Singh, Choudhary M, Jat M L, Gathala M K and Sharma D K (2015) Management influence on maize–wheat system performance, water productivity and soil biology. *Soil Use Manage* **31:** 534-43.

Jat H S, Jat R K, Yadvinder-Singh, Parihar C M, Jat S L, Tetarwal J P, Sidhu H S and Jat M L (2016) Nitrogen Management under Conservation Agriculture in Cereal-based Systems *Indian J Fertilisers* **12:** 76-91.

Jat M L, Gathala M K, Ladha J K, Saharawat Y S, Jat A S, Kumar V, Sharma S K, Kumar V and Gupta, R K (2009) Evaluation of precision land levelling and double zero-till systems in the rice–wheat rotation: water use, productivity, profitability and soil physical properties. *Soil Till Res* **105:** 112–21.

Jat M L, Gathala M K, Saharawat Y S, Tetarwal J P, Gupta R and Yadvinder-Singh (2013) Double no-till and permanent raised beds in maize–wheat rotation of north-western Indo-Gangetic plains of India: Effects on crop yields, water productivity, profitability and soil physical properties. *Field Crops Res* **149:** 291–99.

Jat M L, Saharawat Y S and Gupta Raj (2011) Conservation agriculture in cereal systems of South Asia: nutrient management perspectives. *Karnataka J Agric Sci* **24:** 100-105.

Jat M L, Singh S, Rai H K, Chhokar R S, Sharma S K and Gupta R K (2005) Furrow irrigated raised bed planting technique for diversification of rice–wheat system of Indo-Gangetic Plains. *J Japan Assoc Int Coop Agric Forestry* **28:** 25–42.

Jat, M.L., Sharma, S.K., Rai, H.K., Srivastava, A. and Gupta, R.K. 2006. Effect of tillage on performance of winter maize in northern India. *Paper Presented in 6th Triennial Conference of Maize Association of Australia*. 21–23 February, Griffith, NSW, Australia.

Jat, M.L., Sharma, S.K., Rai, H.K., Srivastava, A. and Gupta, R.K. 2006. Effect of tillage on performance of winter maize in northern India. *Paper Presented in 6th Triennial Conference of Maize Association of Australia*. 21–23 February, Griffith, NSW, Australia.

Jing Q, Keulen H V, Hengsdijk H, Cao W, Bindraban P S, Dai T and Jiang D (2009) Quantifying N response and N use efficiency in rice-wheat (RW) cropping systems under different water management. *J Agric Sci* **147** : 303-12.

Johansson E, Prieto-Linde M L and Jonsson J O (2001) Effects of wheat cultivar and nitrogen application on storage protein composition and bread making quality. *Cereal Chem* **78** : 19-25.

Jones C and Jacobsen J (2009) Fertilizer placement and timing. In: *Nutrient Management* Module No. 11. Montana State University, Bozeman, USA.

Kachroo D and Ravinder R (2006) Growth, nutrient uptake and yield uptake as influenced by biofertilizers and nitrogen. *Indian J Agron* **51** : 37-39.

Kahlon M S and Khera K L Effect of Irrigation Methods and Regimes on Maize (Zea Mays L.) growth. *Int J Tropical Agric* **34**:245-48.

Kandeler E, Tscherko D and Spiegel H (1999) Long-term monitoring of microbial biomass, N mineralization and enzyme activities of a Chernozem under different tillage management. *Biol Fert Soils* **28:** 343-51.

Kargas G, Kerkides P and Poulovassilis A (2012) Infiltration of rain water in semi-arid areas under three land surface treatments. *Soil Till Res* **120:** 15-24.

Kaschuk G, Alberton O, Hungria M (2010) Three decades of soil microbial biomass studies in Brazilian ecosystems: lessons learned about soil quality and indications for improving sustainability. *Soil Bio Biochem* **42:** 1-13.

Kassam A, Friedrich T, Shaxson F and Pretty J (2009) The spread of conservation agriculture: justification, sustainability and uptake. *Int J Agri Sust* **7:** 292-320

Kaur, T. and Mahey, R.K. 2005. Effect of planting method and irrigation levels on water use of maize (*Zea mays*). *Indian Journal of Environment and Ecoplanning*, **10**(4): 373-76.

Kay B D (1990) Rates of change of soil structure under different cropping systems. *Adv Soil Sci* **12:** 1–52.

Keeney D R, Nelson D W (1982) Nitrogen—Inorganic forms. In: Page A L, Miller R H and Keeney D R (eds) *Methods of soil analysis.* Part 2. 2nd edn. Agron. Monogr. 9. ASA and SSSA, Madison, WI, pp 643-98

Kemper, W.D. and Rosenau, R.C. 1986. Aggreagate stability and size distribution. In: *Method of Soil Analysis, Part 1, Physical and Mineralogical Properties, Agronomy Monograph No. 9*. Klute, A. (Ed.). *American Society of Agronomy*, Madison, Wisconsin, USA, pp. 425-442

Kern J S and Johnson M G (1993) Conservation tillage impacts on national and atmospheric carbon levels. *Soil Sci Soc Am J* **57:** 200-10.

Khaleque M, Paul N and Meisner C (2008) Yield and nitrogen use efficiency of wheat as influenced by bed planting and nitrogen application in Bangladesh. *J Agri Res* **33(3):** 439-48

Khalil S K, Khan F, Rehman A, Muhammad F, Amanullah, Khan A Z, Wahab S, Akhtar S, Zubair M, Khalil I H, Shah M K and Khan H (2011) Dual purpose wheat for forage and grain yield in response to cutting, seed rate and nitrogen. *Pak J Bot* **43**: 937-47.

Khan M I, Jan A, Hussain N, Jan M T and Qadoos M (2011) Rainfedwheat response to tillage and nitrogen. *Sarhad J Agric* **27**: 519-23.

Kibe A M, Singh S and Kalra N (2006) Water–nitrogen relationships for wheat growth and productivity in late sown conditions. *Agric Water Mgt* **84** : 221-228.

Kirda C (2002) Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. In: Deficit irrigation practice. Water Reports 22. FAO, Rome pp 1-3.

Kukal S S, Humphreys E, Yadvinder-Singh, Balwinder-Singh, Yadav S, Amanpreet- Kaur, Thaman S, Timsina J, Dhillon S S, Brar N K, Prashar A and Smith D J (2008)

Permanent beds for rice-wheat in Punjab, India. In: Humphreys E and Roth C H (Eds.) *Permanent Beds and Rice-residue Management for Rice-wheat Systems in Indo-Gangetic Plains*. Ludhiana, India: PAU, ACIAR

Kukal S S, Sudhir-Yadav, Humphreys E, Kaur A, Yadvinder-Singh, Thaman S, Singh B and Timsina J (2010). Factors affecting irrigation water savings in raised beds in rice and wheat. *Field Crops Res* **118:** 43-50.

Kumar A (2009) Production potential and nitrogen use efficiency of sweet corn (*Zea mays* L.) as influenced by different planting densities and nitrogen levels. *Indian J Agric Sci* **79**: 231-55.

Kumar K and Goh K M (2002) Management practices of antecedent leguminous and non-leguminous crop residues in relation to winter wheat yields, nitrogen uptake, soil nitrogen mineralization and simple nitrogen balance. *Eur J Agr* **16:** 295–308.

Kumar K and Goh K M (2003) Nitrogen release from crop residues and organic amendments as affected by biochemical composition, *Commun Soil Sci Plant Anal* **34:** 2441-60.

Kumar V and Ahlawat I P S (2006) Effect of biofertilizer and nitrogen on wheat (Triticum aestivum) and their after increase on succeeding maize (*Zea mays*) in wheat-maize cropping systems. *J Agric Sci* **76**: 465-68.

Kumar V, Saharawat Y S, Gathala M K, Jat A S, Singh S K, Chaudhary N and Jat M L (2013) Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in Indo-Gangetic plains. *Field Crops Res* **142:** 1-8.

Kumar, R. and Yadav, D.S. 2005. Effect of zero and minimum tillage in conjunction with nitrogen management in wheat (*Triticum aestivum*) after rice (*Oryza sativa*). *Indian J Agron* **50**(1): 54-57.

Kundu D K and Pillai K G (1992) Integrated nutrient supply in rice and rice-based cropping systems. *Fert. News* **37:** 35-41.

Labios R V, Villancio V T, Labios J D, Salazar A M, Delos Sanos R E (1997) Development of alternative cropping pattern in rainfed lowland areas with small farm reservoirs. *Philippine Agriculturist* **80:** 187–99.

Ladha J K, Pathak H, Tirol-Padre A, Dawe D and Gupta R K (2003) Productivity trends in intensive rice-wheat cropping systems in Asia. In: Ladha J K, Hill J E, Duxbury J M, Gupta R K and Buresh RJ (Eds) *'Improving the Productivity and Sustainability of Rice-Wheat Systems: Issues and Impacts', pp. 45-76. ASA Special Publication 65 (ASAInc, CSSAInc, SSSAInc, Madison, USA).*

Ladha J K, Singh Y, Erenstein O and Hardy B (eds.) (2009) *Integrated Crop and Resource Management in the Rice–Wheat Systems of South Asia.* International Rice Research Institute, Los Banos, Philippines, pp. 395.

Lal B, Chandra N and Yadav M S (1988) Response of water logged maize to plantingmethod and time of nitrogen application. *Indian J Agron* **33:** 191-95.

Lal R (1990) Soil erosion in the tropics: Principles and management. *New York: McGraw-Hill*.

Lal R (1996) Axle load and tillage effects on crop yields on a mollic ochraqualf in northwest Ohio. *Soil Till Res* **37:** 143-60.

Lal R, Reicosky D C and Hanson J D (2007) Evolution of the plow over 10,000 years and the rationale for no-till farming. *Soil Till Res* **93:** 1–12.

Lal, R. and Kimble, J.M. 1997. Conservation tillage for carbon sequestration. *Nutrient Cycling in Agroecosystems,* **49**: 243-53.

Lampurlanés, J. and Cantero-martínez, C. 2006. Hydraulic conductivity, residue cover and soil surface roughness under different tillage systems in semiarid conditions. *Soil and Tillage Research,* **84:** 13-26.

Lathwel B P, Goyal S P and Chonkar R S (2010) Introduction of summer mungbean in rice-wheat cropping system in Haryana. *Indian J Fert* **6:** 37-39.

Lehrsch G A, Sojka R and Westermann D (2008) Nitrogen placement, row spacing and water management for furrow-irrigated field corn. In: Proceedings of the Idaho. *Nutr Mgt Conf* **4**: 42–48.

Li H W, Gao H W, Wu H D, Li W Y, Wang X Y and He J (2007) Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. *Aust J Soil Res* **45:** 344–50.

Lichter K, Govaerts B, Six J, Sayre K D, Deckers J and Dendooven L (2008) Aggregation and, carbon and nitrogen contents of soil organic matter fractions in a permanent raised-bed planting system in the Highlands of Central Mexico. *Plant Soil* **305:** 237–52.

Limon-Ortega A, Govaerts B, Deckers J and Sayre K D (2006) Soil aggregate and microbial biomass in a permanent bed wheat–maize planting system after 12 years. *Field Crops Res* **97:** 302-09.

Limon-Ortega A, Sayre K D and Francis C A (2000) Wheat and maize yields in response to straw management and nitrogen under a bed planting system. *Agron J* **92:** 295–302

Liu K, Sollenberger L E, Silveira M L, Vendramini J M B and Newman Y C (2011) Grazing intensity and nitrogen fertilization affect litter responses in 'Tifton 85% Bermuda grass pastures: II. Decomposition and nitrogen mineralization. *Agron J* **103**: 163-68.

Loranger G, Ponge J F, Imbert D and Lavelle P (2002) Leaf decomposition in two semi-evergreen tropical forests: influence of litter quality. *Biol Fertil Soils* **35:** 247-52.

Lupwayi N Z, Clayton G W, O'Donovan J T, Harker K N, Turkington T K and Soon Y K (2007) Phosphorus release during decomposition of crop residues under conventional and zero tillage. *Soil Till Res* **95:** 231-39.

Lupwayi N Z, Lafond G P, Ziadi N, Grant C A (2012) Soil microbial response to nitrogen fertilizer and tillage in barley and corn. *Soil Tillage Res* **118**: 139-46.

Ma L, Peterson G A, Ahuja L R, Sherrod L, Shaffer M J and Rojas K W (1999) Decomposition of surface crop residues in long-term studies of dryland agroecosystems. *Agron J* **91:** 401-09.

MacRae R J and Mehuys G R (1985) The effect of green manuring on the physical properties of temperate-area soils. *Adv Soil Sci* **3:** 71–94.

Mahmood M T, Maqsood M, Awan T H and Sarwar R (2001) Effect of different levels of nitrogen and intra-row plant spacing on yield and yield components of maize. *Pakistan J Agi Sci* **38:** 48-49

Mailhol J C, Ruelle P and Nemeth I (2001) Impact of fertilisation practices on nitrogen leaching under irrigation. *Irri Sci* **20:** 139-47.

Mann R A, Ramzan M and Munir A (2008) Improving the sustainability of wheat production in irrigated areas of Punjab, Pakistan through conservation tillage technology. *Int J Agri Bio* **10:** 249-54

Marongwe L S, Nyagumbo I, Kwazira K, Kassam A and Friedrich T (2012) Conservation agriculture and sustainable crop intensification: A Zimbabwe case study. *Integ Crop Manage* **17:** 1-44

Mazzoncini M, Sapkota T B, Barberi P, Antichi D and Risaliti R (2011) Long-term effect of tillage, nitrogen fertilization and cover crops on soil organic carbon and total nitrogen content. *Soil Tillage Res* **114**: 165–74.

McFarland M L, Hons F M and Saladino V A (1991) Effects of furrow diking and tillage on corn grain yield and nitrogen accumulation. *Agron J* **83:** 382-86

Mclaughlin M J, Alston A M, Martin J K (1988) Phosphorus cycling in wheat-pasture rotations. I. The source of phosphorus taken up by wheat. *Aust J Soil Res* **26:** 323-32

McVay K A, Budde J A, Fabrizzi K, Mikha M M, Rice C W and Schlegel A J (2006) Management effects on soil physical properties in long-term tillage studies in Kansas. *Soil Sci Soc America J* **70:** 434-38.

Meelu O P, Beri V, SharmaK N, Jalota S K. and Sandhu B S (1979) Influence of paddy and corn in different rotations on wheat yield nutrient removal and soil properties. *Plant Soil* **51:** 51–58.

Meelu O P, Yadvinder-Singh and Bijay-Singh (1994) Green manuring for Soil Productivity Improvement. FAO World Soil Resources Reports No. 76. Pp123.

Minhas P S, Jalota S K, Arora V K, Jain A K, Vashist K K, Choudhary O P, Kukkal S S and Vashist B B (2010) *Managing water resources for ensuing sustainable agriculture: situational analysis and options for Punjab.* Research Bulletin No. 2/2010.

Mishra B, Sharma PK, Bronson KF (2001) Decomposition of rice residue and mineralization of carbon, nitrogen, phosphorous and potassium in wheat field soil in Western Uttar Pradesh. *J Indian Soc Soil Sci* **49:** 419-24.

Mishra J S and Singh V P (2009) Weed dynamics and productivity of soybean (*Glycine max*)–based cropping systems as influenced by tillage and weed management. *Indian J Agron* **54:** 29-35.

Mishra S K, Tripathi D K, Srivastava N K, Beg M Z and Singh C (2011) Effect of different level of nitrogen on wheat (*Triticum aestivum*) after Rice (*Oryza sativa*) under zero tillage. *Indian J Sci Res* **2:** 97-100.

Mohammad M J (2004) Utilization of applied fertilizer nitrogen and irrigation water by drip-fertigated squash as determined by nuclear and traditional techniques. *Nutrient Cycling in Agroecosystems*, **68**:1-11.

Munoz, A., Lopez-pineiro, A. and Ramirez, M. 2007. Soil quality attributes of conservation management regimes in a semi-arid region of South Western Spain. *Soil Tillage Res* **95**(1-2): 255-65.

Murungu F S, Chiduza C, Muchaonyerwa P and Mnkeni P N S (2011) Decomposition, nitrogen, and phosphorus mineralization from residues of summer-grown cover crops and suitability for a smallholder farming system in South Africa. *Commun Soil Sci Plant Anal* **42:** 2461-72.

Nemati A R and Sharifi R S (2012) Effects of rates and nitrogen application timing on yield, agronomic characterstics and nitrogen use efficiency in corn. *Int J Agri Crop Sci* **4:** 534-39

Ngatia L W, Reddy R L, Nair P K R, Pringle R M, Palmer T D and Turner B L (2014) Seasonal patterns in decomposition and nutrient release from East African savanna grasses grown under contrasting nutrient conditions. *Agric Ecosys Environ* **188:** 12-19.

Niaz A, Yaseen M, Arshad M and Ahmad R (2014) Variable nitrogen rates and timing effect on yield, nitrogen uptake and economic feasibility of maize production. *J Agric. Res* **52:** 1-10.

Nourbakhsh F and Dick R P (2005) Net nitrogen mineralization or immobilization potential in a residue-amended calcareous soil. *Arid Land Res Manage* **19:** 299-306.

Novara A, Gristina L, Rühl J, Pasta S, D'Angelo G, La Mantia T and Pereira P (2013) Grassland fire effect on soil organic carbon reservoirs in a semiarid environment. *Solid Earth* **4:** 381-85.

Nyberg G, Ekblad A, Buresh R and Hogberg P (2002) Short-term patterns of carbon and nitrogen mineralization in a fallow field amended with green manures from agroforestry trees. *Biol Fertil Soils* **36:** 18-25.

Nygaard Sorensen J and Thorup-Kristensen K (2011) Plant-based fertilizers for organic vegetable production. *J Plant Nutr Soil Sci* **174:** 321-32.

Oliveira S P, Lacerda N B, Blum S C, Escobar M E O and Oliveira T S (2014) Organic carbon and nitrogen stocks in soils of northeastern brazil converted to irrigated agriculture. *Land Degrad Dev* **26:** 9–21.

Olsen S R, Cole C V, Watanabe F S and Dean L A (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939. U.S. Gov. Print Office,Washington.

Ordpnez-Fernandz A, Rodrı´guez-Lizana A, Carbonell R, Gonza´lez P and Perea F (2007) Dynamics of residue decomposition in the field in a dryland rotation under mediterranean climate conditions in southern Spain. *Nutr Cycl Agroecosyst* **79:** 243-53.

Ozpinar S (2006) Effects of tillage on productivity of a winter wheat-vetch rotation under dry land Mediterranean conditions. *Soil Till Res* **89:** 258-265.

P Jha, N Garg, B L Lakaria, A K Biswas and A Subba Rao (2012), Soil and residue carbon mineralization as affected by soil aggregate size. *Soil Tillage Res* **121**: 57–62

Pagliai M, Vignozzi N and Pellegrini S (2004) Soil structure and the effect of management practices. *Soil Till Res* **79:** 131-43.

Parihar C M, Jat S L, Singh A K and Jat M L (2011) Energy scenario and water and productivity of maize based cropping system under conservation agriculture practices in south Asia. *In: Abstracts of 5th world congress on conservation agriculture, incorporating the 3rd farming system design conference held at Brisbane, Australia from 26th to 29th Sept. Page: 144–45.*

Parihar C M, Jat S L, Singh A K, Kumar B, Yadvinder-Singh, Pradhan S, Pooniya V, Dhauja A, Chaudhary V, Jat M L, Jat R K and Yadav O P (2016) Conservation agriculture in irrigated intensive maize-based systems of north-western India: effects on crop yields, water productivity and economic profitability. *Field Crops Res***193:**104-116.

Parihar C M, Yadav M R, Jat S L, Singh A K, Kumar B, Pradhan S, Chakraborty D, Jat M L, JatR K, Saharawat Y S, and Yadav O P. (2016a) Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. *Soil Till Res* **161:** 116-28.

Parodi P W (2003) Conjugated linoleic acid in food. In advances in conjugated linoleic acid research. Vol. 2. (Ed. J. Sebedio, W. W. Christie, and R. Adlof) p. 101-121. AOCS Press, Champaign, IL, USA

Patel N and T B S Rajput (2000) Fertigation a Technique for Efficient Use of Granular Fertilizer through Drip Irrigation. *J Agr Water Management* 85.

Patil P P and Patil V S (2009) Effect of mulching with drip irrigation on summer capsicum yield and economics *Indian J Soil Cons* **37:** 50-54

Pawar D D, S K Dingre M G Shinde and S V Kaore (2013) Drip fertigation for Higher Crop Productivity. Research Book No. MPKV/ Res.Pub. No. 99/2013, MPKV, Rahuri-413 722, Maharashtra, India.

Pei X X, Wang X B, He P, Zhang X Z, Li K J, Zhou W, Liang G Q and Jin J Y (2009) Effect of postponing N application on soil N supply, plant N uptake and utilization in winter wheat. *Plant Nut Fert Sci* **15:** 9-15 (in Chinese).

Pereira L S, Oweis T and Zairi A (2002) Irrigation management under water scarcity. *Agric Water Manage* **57:** 175-206

Pinheiro E F, Pereira M M G and Anjos L H C (2004) Aggregate distribution and soil organic matter under different tillage systems for vegetable crops in a red latosol from Brazil. *Soil Tillage Res* **77:** 79–84.

Power J F (1990) Use of green manures in the Great Plains. In: Havlin J L and Jacobsen J S (eds), *Proc the Great Plains Soil Fertility Conference* Pp 1–18. Denver, CO. Kansas State University,Manhattan, KS.

Prado R M (2008) *Nutrição de plantas. UNESP, São Paulo*. 407 pp.

Prasad R (1987) *Water use and fertilizer use efficiency of maize and wheat as effected by root manipulation through tillage on two soils*. Ph.D. Dissertation, Department of Agronomy, Punjab Agricultural University, Ludhiana.

Prasad T V, Khrishnamurthy K and Shivashankar K (1990) Canopy and growth differences in maize genotypes in relation to plant densities and nitrogen levels. *Mysore J Agric Sci* **24**: 437-44.

Prichard T, Hanson B, Schwankl L, Verdegaal P and Smith R (2004) Deficit Irrigation of Quality of Wine Grapes Using Micro-irrigation Techniques. Publications of University of California Co-operative Extension, Department of Land, Air and Water Resources, University of California, Davis, pp. 5. Proceedings No. 127.

Rahman M A, Chikushi J, Saifizzarman M and Lauren J G (2005) Rice straw mulching and nitrogen response of no-till wheat following rice in Bangladesh. *Field Crops Res* **91**: 71–81.

Ram H (2006) Micro-environment and productivity of maize–wheat and soybean–wheat sequences in relation to tillage and planting systems. Ph.D. dissertation, Punjab Agricultural University, Ludiana, Punjab, India.

Ram H, Kler D S, Singh Y and Kumar K (2010) Productivity of maize (*Zea mays*)–wheat (*Triticum aestivum*) system under different tillage and crop establishment practices. *Indian J Agron* **55**(3): 185-90.

Ram H, Kler D S, Yadvinder-Singh, Kumar K (2010) Productivity of maize (Zea mays)-wheat (Triticum aestivum) system under different tillage and crop establishment practices. *Indian J Agro* 55**(3):** 185-90.

Ram T, Yadav S K and Sheoran R K (2002) Nutrient uptake pattern of wheat (*Triticum aestivum* L.) as Influenced by azotobacter and nitrogen fertilization environment and ecology. *Environ Ecol* **20**: 661-65.

Ramu Y R and Reddy (2007) Yield, nutrient uptake and economics of maize as influenced by plant stand, levels and time of nitrogen application. *Crop Res* **33**: 41-45.

Ranjbar F and Jalali M (2012) Calcium, magnesium, sodium, and potassium release during decomposition of some organic residues. *Commun Soil Sci Plant Analysis* **43:** 645-59.

Rashidi, M. and Keshavarzpour, F. 2007. Effect of different tillage methods on soil physical properties and crop yield of watermelon (*Citrullus Vulgaris*). *ARPN J Agric Biol Sci* **2**(6): 1-6

Rasmussen K J (1999) Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review. *Soil Tillage Res* **53**: 3–14.

Rasool R, Kukal S S and Hira G S (2007) Farmyard and inorganic fertilization effects on saturated hydraulic conductivity of soil and performance of rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) systems. *Indian J Agric Sci* **77**(11): 768-71.

Raun W R and Johnson G V (1999) Improving nitrogen use efficiency for cereal production. *Agron J* **91:** 357–63

Rautaray S K (2005) Machinery for conservation agriculture: Progress and Needs. In: Abrol I P, Gupta R K and Malik R K (Eds.) *Conservation agriculture: Status and prospects Centre for Advancement of Sustainable Agriculture*. New Delhi, pp. 43.

Rekhi R S and Meelu O P (1983) Effect of complementary use of mung straw and inorganic fertilizer nitrogen on the nitrogen availability and yield of rice. **20:** 125-29.

Rezig F A M, Elhadi E A and Abdalla M R (2014) Decomposition and nutrient release pattern of wheat (Triticum aestivum) residues under different treatments in desert field conditions of Sudan. *Int J Recycl Org Waste Agricult* **3:** 1-9.

Rhoton F E (2000). Influence of time on soil response to no-till practices. Soil Science Society of America Journal, **64**: 700–709.

Rodrı´guez-Lizana A, Carbonell P, Gonza´lez R, Ordo´n˜ez R (2010) N, P and K released by the field decomposition of residues of a pea–wheat–sunflower rotation. *Nutr Cycl Agroecosyst* **87:**199-208.

Saeed B, Gu H, KhanA Z, Parveen L, Badshah N L and Khan A (2012) Physiological and quality assessment of wheat (*Triticum aestivum* l.) cultivars in response to soil and foliar fertilization of nitrogen and sulphur. *ARPN J Agric Biol Sci* **7**: 121-29.

Saharawat Y S, Ladha J K, Pathak H, Gathala M, Chaudhary N and Jat M L (2012) Simulation of resource-conserving technologies on productivity, income and greenhouse gas (GHG) emission in rice–wheat system. *J Soil Sci Environ* **3:** 9–22.

Saharawat Y S, Singh B, Malik R K, Ladha J K, Gathala M, Jat M L, Kumar V (2010) Evaluation of alternative tillage and crop establishment methods in a rice–wheat rotation in North Western IGP. *Field Crops Res* **116:** 260–67..

Sahoo S C and Mahapatra P K (2004) Response of sweet corn (*Zea mays*) to nitrogen levels and plant population. *Indian J Agric Sci* **74**: 337-38.

Salinas-Garcia J R, Velazquez-Garcia J D, Gallardo-Valdez A, Diaz-Mederos P, Caballero-Hernandez F, Tapia-Vargas L M and Rosales-Robles E (2002) Tillage effects on microbial biomass and nutrient distribution in soils under rain-fed corn production in central-western Mexico. *Soil Tillage Res* **66:** 143-52.

Salvagiotti F and Miralles D J (2008) Radiation interception, biomass production and grain yield as affected by the interaction of nitrogen and sulphur fertilization in wheat. *Europ J Agron* **28**: 282-90.

Sampath K T, Pandianb B J and Mahimairaja S (2102) Soil moisture distribution and root characters as influenced by deficit irrigation through drip system in cotton–maize cropping sequence. *Agric Water Manage* **103:** 43-53.

Sampathkumar T and Pandian B J (2010) Efficiency of applied nutrients and SPAD values in hybrid maize under drip fertigation. *Madras Agric J* **97:** 237-41.

Sampathkumar T and Pandian B J (2011) Nutrient uptake rate and relationship with grain yields of hybrid maize under drip fertigation. *Madras Agric J* **98:** 151-53.

Saraf C S and Patil R R (1995) Fertilizer use in pulse based cropping systems. *Fert. News* **40:** 55-65.

Sarkar A K, Singh K P, Singh B P and Singh R P (2000) *Long term effects of fertilizers, manures and amendments on crop production and soil fertility*. Tech Bull Pp 31-45

Sayre K and Hobbs P (2004) The raised-bed system of cultivation for irrigated production conditions. In: Lal R, Hobbs P, Uphoff N and Hansen D O (Eds.) *Sustainable agriculture and the Rice-Wheat system*. Ohio State University, Columbia, Ohio, USA, pp. 337-55

Sayre K D (2004) Raised-bed cultivation. In: Lal R (ed) Encyclopedia of Soil Science. Marcel Dekker, Inc. eBook Site Online publication.

Sayre K D and Moreno-Ramos O H (1997) Applications of raised-bed planting systems to wheat. Mexico DF, Mexico, CIMMYT. In: Int. Wheat Special Report 31. pp. 28.

Sayre, K.D., Limon-Ortega, A. and Govaerts, B. 2005. Experiences with permanent bed planting systems CIMMYT, Mexico. In: *proceedings of Workshop on Evaluation and Performance of Permanent Raised Bed Cropping Systems in Asia, Australia and Mexico*. 1–3 March, Griffith, Australia, pp. 12–25.

Schomberg H H and Steiner J L (1997) Comparison of residue decomposition models used in erosion prediction. *Agron J* **89:** 911-19.

Schomberg H H, Steiner J L, Evett S R and Moulin A P (1996) Climatic influence on residue decomposition prediction in the wind erosion prediction system. *Theor Appl Climatol* **54:** 5–16.

Sharma A R and Behera U K (2009) Nitrogen contribution through sesbania green manure and dual-purpose legumes in maize–wheat cropping system: agronomic and economic considerations. *Plant Soil* **325**: 289-304.

Sharma A R, Jat M L, Saharawat Y S, Singh V P and Singh R (2012) Conservation agriculture for improving productivity and resource-use efficiency: prospects and research needs in Indian context. *Indian J Agron* **57:** 131–40.

Sharma P, Abrol V and Sharma R K (2011) Impact of tillage and mulch management on economics, energy requirement and crop performance in maize–wheat rotation in rainfed subhumid inceptisols, India. *European J Agron* **34:** 46-51.

Shivay Y S, Singh R P and Pandey C S (2002) Physiological analysis of growth in maize to sowing dates, irrigation and nitrogen. *Indian J Agron* **36:** 239-42.

Silburn D M, Freebairn D M and Rattray D J (2007) Tillage and the environment in sub-tropical Australia-Tradeoffs and challenges. *Soil Till Res* **97:** 306-17.

Sinebo W, Gretzmacher R, Edelbauer A (2004) Genotypic variation for nitrogen use efficiency in Ethiopian barley. *Field Crops Res* **85**: 43-60.

Singh B and Brar S P S (1985) Effect of organic manures and nitrogen on grain yield and soil properties in a maize-wheat rotation. *J Res Punjab Agric Univ* **22:** 243-52.

Singh P, Singh P, Singh K N, Singh R, Aga F A, Bahar F and Raja W (2010) Evaluation of wheat (*Triticum aestivum*) genotypes for productivity and economics under grades levels of nitrogen in temperate Kashmir. *Indian J Agric Sci* **80**: 380-84.

Singh R, Sharma A R and Behera U K (2007a) Tillage and crop establishment practices for improving productivirty of maize (*Zea mays*) under different weed control methods. *Indian J Agric Sci* **77**(11): 731–37.

Singh Y, Gupta R K, Singh G, Singh J, Sidhu H S and Singh B (2009) Nitrogen and residue management effects on agronomic productivity and nitrogen use efficiency in rice-wheat system in Indian Punjab. *Nut Cyc Agro* **84**: 141-54.

Singh Y, Singh M, Sidhu H S and Blackwell J (2011) Enhancing nitrogen use efficiency in wheat sown into rice residue and effect of straw management on soil health in rice-wheat system in North West India.

Singh, R., Sharma, A,R., Dhayani, S.K. and Dube, R.K. 2011. Tillage and mulching effects on performance of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system under varying land slopes. *Indian Journal of Agricultural Sciences,* **81**(4), 330–335.

Six J, Elliott E T and Paustian K (2000) Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under zero tillage agriculture. *Soil Biol Biochem* **32:** 2099-2103

Siyal A A, Bristowc K L and Simunek J (2012) Minimizing nitrogen leaching from furrow irrigation through novel fertilizer placement and soil surface management strategies. *Agric Water Manage* **115:** 242-5.

Soane B D (1990) The role of organic matter in soil compactibility-a review of some practical aspects. *Soil Tillage Res* **16:** 179–201.

Srinivasan G, Zaidi P H, Prasanna B M, Gonzalez F and Lesnick K (Eds.) (2004) *Proceedings of Eighth Asian Regional Maize Workshop: New Technologies forthe New Millennium.* Bangkok, Thailand, 5–8 August 2002. CIMMYT, Mexico, DF.

Stewart C E, Pratibha Moturi, Follett R F and Halvorson A D (2015) Lignin biochemistry and soil N determine crop residue decomposition and soil priming. *Biogeochem* **124:** 335-51.

Stroo H F, Bristow K L, Elliott L F, Papendick R I and Campbell G S (1989) Predicting rates of wheat residue decomposition. *Soil Sci Soc Am J* **53:** 91-99.

Sylvia D M, Fuhrmann J J, Hartel P G and Zuberer D A (2005) *'Principles and applications of soil microbiology.'* Pearson Education Inc: New Jersey, USA.

Tarkalson D D and Payero J O (2008) Cmparison of nitrogen fertilization methods and rates for subsurface drip irrigated corn in the semiarid great plains. *Transactions Am Soc Agri Biol Engin* **51:** 1633-1643.

Taser O F and Metinoglu F (2005) Physical and mechanical properties of a clayey soil as affected by tillage systems for wheat growth. *Acta Agriculture Scandinavica Section B Soil Plant Sci* **55**: 186**-**91

Tejada M and Benítez C (2014) Effects of crushed maize straw residues on soil biological properties and soil restoration. *Land Degrad Dev* **25:** 501-09.

Thuy N H, Yuhuna S, Singh S, Wang K, Cai Z, Singh Y and Buresh R J (2008) Nitrogen supply in rice–based cropping systems as affected by crop residue management. *Soil Sci Soc Am J* **72**: 514**-**23.

Tian G, Kang B T, Brussaard L (1992) Biological effects of plant residues with contrasting chemical compositions under humid tropical conditions - decomposition and nutrient release. *Soil Biol Biochem* **24:** 1051-60.

Tisdall J M and Oades J M (1982) Organic-matter and water-stable aggregates in soils. *J Soil Sci* **33:** 141–63.

Tiwari K N, Singh A and Mal P K (2003) Effect of drip irrigation on yield of cabbage (Brassica oleracea L., va.Capitata) under mulch and non-mulch conditions. *Agric Water Manage* **58:** 19–28.

Trinsoutrot I, Recous S, Mary B and Nicolardot B (200) C and N flux of decomposing 13C and 15N *Brassica napus* L.: effect of residue composition and N content. *Soil Biol Biochem* **32:** 1717-30.

Tumbare A D, Shinde B N, Bhoite S U (1999) Effects of liquid fertilizer through drip irrigation on growth and yield of okra (Hibiscus esculentus) *Ind J Agron* **44**:176-78.

Vahdat E, Nourbakhsh F and Basiri M (2011) Lignin content of range plant residues controls N mineralization in soil. *Eur J Soil Biol* **47:** 243-46.

Van Vliet P C J, Gupta V V S R and Abbot L K (2000) Soil biota and crop residue decomposition during summer and autumn in south-western Australia. *Appl Soil Ecol* **14:** 111-14.

Varco JJ, Frye WW, Smith MS, MacKown CT (1993) Tillage effects on legume decomposition and transformation of legume and fertilizer nitrogen-15. *Soil Sci Soc Am J* **57:** 750–756.

Verachtert E, Govaerts B, Lichter K, Sayre K, Ceballos-Ramirez J, Luna-Guido M, Deckers J and Dendooven L (2009) Short term changes in dynamics of C and N in soil when crops are cultivated on permanent raised beds. *Plant Soil* **320(1):** 281-93.

Verhulst N, Govaerts B, Verachtert E, Castellanos-Navarrete A, Mezzalama M, Wall P C, Chocobar A, Deckers J and Sayre K D (2010) Conservation agriculture, improving soil quality for sustainable production system? In: Lal R and Stewart B A (Eds.) *Advances in Soil Science: Food security and Soil Quality*. CRC Press, Boca Raton, FL, USA.

Verhulst N, Nelissen V, Jespers N, Haven H, Sayre K D, Raes D, Deckers J and Govaerts B (2011) Soil water content, maize yield and its stability as affected by tillage and crop residue management in rainfed semi-arid highlands. *Plant Soil* **344:** 73-85.

Vishwanatha G B, Ramachandrappa B K and Nanjappa (2002) Soil-plant water status and yield of sweet corn (*Zea mays* L. cv. Saccharata) as influenced by drip irrigation and planting methods. *Agric Water Manage* **55:** 85-90.

Vories E D, Tacker P L, Lancaster S W and Glover R E (2009) Subsurface drip irrigation of corn in the United States Mid-South. *Agric Water Manage* **96:** 912-16.

Vos J, Vanderputten P E and Birch C J (2005) Effect of nitrogen supply on leaf appearance, leaf growth, leaf nitrogen economy and photosynthetic capacity in maize (*Zea mays* L.). *Field Crops Res* **93**: 64-73.

Waddell J T and Weil R R (2006) Effect of fertilizer placement on solute leaching under ridge tillage and no till. *Soil Tillage Res* **90:** 194-204.

Wang F H, Wang X Q and Sayre K D (2004) Comparison of conventional, flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. *Field Crops Res* **87:** 35-42.

Wang H and Zhou J (2013) RootzonefertilizationA key and necessary approach to improve fertilizer use efficiency and reduce nonpoint source pollution from the cropland Soils 05:785–790 (In Chinese)

Wang H, Curtin D, Jame Y W, McConkey B G and Zhou H F (2001) Simulation of soil carbon dioxide flux during plant residue decomposition. *Soil Sci Soc Am J* **66:** 1304-10.

Wang J D, Gong S H, Sui J, Xu H and Yu Y D (2008) Effects of drip irrigation frequency on the farmland soil water-heat distribution and spring maize growth in North China. *Transactions Chinese Society Agrial Engg* **24:** 39-45.

West T O and Post W M (2002) Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. *Soil Sci Soc Am J* **66:** 1 930–46.

Yadav A K, Chauhan S K, Singh S K and Goyal V (2010) Effect of sowing dates and nitrogen levels on growth and yield of vegetable pea (*Pisum sativum*) and its residual effect on wheat (*Triticum aestivum*) and maize (*Zea mays*) in vegetable pea-wheat-maize cropping sequence. *Indian J Agric Sci* **80**: 1085-88.

Yadav M R, Parihar C M, Jat S L,Singh A K ,Kumar D,Pooniya V, Parihar M D, Saveipune D, Parmar H and Jat M L (2016) Effect of long-term tillage and diversified crop rotations on nutrient uptake, profitability and energetics of maize (*Zea mays*) in north-western India. *Indian J Agri Sci* **86(6):** 743–49.

Yadav R L and Rao S (2001) *Atlas of Cropping Systems in India.* PDCSR Bulletin No 2001-02 Project Directorate for Cropping Systems Research, Modipuram, Meerut 250110, India pp. 96.

Yadvinder-Singh, Bijay-Singh and Thind H S (2010) Green manure approaches to crop production and sustainable agriculture, In *ING Bulletins on Regional Assesment of Reactive Nitrogen*, Bulletin No. 14, SCON-ING, New Delhi, pp 1-130.

Yadvinder-Singh, Bijay-Singh and Timsina J (2005) Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. *Adv Agron* **85:** 269-407.

Yadvinder-Singh, Bijay-Singh, Ladha J K, Khind C S, Khera T S and Bueno C S (2004) Effects of residue decomposition on productivity and soil fertility in rice–wheat rotation. *Soil Sci Soc Am J* **68:** 854-64.

Yadvinder-Singh, Gupta R K, Singh J, Singh G, Singh G and Ladha J K (2010b) Placement effects on rice residue decomposition and nutrient dynamics on two soil types during wheat cropping in rice–wheat system in northwestern India. *Nutr Cycl Agroecosyst* **88:** 471-80.

Yadvinder-Singh, Humphreys E, Kukal S S, Bijay-Singh, Amanpreet-Kaur, Thaman S, Prashar A, Yadav S, Timsina J, Dhillon S S, Kaur N, Smith D J and Gajri P R (2009) Crop performance in permanent raised bed rice-wheat cropping system in Punjab, India. *Field Crop Res* **110:** 1-20.

Yi Q, X Z Zhang, P He, L Yang and G Y Xiong (2010) Effect of reducing nitrogen application on crop nitrogen uptake, utilization, and soil nitrogen balance in rice-wheat rotation system. *Plant Nut Fert Sci* **16:** 1069–77 (in Chinese).

Yuan B Z, Nishiyama S and Kang Y (2003) Effects of different irrigation regimes on the growth and yield of drip irrigated potato. *Agric Water Manage* **63:** 153–67

Yusuf A A, Iwuafor E N O, Abaidoo R C, Olufajo O O and Sanginga N (2009) Effect of crop rotation and nitrogen fertilization on yield and nitrogen efficiency in maize in the northern Guinea savanna of Nigeria. *African J Agri Res* **4:** 913-21

Zagal E and Persson J (1994) Immobilization and remineralization of nitrate during glucose decomposition at four rates of nitrogen addition. *Soil Biol Biochem* **26:** 1313-21.

Zaman W U, Arshad M and Saleem A (2001) Distribution of nitrate nitrogen in the soil profile under different irrigation methods. *Int J Agric Biol* **2:** 208–09.

Zeng C, Bie Z and Yuan B (2009) Determination of optimum irrigation water amount for drip-irrigated muskmelon (*Cucumis melon* L.) in plastic greenhouse. *Agric Water Manage* **96:** 595–602

Zhang S, Lovdahl L, Grip H, Jansson P E and Tong Y (2007) Modelling the effects of mulching and fallow cropping on water balance in the Chinese Loess Plateau. *Soil Till Res* **93:** 283-98.

Zwart S J and Bastiaanssen W G M (2004) Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. *Agric Water Manage* **69:** 115–33.

APPENDIX-I

Weekly mean meteorological data recorded during the crop season 2013-14

Standard week	Max. temp (°C)	Min. temp (°C)	Mean temp.	Mean RH (%)	Rainfall (mm)	Total evaporation (mm)	Sunshine (hrs)
44	28.1	13.8	21.0	63.0	12.0	20.0	9.1
45	24.7	11.9	18.3	68.0	4.6	13.6	5.2
46	25.7	8.1	16.9	60.0	0.0	15.5	5.7
47	26.3	9.5	17.9	66.0	0.0	13.8	4.1
48	26.3	9.4	17.9	65.0	0.0	14.0	8.8
49	24.5	8.1	16.3	69.0	0.0	11.4	7.3
50	22.1	8.1	15.1	72.0	0.0	11.6	8.0
51	15.1	9.6	12.4	90.0	10.4	4.6	6.1
52	17.3	3.9	10.6	69.0	2.8	11.2	5.5
1	16.8	3.8	10.3	73.0	0.0	8.0	0.2
2	17.8	6.0	11.9	72.0	0.0	8.9	7.1
3	15.7	8.2	12.0	86.0	26.1	8.1	5.4
4	18.9	8.9	13.9	82.0	29.4	9.1	4.7
5	18.4	9.7	14.1	84.0	1.0	7.7	2.5
6	18.3	8.0	13.2	80.0	2.8	10.2	6.1
7	18.3	6.6	12.5	77.0	6.1	10.5	2.7
8	21.8	8.8	15.3	76.0	16.0	15.0	5.0
9	21.3	8.9	15.1	77.0	13.6	15.4	6.5
10	20.3	11.4	15.9	73.0	4.0	18.9	7.1
11	25.5	12.6	19.1	72.0	16.0	27.5	6.3
12	26.2	13.5	19.9	71.0	9.9	20.6	9.2
13	28.0	14.6	21.3	66.0	3.3	28.3	9.1
14	28.8	15.1	22.0	64.0	2.4	33.5	7.3
15	32.6	15.1	23.9	54.0	0.0	45.6	10.1
16	31.0	16.7	23.8	60.5	28.0	35.5	8.9
17	37.2	19.5	28.4	52.7	0.0	56.0	12.2
18	39.2	23.5	31.3	47.9	3.0	64.6	7.7
19	35.7	21.6	28.6	54.1	12.8	52.8	7.5
20	35.2	21.2	28.2	51.1	0.0	50.0	10.5
21	38.8	23.4	31.1	47.3	10.0	63.6	11.1
22	40.7	25.6	33.2	47.2	0.4	70.0	11.0
23	44.6	26.1	35.3	41.3	0.0	85.2	11.7
24	41.4	27.6	34.5	49.6	16.2	77.2	9.1
25	39.3	28.1	33.7	53.7	12.8	60.6	7.5
26	36.1	26.7	31.4	58.4	6.2	46.2	4.8
27	36.7	27.2	31.9	59.2	8.6	44.6	8.5
28	38.7	29.7	34.2	57.6	0.0	59.0	9.4
29	34.1	27.7	30.9	66.6	6.8	40.1	6.0
30	33.3	27.5	30.4	68.2	110.0	30.6	1.7
31	34.5	27.5	31.0	68.6	67.8	25.5	6.2
32	34.1	27.3	30.7	69.1	38.4	30.2	6.4
33	33.9	26.9	30.4	64.5	0.0	39.0	8.5
34	34.1	27.0	30.6	59.6	0.0	42.0	10.1
35	32.6	25.3	28.9	67.1	11.2	28.9	4.4
36	30.8	24.5	27.7	74.3	81.8	24.6	3.8
37	32.3	23.6	27.9	71.8	48.0	28.0	7.7
38	33.6	24.8	29.2	65.1	0.0	29.0	8.9
39	33.3	23.4	28.4	57.2	0.0	31.0	9.7
40	34.1	24.9	29.5	62.6	4.8	23.2	2.9
41	31.1	17.9	24.5	59.5	5.6	25.6	8.3
42	30.1	15.7	22.9	55.1	0.0	22.4	8.8
43	30.4	18.0	24.2	59.7	2.5	16.4	3.3
44	29.1	14.1	21.6	53.8	0.0	22.2	7.2

APPENDIX-II

Weekly mean meteorological data recorded during the crop season 2014-15

Standard week	Max. temp (oC)	Min. temp (oC)	Mean temp.	Mean RH (%)	Rainfall (mm)	Total evaporation (mm)	Sunshine (hrs)
44	29.1	14.1	21.6	64.0	0.0	22.2	7.2
45	28.7	14.2	21.4	63.0	0.0	17.2	5.7
46	26.1	8.9	17.5	61.0	0.0	17.6	8.1
47	25.4	8.3	16.8	63.0	0.0	14.8	7.7
48	26.2	9.8	18.0	69.0	0.0	14.0	7.4
49	25.1	7.7	16.4	68.0	0.0	15.0	7.9
50	18.6	7.2	12.9	76.0	42.2	11.2	4.0
51	12.5	6.9	9.7	88.0	0.0	5.4	1.4
52	13.3	5.2	9.3	89.0	0.0	6.2	1.8
1	16.2	8.2	12.2	86.0	0.4	7.2	0.9
2	13.3	7.3	10.3	87.0	4.6	6.1	0.3
3	17.4	6.2	11.8	83.0	6.2	7.2	5.7
4	14.7	7.7	11.2	87.0	14.6	6.0	3.1
5	18.6	7.1	12.9	77.0	11.6	13.2	5.9
6	20.9	7.2	14.1	77.0	0.0	13.6	7.4
7	23.9	11.2	17.5	78.0	8.4	17.2	5.8
8	23.5	14.5	19.0	86.0	19.0	15.4	3.7
9	20.3	10.6	15.5	80.0	0.0	14.8	8.3
10	22.5	9.2	15.8	78.0	8.2	16.4	8.2
11	24.1	12.5	18.3	78.0	36.2	18.5	6.1
12	29.0	15.2	22.1	74.0	0.0	28.2	10.2
13	30.2	17.7	23.9	69.0	15.8	34.2	6.8
14	27.1	17.3	22.2	73.0	3.4	28.0	6.7
15	32.6	18.1	25.4	64.0	17.6	40.6	9.5
16	34.8	20.3	27.5	62.5	8.0	52.0	9.0
17	36.6	21.7	29.2	40.9	0.0	63.5	10.4
18	37.9	20.6	29.3	36.2	0.0	57.5	10.3
19	39.4	24.8	32.1	38.3	10.8	59.8	6.9
20	37.5	23.6	30.5	49.6	6.2	52.2	9.6
21	42.7	25.6	34.2	28.4	0.0	84.0	10.9
22	37.9	24.8	31.3	39.5	1.2	61.2	5.8
23	38.7	24.7	31.7	43.7	4.8	66.8	11.0
24	38.7	26.0	32.3	43.9	0.0	69.2	9.9
25	37.6	27.9	32.8	55.3	7.8	56.8	6.3
26	36.1	26.4	31.2	58.1	4.1	50.1	9.1
27	35.6	27.7	31.6	66.1	11.8	45.4	5.4
28	31.2	25.8	28.5	85.2	181.0	18.2	4.6
29	32.9	27.6	30.2	78.9	60.1	27.1	3.8
30	34.2	27.8	31.0	68.7	0.0	43.0	8.9
31	32.6	27.0	29.8	74.9	7.0	38.0	7.1
32	32.2	26.9	29.5	82.2	48.0	22.3	1.5
33	33.8	26.0	29.9	76.7	87.0	28.2	5.2
34	33.3	25.7	29.5	76.6	26.8	26.8	8.2
35	35.0	27.2	31.1	70.4	0.0	39.5	9.6
36	34.6	25.4	30.0	64.2	0.0	41.0	10.2
37	35.3	25.2	30.2	71.9	1.4	34.4	7.0
38	30.9	23.7	27.3	79.3	65.6	21.2	4.7
39	31.7	21.7	26.7	76.2	18.4	27.4	9.9
40	33.1	20.5	26.8	70.1	0.0	29.0	10.1
41	32.7	22.0	27.3	69.6	7.0	27.0	6.5
42	31.5	19.2	25.4	69.9	0.0	20.6	7.4
43	29.5	16.4	23.0	61.4	9.4	25.4	7.0
44	27.8	14.4	21.1	68.4	0.0	15.5	3.8

LIST OF SUBMITTED/ACCEPTED/PUBLISHED RESEARCH ARTICLES

S. No.	Publication	Journal	NAAS rating	Status
1.	Drip irrigation and residue management influence on performance of maize–wheat system and water productivity	Agriculture, Ecosystems & Environment (Netherlands)	9.40	Submitted
2.	Evaluation of N fertilization management strategies for increasing crop yields and nitrogen use efficiency in maize-wheat system under conservation agriculture	Nutrient Cycling in Agroecosystem	7.90	Submitted
3.	Decomposition rate and nutrient release pattern of different crop residues as affected by method of placement	Soil Biology and Biochemistry	9.93	Submitted

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Drip irrigation and residue management influence on performance of maize–wheat system and water productivity

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ABSTRACT

The extensive use of traditional irrigation systems has led to overexploitation of groundwater and overuse of surface water. In north-western India, maize based systems are being advocated as an alternate to rice-based systems to address the issues of resource degradation particularly water table and climate-change-induced variability in rainfall and temperature. Maize has a significantly lower irrigation requirement than rice and can enhance the productivity of the system, and sustain soil health and environment quality. To this effect a two year field experiment was established with annual maize–wheat rotation in the north-western IGP of India to evaluate the effect of drip irrigation and residue management on crop production and water productivity under the conservation agriculture. Grain yield of wheat and maize was significantly higher under $DIPB_{MB}$+R as compared to DIPB-R which in turn was significantly better than FIPB-R during both the years. In maize the per cent increase in grain yield was 27.1 and 23.4 under $DIPB_{MB}$+R, and 22.1 and 19.8 per cent under DIPB+R over that of FIPB-R during the year 2014 and 2015, respectively. However in wheat there is a approximately 16.1% and 15.2% increase in yield with drip irrigation along with residue retention as compared to furrow irrigation without residue retention in both the years, respectively. The highest system productivity was recorded under $DIPB_{MB}$+R (12.4 and 12.3 Mg ha^{-1}) followed by DIPB+R (9.73 and 9.60 Mg ha^{-1}) over FIPB-R and DIPB-R in both the year of experimentation. Among the different treatments highest WP under maize and wheat was obtained in $DIPB_{MB}$+R which was statistically higher than the FIPB-R and DIPB-R, but statistically at par with the DIPB+R. The study reveals that maize-wheat-moongbean system is more beneficial to the farmers along with drip irrigation and residue retention, however, the long-term effects of these alternative technologies need to be studied under varying agro-ecologies.

Key words: Drip irrigation, permanent beds, water productivity, residue management

1. Introduction

Water is an important natural resource and its increasing scarcity has led to concerns for its efficient use, management, and sustainability. At present, crop water requirements for the Punjab state are estimated to be 45.3 billion cubic meter, against the current availability of only 32.6 billion cubic meters, comprising 15.8 billion cubic meter of surface water and 12.7 billion cubic meter of groundwater resources (Minhas et al., 2010). Thus, a deficit of about 1.27 M ha-m of water is of major concern. The extensive use of traditional irrigation systems has led to overexploitation of groundwater and overuse of surface water (Mohammadzadeh et al., 2014). Modern methods of water application such as drip irrigation system come as the first choice for efficient utilization of water to sustain production, especially in wide row spaced crops like maize. Using advanced irrigation methods (sprinkler and drip) and improved water management practices are very important to water saving (Zaman et al., 2001) in crop production, particularly under conditions of water scarcity (Pereira et al., 2002, Zeng et al., 2009). Water use efficiency and yield of drip irrigated crops could be improved under limited water applications by decreasing the amount of water that leaches beneath the root zone (El-Hendawy et al., 2008). Using drip irrigation method, savings in water usage and yield increases reported by Tiwari et al., 2003 and Yuan et al., 2003. Drip fertigation is a frontier technology, which saves the fertilizers and increases the use efficiency of applied nutrients and also the yield of crop. Drip fertigation apparently increased the uptake rate of nutrients when compared to surface irrigation (Sampathkumar and Pandian, 2011).

In north-western India, maize (*Zea mays* L.) based systems are being advocated as an alternate to rice-based systems to address the issues of resource degradation particularly water table and climate-change-induced variability in rainfall and temperature, etc (Yadav et al., 2016). Maize has a significantly lower irrigation requirement than rice and can enhance the productivity of the system, and sustain soil health and environment quality (Meelu et al., 1979). In the recent past, owing to diminishing water availability as well as increasing cost of pumping for rice cultivation coupled with high yielding cultivars of maize, the acreage under maize-wheat system has shown increasing trends in India. Maize, an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons covering 9.06 m ha acreage in the country (GoI, 2015). Globally, it provides nearly 30% of the food calories to more than 4.5 billion peoples in 94 developing countries, and the demand of maize is expected to double worldwide by 2050 to meet this rising demand and thus higher maize production is need of the hour (Srinivasan et al., 2004). During past one decade (2003-04 to 2012-13), in maize area increased by 1.8%, production by 4.9% and productivity by 2.6% per annum which was mainly due to increasing maize demand in India (GoI, 2015).

Traditionally, maize and wheat are grown by broadcast seeding on flat layout after 6–7 tillage operations and using flood irrigation. The traditional practice of growing these crops is costly and results in inefficient utilization of irrigation water and nutrients leading to low productivity and input efficiency. Conservation agriculture based crop management technologies, such as no-till and permanent raised beds with residue retention and judicious crop rotation, are gaining more attention in recent years with the rising concern over degradation of natural resources, mainly soil and water, and to offset the production cost (Jat et al., 2009).Tillage practices contribute greatly to the energy and labour cost in any crop production system resulting to lower economic returns (Vivak-Kumar et al., 2013). No-till system is now being widely used by farmers in many parts of the world. The origin and use of permanent raised beds have traditionally been associated with water management issues, either by providing opportunities to reduce the adverse impact of excess water on crop production or to irrigate crops in semi-arid and arid regions (Gathala et al., 2011a). The permanent raised beds with only superficial reshaping in the furrows between the raised beds as needed before planting of each succeeding crop can reduce cultivation costs and increase sustainability of maize-wheat system (Govaerts et al., 2005). Moreover, it controls machine traffic, limiting compaction to furrow bottoms, allows the use of lower seeding rates than with conventional till flat planting systems and reduces crop lodging (Sayre and Moreno-Ramos, 1997). Published experimental results across the globe have shown increased productivity and soil quality, mainly through SOM build-up (Ladha et al., 2009, Bhattacharyya et al., 2013) and higher SOC content under zero-tilled compared to conventionally tilled soils (Parihar et al., 2016a). Akbar et al., (2007) reported that there was about 36% water saving for broad-beds and about 10% for narrow-beds compared to flat sowing, and grain yield increased by 6% for wheat and 33% for maize. Devkota et al., (2013) reported that grain yields of wheat and maize after cotton increased by 12 and 42% under PB than under CT, respectively. Under PB, water productivity increased by 27% in wheat and 84% in maize compared to CT in irrigated lands of central Asia. Residue retention on PB increased the grain yield of wheat and maize by 5% and 15% compared to residue removed, respectively.

Keeping these considerations in view, the present study was planned. The hypothesis was that drip fertigation along with residue management may produce a higher grain yield without affecting crop phenology. Therefore, the experiment was conducted to determine the effect of drip fertigation and crop residue management on performance of maize-wheat.

2 Material and methods

2.1. Experimental site and soil characteristics

Field experiment on maize-wheat system was conducted for two consecutive years (2013-14 and 2014-15) at Borlaug Institute for South Asia (BISA), Ladhowal (30.99◦N latitude, 75.44◦E longitude and at an elevation of 229 m above mean sea level), Punjab located in Trans-Gangetic alluvial plains of India. Before 2013, the field was under maize-wheat system for the last three years and received recommended mineral fertilization for both crops. The soil (0–15 cm layer) of the experimental field was sandy loam in texture, with pH 8.4, Walkley-Black organic C 5.40 g kg^{-1}, electrical conductivity 0.260 dS m^{-1}, $KMnO_4$ oxidizable N 167.4 kg ha^{-1}, 0.5 M $NaHCO_3$ extractable P 33.60 kg ha^{-1}, and 1N NH_4OAc extractable K 198 kg ha^{-1}.

2.2. Climate characteristics

Experimental site represented the sub-tropical climate with hot and dry (May–June) to wet summers (July–November) during the maize growing season and cool dry winters (December–April) during wheat growing season with mean annual rainfall of 680 mm and nearly 80% is received during the cotton season. The mean maximum and minimum temperatures show considerable variations during different months of the year. Temperature often exceeds 38°C during summer and sometimes touches 45°C with dry spells during May and June. Minimum temperature falls below 0.5°C with some frosty spells during the winter months of December and January. The average annual pan evaporation is about 850 mm. May and June are the hottest month (40-44.8◦C), while January is the coldest month (as low as 1.6◦C). During crop season of 2013-14, the weakly mean temperature ranged between 10.3°C in the 1st SMW (1-7 January) and 35.3°C in the 23rd SMW, while in 2014-15, the weakly mean temperature ranged between 9.3°C in the 52nd SMW (24-31 December) and 34.0°C in the 21th SMW (Fig. 1). Wheat in 2013-14 experienced lower minimum temperature in the month of January compared to that in 2014-15, while the trend in maximum temperature was reversed during the same period. In 2013-14 rainfall of 635.3 mm was recorded during crop season with maximum rainfall of 110.0 mm received in 30th SMW, while in 2014-15 rainfall of 754.6 mm was recorded during crop season with maximum rainfall of 181.0 mm received in 28th SMW.

2.3. Treatments and experimental design

The experiment was laid out in a split plot design with four main treatments and five sub treatments. The main treatments were the combinations from residue management and method of irrigation. i.e. residue removed and residue retained, furrow irrigation and drip irrigation. The sub treatments consist of five levels of N i.e. zero, 50, 75, 100 per cent of recommended N and fifth level of N on the basis of nutrient expert (computer based software). Each experimental unit was 81 m^2 (4.05 m × 20 m) in gross. The treatment details are given in Table 1.

2.4. Formation o f permanent raised beds

Before establishment of the cover crop at the start of experiment, the field was ploughed using disc plough to break hard pan if any. Thereafter, it was pulverized at the optimum moisture level (field capacity) with a cultivator and then levelled using a laser-assisted precision land levelling system attached with a 60- horsepower (hp) tractor. Permanent raised beds were made with a bed planter at a distance of 67.5 cm from top of the one bed to top of the second bed with 37.5 cm top and 30 cm furrow and bed height of 8 inch for sowing of crop, which can accommodate one row of maize and two rows of wheat (Fig 2). These permanent beds were reshaped during sowing of succeeding crops with bed planter during both years.

2.5. Crop management

2.5.1. Maize

The maize hybrid PMH-1 was sown with one row on top of the raised beds at a spacing of 67.5 cm between two beds and 20 cm plant to plant distance in all treatments by using the double-disc drilling machine. The seed rate of maize used was 20 kg ha^{-1}. Seed was treated with Gaucho (imidacloprid) 600 FS @ 6.0 ml per kg seed before planting for protection against attack of shoot fly and with Bavistin (carbendazim) @ 3g per kg seed for protection against various fungal diseases. Nitrogen was applied as per treatment in each experimental unit through fertigation in seven splits after 20 days of sowing at 10 days interval by taking the recommended dose of nitrogen as 120 kg ha^{-1}. Rate of nitrogen application as worked out was 60, 90, 120 and 140 kg N ha^{-1} for treatments of 50, 75, and 100 per cent of recommended nitrogen dose and for NE treatment, respectively. While whole of the P and K @ 60 kg P_2O_5 and 30 kg K_2O ha^{-1}, respectively was applied at the time of seeding by drilling the DAP, balance of fertilizer N (total minus added through DAP at the time of sowing) was applied through fertigation. Extra plants in the rows were thinned to maintain intra-row spacing at three weeks after sowing. The gap filling was accomplished immediately after the germination in order to maintain optimum and uniform plant population. Herbicide Atrataf 50 WP (atrazine) was applied as pre-emergence @ 1.25 kg ha^{-1} using 500 litres of water with knap sack sprayer using flat fan nozzle for controlling the weeds. One inter-cultivation was done at knee high stage with the tractor operated reshaper, by hoeing the soil which besides checking weed growth provides good aeration to plant roots. One hand weeding was also done at 55 days after planting. Tank mix solution of chlorpyrifos (20 EC) and endosulfan (Thiodone @ 0.03%) was sprayed once in the standing crop in order to control stem borer and termite infestation.

2.5.2. Wheat

Wheat variety HD-2967 was sown with a seed rate of 100 kg ha^{-1} in second week of November. Seed was treated with chlorpyrifos (20EC, 400 ml 100-kg-$seed^{-1}$ mixed in 5 l of water) to control termite attack. Recommended doses of 120 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1}were applied as urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively, in both the years. Nitrogen was applied as per treatment in each experimental unit through fertigation in five splits after 25 days of sowing at 10 days interval by taking the recommended dose of nitrogen as 120 kg ha^{-1}. Rate of nitrogen application as worked out was 60, 90, 120 and 140 kg N ha^{-1} for treatments of 50, 75, 100 per cent of recommended nitrogen dose and for NE treatment, respectively. While whole of the P and K @ 60 kg P_2O_5 and 30 kg K_2O ha^{-1}, respectively was applied at the time of seeding by drilling the DAP, balance of fertilizer N (total minus added through DAP at the time of sowing) was applied through fertigation. Tank mix solution of Total (sulfosulfuron + metsulfuron) at 16 g ha−1was applied to control Phalaris minor weed at 25–30 DAS.

2.5.3. Moongbean

Mungbean (var. SML-668) was relay sown wit wheat in third week of March, when the wheat crop was at maturity stage in both years by kera-pora method with a seed rate of 20 kg ha^{-1}. Moongbean seeds were treated with cultures of Rhizobium and phosphate solubilizing bacteria before seeding. Two rows of moongbean were planted in DIPB+R_{Mb} treatment on the sides of furrow No pesticides were used in moongbean crop.

2.6. Irrigation management

The irrigation was applied on the basis of tensiometer reading, by using soil matric potential of 35 kPA at 15 cm depth. Every drop of water applied to the plots was recorded by using the water meter(DasmeshMechanical Works, Punjab, India) installed at the main pipe of the water source to calculate the water use efficiency of the crop. Total amount of irrigation water (cm) applied was computed for each crop. Moongbean received one post-sowing irrigation in addition to the pre-sowing irrigation as and when required depending on the rains.

2.7. Crop residue management

Maize harvest manually at cob height and 50 % stover (below cob portion) was left standing in all residue management treatments except residue removed treatments, in which maize harvested at ground level and all maize stover removed from field. After wheat harvest, all the loose residues were removed and only the anchored wheat stubbles were retained after straw retrieval in residue retained treatments and remove of wheat stables after straw retrieval in case of residue removed treatments. In case of moongbean all the residues after removing grains were retained in DIPB+R_{Mb} plots. Residue load was calculated on dry weight basis.

2.8. Yield measurement

At maturity, grain yield of maize and wheat was determined on an area of 13.5 m^2 (4 beds × 5 m long) in the middle of each plot. Grain yields of maize and wheat are reported at 14.5% and 12% grain moisture content, respectively.

2.9. Wheat equivalent yield

To express the overall impact of different treatments, system productivity was calculated on wheat equivalent yield (WEY) basis for maize and moongbean grain yields. System productivity (Mg ha^{-1}) was computed using Eq. (3).

WEY (Mg ha^{-1}) = {Maize/Moongbean yield (Mg ha^{-1}) × MSP of Maize/ Moongbean (‘Mg ha^{-1})}/MSP of wheat (‘Mg ha^{-1})} .... (3)

Where, MSP is the minimum support price fixed by the Government of India; ‘ is the Indian Rupee

2.10. Water productivity (WP)

The water productivity was calculated by the formula (Reddi and Reddy 2006).

$$\mathrm{WUE} = \frac{\mathrm{Y}}{\mathrm{W}}$$

Where,

WUE = Water productivity (kg $ha^{-1}cm^{-1}$)

Y = Grain yield (kg ha^{-1})

W = Irrigation water applied (cm) to the crop

2.11. Statistical analysis

The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for split plot design using SAS 9.1 software (SAS Institute, Cary, NC). Treatment differences were compared at 5% level of significance.

3. Results

3.1. Crop yields

Irrigation and residue management affected yield and yield attributes and water productivity by significantly and thus has been discussed in detail along with the supporting studies. The various interaction effects were also not significant for various parameters. Hence, to avoid repetition have not been discussed under the individual parameters. Only the effects of main treatments and sub treatments have been discussed.

3.1.1. Maize

Grain yield is function of cob length, no of cobs palnt^{-1} and 1000-grain weight etc. The grain yield of maize crop was significantly influenced due to different irrigation, residue and legume treatments. The data regarding grain yield presented in Table 2. Grain yield was significantly higher under $DIPB_{MB}$+R (6.20 and 6.17 t ha^{-1}) as compared to DIPB-R (5.41 and 5.57 t ha^{-1}) which in turn was significantly better than FIPB-R (4.88 and 5.00 t ha^{-1}) during both the years. However grain yield obtained under DIPB+R (5.96 and 5.99) was significantly at par with the $DIPB_{MB}$+R (6.20 and 6.17 t ha^{-1}) during both the years, respectively. The per cent increase in grain yield was 27.05 and

23.40 under $DIPB_{MB}$+R, and 22.13 and 19.80 per cent under DIPB+R over that of FIPB-R during the year 2014 and 2015, respectively. Among the different treatments, the straw yield recorded under $DIPB_{MB}$+R (12.75 and 12.67 t ha^{-1}) and DIPB+R (12.23 and 12.46 t ha^{-1}) statistically at par but recorded significantly higher straw yield as compared to the FIPB-R (10.30 and 10.71t ha^{-1}) during both the years of study. The straw yield recorded under the DIPB-R (11.42 and 11.70 t ha^{-1}) was significantly higher than the FIPB-R (10.30 and 10.71 cm) but statistically at par with the DIPB+R (12.23 and 12.46 t ha^{-1}).

Grain and straw yield increased with increase in N-levels from $RN_{50\%}$ i.e. 60 kg N ha^{-1} to NE i.e. 140 kg N ha^{-1}. The treatment NE i.e. 140 kg N ha^{-1} was significantly superior than $RN_{75\%}$ i.e. 90 kg N ha^{-1} but was at par with $RN_{100\%}$ i.e. 120 kg N ha^{-1} on the basis of grain yield during both the years of study. The yield under $RN_{100\%}$ i.e. 120 kg N ha^{-1} (6.48 and 6.54 t ha^{-1}) was statistically higher than recorded under $RN_{50\%}$ i.e. 60 kg N ha^{-1} (5.17 and 5.04 t ha^{-1}) but it was at par with that obtained under $RN_{75\%}$ i.e. 90 kg N ha^{-1} (6.23 and 6.43 t ha^{-1}). The per cent increase in grain yield was 30.17 and 36.71 under NE i.e. 140 kg N ha^{-1} and 25.3 and 29.76 per cent under $RN_{100\%}$ i.e. 120 kg N ha^{-1} over that of $RN_{50\%}$ i.e. 60 kg N ha^{-1} during 2014 and 2015, respectively. The corresponding increase in grain yield under $RN_{100\%}$ i.e. 120 kg N ha^{-1} was 4.01 and 1.71 per cent over $RN_{75\%}$ i.e. 90 kg N ha^{-1} for the two years, respectively. Highest straw yield was obtained under NE i.e. 140 kg N ha^{-1} which was statistically at par with the yield recorded under $RN_{100\%}$ i.e. 120 kg N ha^{-1} and both the N-levels were significantly better than $RN_{50\%}$ i.e. 60 kg N ha^{-1}. However the yield under $RN_{100\%}$ i.e. 120 kg N ha^{-1} (13.20 and 13.62 t ha^{-1}) was statistically higher than recorded under $RN_{50\%}$ i.e. 60 kg N ha^{-1} (11.02 and 10.74 t ha^{-1}) but it was statistically at par with that obtained under $RN_{75\%}$ i.e. 90 kg N ha^{-1} (12.90 and 13.42 t ha^{-1}). The per cent increase in straw yield was 23.50 and 30.6 under NE i.e. 140 kg N ha^{-1} and 19.78 and 26.8 per cent under $RN_{100\%}$ i.e. 120 kg N ha^{-1} over that of $RN_{50\%}$ i.e. 60 kg N ha^{-1} during 2014 and 2015, respectively. The N level NE i.e. 140 kg N ha^{-1} and $RN_{100\%}$ i.e. 120 kg N ha^{-1} were statistically better by 5.50 and 4.55 per cent and 2.33 and 1.49 per cent respectively over $RN_{75\%}$ i.e. 90 kg N ha^{-1} during the two years, respectively.

3.1.2. Wheat

The data regarding grain yield of wheat presented in Table 3. Among the different treatments highest grain yield was obtained in $DIPB_{MB}$+R (4.40 and 4.54 t ha^{-1}) which was statistically similar with DIPB+R (4.35 and 4.38) and, statistically higher than the FIPB-R (3.79 and 3.94 t ha^{-1}) and DIPB-R (4.08 and 4.20 t ha^{-1}). There is a approximately 16.09% and 15.22% increase in yield with drip irrigation along with residue retention as compared to furrow irrigation without residue retention in both the years, respectively. Straw yield was obtained in $DIPB_{MB}$+R (5.55 and 5.79 t ha^{-1}) was statistically higher than the FIPB-R (4.77 and 4.89 t ha^{-1}), but statistically similar with DIPB+R (5.50 and 5.49 t ha^{-1}) and DIPB-R (5.45 and 5.42 t ha^{-1}). However, the nitrogen levels significantly influenced the grain yield. All fertilizer treatments produced significantly higher grain yield than unfertilised control in both the years. The nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher grain yield than control and nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1}, but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1}. Fertigation with nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} produced similar yield with the nitrogen level $RN_{100\%}$ i.e 120 kg N ha^{-1}, and thereby saving the 25% of the nitrogen fertilizer. he nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher straw yield than control, nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} and nitrogen level of $RN_{75\%}$ i.e 90 kg N ha^{-1} but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1}.

3.2. System productivity

The system productivity of maize–wheat-moongbean (wheat equivalent yield) cropping system was influenced significantly during the year 2013-14 and 2014-15 (Table 4). In general, the system productivity enhanced in $DIPB_{MB}$+R over the other main treatments. The highest system productivity was recorded under $DIPB_{MB}$+R (12.40 and 12.32 t ha^{-1}) followed by DIPB+R (9.73 and 9.60 t ha^{-1}) over FIPB-R and DIPB-R in both the year of experimentation. The lowest system productivity was obtained under FIPB-R (8.20 and 8.28 t ha^{-1}) followed by PB (8.97 and 9.04 t ha^{-1}) as compared to $DIPB_{MB}$+R and FIPB-R during both year of study, respectively. The treatment PB+GG increased system productivity like 51.22 and 48.79 % as compared to FIPB-R during 2013-14 and 2014-15, respectively. The WEY of the system maize–wheat-mungbean cropping system was significantly influenced due to different N levels. The system productivity was increased from $RN_{75\%}$ to $RN_{100\%}$ to NES. The highest system productivity was recorded under NES, which was significantly higher than $RN_{75\%}$ and $RN_{100\%}$ in both the years.

3.3. Irrigation water productivity

Irrigation and WP are positively correlated with grain yield of the crop and negatively correlated with amount of irrigation water applied (Table 5). Among the different treatments highest WP under maize was obtained in $DIPB_{MB}$+R (659.82 and 609.89 kg ha^{-1}-cm) which was statistically higher than the FIPB-R (172.55 and 174.03 kg ha^{-1}-cm) and DIPB-R (421.73 and 480.02 kg ha^{-1}-cm), but statistically at par with the DIPB+R (634.05 and 591.89 kg ha^{-1}-cm). However in wheat the lowest WP was obtained under FIRB-R (131.55 and 147.65 kg ha^{-1}-cm) as compared to the all other treatments during 2012-13 and 2013-14. In both the years $DIPB_{MB}$+R (226.98 and 245.72 kg ha^{-1}-cm) gave significantly higher WP as compared to the FIRB-R (131.55 and 147.65 kg ha^{-1}-cm) and DIPB-R (192.27 and 214.78 kg ha^{-1}-cm). All fertilizer treatments produced significantly higher WP than unfertilised control in both the years. In maize the nitrogen level of NE i.e 140 kg ha^{-1} had significantly higher WP (233.21 and 258.07 kg ha^{-1}-cm) than control (117.92 and 130.69 kg ha^{-1}-cm), nitrogen level of $RN_{50\%}$ i.e 60 kg N ha^{-1} (172.36 and 187.33 kg ha^{-1}-cm) and nitrogen level of

$RN_{75\%}$ i.e 90 kg N ha^{-1} (219.42 and 239.74 kg ha^{-1}-cm), but statistically at par with nitrogen level of $RN_{100\%}$ i.e 120 kg N ha^{-1} (225.67 and 246.83 kg ha^{-1}-cm). The higher WP with increase in the N level was mainly due to the increase in grain yield with successive increase in N rate. In wheat crop the lowest WP was obtained under FIRB-R (131.55 and 147.65 kg ha^{-1}-cm) as compared to the all other treatments during 2012-13 and 2013-14. In both the years $DIPB_{MB}$+R (226.98 and 245.72 kg ha^{-1}-cm) gave significantly higher WP as compared to the FIRB-R (131.55 and 147.65 kg ha^{-1}-cm) and DIPB-R (192.27 and 214.78 kg ha^{-1}-cm).

4. Discussion

Inappropriate management practices in the past have led to the twin challenges of resource depletion and decelerating productivity growth of cereal crops (Jat et al., 2009). Future global food security relies not only on high production and access to food but also on the need to address the destructive effects of current agricultural production systems on ecosystem sustainability and increase the resilience of production systems to the effects of climate change (Foresight, 2011). Declining soil fertility, erratic precipitation patterns, high input costs and unstable market conditions have all affected the profitability, sustainability and therefore the livelihood of the small holder farming sector (Marongwe et al., 2012). Grain yield of wheat and maize was significantly higher under $DIPB_{MB}$+R as compared to DIPB-R which in turn was significantly better than FIPB-R during both the years. In maize the per cent increase in grain yield was 27.05 and 23.40 under $DIPB_{MB}$+R, and 22.13 and 19.80 per cent under DIPB+R over that of FIPB-R during the year 2014 and 2015, respectively. However in wheat there is a approximately 16.09% and 15.22% increase in yield with drip irrigation along with residue retention as compared to furrow irrigation without residue retention in both the years, respectively. The higher grain yield under drip irrigation as compared to furrow irrigation might be due to the fact that as water and nutrient is applied very frequently and uniformly, usually there is no moisture stress in crop root zone and it results into 25 to 30 per cent increase in crop yield as compared to surface irrigated crop (Wang et al., 2013) reported 39% higher maize yield with drip irrigation as compared to surface irrigation. The significantly higher yield of wheat under $DIPB_{MB}$+R in comparison to FIPB-R was may also attributed to increase in cob length and 1000-grain weight which was enhanced by optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues. Parihar et al., (2016) also showed the positive effects of PB and residue retention on grain yield of maize. The inclusion of summer legumes in pre-ceding season might have improved the soil fertility; particularly N availability thereby improved growth and yield of maize Sharma and Behera (2009) also reported that growth and yield of maize was improved significantly after inclusion of a summer legume into the maize-wheat system as compared with fallow. As water and nutrient is applied very frequently and uniformly, usually there is no moisture stress in crop root zone and it results into 25 to 30 per cent increase in crop yield as compared to surface irrigated crop

(Wang et al., 2013, Pawar et al 2014).The significantly higher yield of wheat under $DIPB_{MB}$+R in comparison to FIPB-R was mainly attributed to increase in effective tillers m^{-2}, spike length and 1000- grain weight which was enhanced by optimum and favourable soil moisture. The increase in growth and yield owing to the application N fertilizer may be attributed to the fact that this nutrient being constituents of nucleotides, protein, enzymes and chlorophyll which have direct positive effect on reproductive and vegetative growth. Kachroo and Razdan (2006) observed the similar effects. These results are in agreement with Khan et al., (2001) who reported that grain yield increased with increasing nitrogen. Ram et al., (2002) also reported significant increase in grain yield up to 120 kg N ha^{-1}. Singh et al., (2009) also studied the same nitrogen effects of nitrogen levels on grain yield. Grain yield was increased from 15.75 to 17.09 q ha^{-1} with increase in nitrogen level from 0 to 75 kg N ha^{-1}, showing a linear trend (Khan et al., 2011). Singh et al., (2011) showed that the recommended practice of 120 kg N ha^{-1} increased the wheat yield by 61-95% over the control without N fertilizer.

The treatment PB+GG increased system productivity like 51.22 and 48.79 % as compared to FIPB-R during 2013-14 and 2014-15, respectively. The higher system productivity under $DIPB_{MB}$+R was due to good crop growth, higher values of yield attributes and yield under this treatment. Maize and wheat performed significantly better under $DIPB_{MB}$+R, while mungbean was the also component under $DIPB_{MB}$+R treatment, thus contribution of all crops resulted in higher productivity of the system under this treatment. The higher WUE in drip irrigation as compared to the furrow irrigation was mainly due to reduction in irrigation water requirement in drip as compared to the furrow irrigation. The better root growth and lower infestation of weeds in the drip irrigation was might be other possible reasons of higher IWP under $DIPB_{MB}$+R. The higher WP in residue retained plots as compared to the residue removed plots might be due to residue retention, which might suppressed the weed growth and also helped in soil moisture conservation that made available for the longer durations to the crop. Jat et al., (2005) reported that irrigation water use (m^3 ha^{-1}) in both maize and wheat was highest (3231 and 3700) under conventional till followed by zero-till (2723 and 2934) and the lowest being (2030 and 2619) under FIRB planting system, respectively. Remarkably higher water productivity (kg grain m^{-3} water) of either crop of maize and wheat was recorded in FIRB planting (2.79 and 1.98) followed by flat no-till (1.74 and 1.89) and the lowest (1.36 and 1.38) in conventional-till system. The increase in water productivity is the resultant of both increase in yield and saving in irrigation water.

5. Conclusions

The study showed that maize-wheat-moongbean system is more beneficial to the farmers along with drip irrigation and residue retention. The drip irrigation system along with residue retention was superior to drip irrigation without retention and furrow irrigation without residue retention when taking into account grain and straw yield, water productivity and system productivity in a sandy loam soil.

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References

Akbar, G., Hamilton, G., Hussain, Z. and Yasin, M. (2007) Problems and potentials of permanent raised bed cropping systems in Pakistan. Pak. J. Water Res. 11, 11–21.

Bhattacharyya, R., Das, T.K, Pramanik, P., Ganeshan, V., Saad, A.A. and Sharma, A.R. (2013) Impacts of conservation agriculture on soil aggregation and aggregate-associated N under an irrigated agroecosystem of the Indo-Gangetic Plains. Nutr Cycl Agroecosyst 96,185–202.

El-Hendawy, S. E., El-Lattief, E. A., Ahmed, A. S and Schmidhalter, U (2008) Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. Agric Water Manage 95**,** 836-44.

Foresight (2011) The future of food and farming. Published by Government Office for Science.

Gathala M. K., Ladha, J. K., Kumar, V., Saharawat, Y. S., Kumar, V., Sharma, P. K., Sharma, S., and Pathak, H. (2011a.) Tillage and crop establishment affects sustainability of South Asian rice–wheat system. Agron. J. 103, 961–971.

Govaerts, B., Sayre, K. D., Goudeseune, B., De Corte, P., Lichter, K., Dendooven, L. and Deckers J. (2009) Conservation agriculture as a sustainable option for the central Mexican highlands. Soil Till Res, 103, 222-230.

Jat, M. L., Gathala, M. K., Ladha, J. K., Saharawat, Y. S., Jat, A. S., Kumar, V., Sharma, S. K., Kumar, V. and Gupta, R. K. (2009) Evaluation of precision land levelling and double zero-till systems in the rice–wheat rotation: water use, productivity, profitability and soil physical properties. Soil Till Res 105**,** 112–21.

Jat, M. L., Singh, S., Rai, H. K., Chhokar, R. S., Sharma, S. K., Gupta, R. K. (2005) Furrow irrigated raised bed planting technique for diversification of rice–wheat system of Indo-Gangetic Plains. J Japan Assoc Int Coop Agric Forestry 28**,** 25–42.

Kachroo, D. and Ravinder, R. (2006) Growth, nutrient uptake and yield uptake as influenced by biofertilizers and nitrogen. Indian J Agron 51,37-39.

Khan, M. I., Jan, A., Hussain, N., Jan, M. T. and Qadoos, M. (2011) Rainfedwheat response to tillage and nitrogen. Sarhad J Agric 27, 519: 23.

Ladha, J.K., Singh, Y., Erenstein, O. and Hardy, B. (eds.) (2009) Integrated Crop and Resource Management in the Rice–Wheat Systems of South Asia. International Rice Research Institute, Los Banos, Philippines, pp. 395.

Marongwe, L. S., Nyagumbo, I., Kwazira, K., Kassam, A. and Friedrich, T. (2012) Conservation agriculture and sustainable crop intensification: A Zimbabwe case study. Integ crop manage 17, 1-44

Meelu, O. P., Yadvinder-Singh and Bijay-Singh (1994) Green manuring for Soil Productivity Improvement. FAO World Soil Resources Reports No. 76. Pp123.

Minhas, P. S., Jalota, S. K., Arora, V. K., Jain, A. K., Vashist, K. K., Choudhary, O. P., Kukkal, S. S. and Vashist, B. B. (2010) Managing water resources for ensuing sustainable agriculture: situational analysis and options for Punjab. Research Bulletin No. 2/2010.

Mohammadzadeh, S., Sadighi, H.. and Rad, G. P. (2014). Modeling the Process of Drip Irrigation System Adoption by Apple Orchardists in the Barandooz River Basin of Urmia Lake Catchment, Iran. J. Agr. Sci. Tech., 16, 1253-66.

Parihar, C.M., Jat, S.L., Singh, A.K., Kumar, B., Yadvinder-Singh, Pradhan, S., Pooniya, V., Dhauja, A., Chaudhary, V., Jat, M.L., Jat, R.K. and Yadav, O.P. (2016) Conservation agriculture in irrigated intensive maize-based systems of north-western India: effects on crop yields, water productivity and economic profitability. Field Crops Res, 193**,** 104-116.

Parihar, C.M., Yadav, M.R., Jat, S.L., Singh, A.K., Kumar, B., Pradhan, S., Chakraborty, D., Jat, M.L., Jat, R.K., Saharawat, Y.S., and Yadav, O.P. (2016a) Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. Soil Till Res 161, 116-128.

Pereira, L. S., Oweis, T. and Zairi, A. (2002) Irrigation management under water scarcity. Agric Water Manage 57, 175-206

Ram, T., Yadav, S. K. and Sheoran, R. K. (2002) Nutrient uptake pattern of wheat (*Triticum aestivum* L.) as Influenced by azotobacter and nitrogen fertilization environment and ecology. Environ Eco 20, 661-65.

Sampathkumar, T. and Pandian, B. J. (2010) Efficiency of applied nutrients and SPAD values in hybrid maize under drip fertigation. Madras Agric J 97, 237-41.

Sayre, K. D. and Moreno-Ramos, O. H. (1997) Applications of raised-bed planting systems to wheat. Mexico DF, Mexico, CIMMYT. In: Int. Wheat Special Report 31. pp. 28.

Sharma, A. R. and Behera, U. K. (2009) Nitrogen contribution through sesbania green manure and dual-purpose legumes in maize–wheat cropping system: agronomic and economic considerations. Plant Soil 325, 289-304.

Singh, Y., Gupta, R. K., Singh, G., Singh, J., Sidhu, H. S. and Singh, B. (2009) Nitrogen and residue management effects on agronomic productivity and nitrogen use efficiency in rice-wheat system in Indian Punjab. Nutr Cycl Agroecosyst 84, 141-154.

Singh, Y., Singh, M., Sidhu, H. S. and Blackwell, J. (2011) Enhancing nitrogen use efficiency in wheat sown into rice residue and effect of straw management on soil health in rice-wheat system in North West India.

Srinivasan, G., Zaidi, P. H., Prasanna, B. M., Gonzalez, F. and Lesnick, K. (Eds.) (2004) Proceedings of Eighth Asian Regional Maize Workshop: New Technologies forthe New Millennium. Bangkok, Thailand, 5–8 August 2002. CIMMYT, Mexico, DF.

Tiwari, K. N., Singh, A. and Mal, P. K. (2003) Effect of drip irrigation on yield of cabbage (Brassica oleracea L., va.Capitata) under mulch and non-mulch conditions. Agric Water Manage 58, 19–28.

Vivak-Kumar, Saharawat, Y. S., Gathala, M. K., Jat, A. S., Singh, S. K, Chaudhary, N., Jat, M.L. (2013) Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in Indo-Gangetic plains. Field Crop Res. 142, 1–8.

Wang, H. and Zhou, J. (2013) Rootzone fertilizationA key and necessary approach to improve fertilizer use efficiency and reduce nonpoint source pollution from the cropland Soils 05, 785–790 (In Chinese)

Yadav M R , Parihar C M, Jat S L,Singh A K ,Kumar D,Pooniya V, Parihar M D, Saveipune D, Parmar H and Jat M L (2016) Effect of long-term tillage and diversified crop rotations on nutrient uptake, profitability and energetics of maize (*Zea mays*) in north-western India. Indian J Agri Sci **86 (6):** 743–49.

Yuan, B. Z., Nishiyama, S. and Kang, Y. (2003) Effects of different irrigation regimes on the growth and yield of drip irrigated potato. Agric Water Manage 63, 153–67

Zaman, W. U., Arshad, M. and Saleem, A. (2001) Distribution of nitrate nitrogen in the soil profile under different irrigation methods. Int J Agric Biol 2, 208–09

Zeng, C., Bie, Z. and Yuan, B. (2009) Determination of optimum irrigation water amount for drip-irrigated muskmelon (*Cucumis melon* L.) in plastic greenhouse. Agric Water Manage 96, 595–602

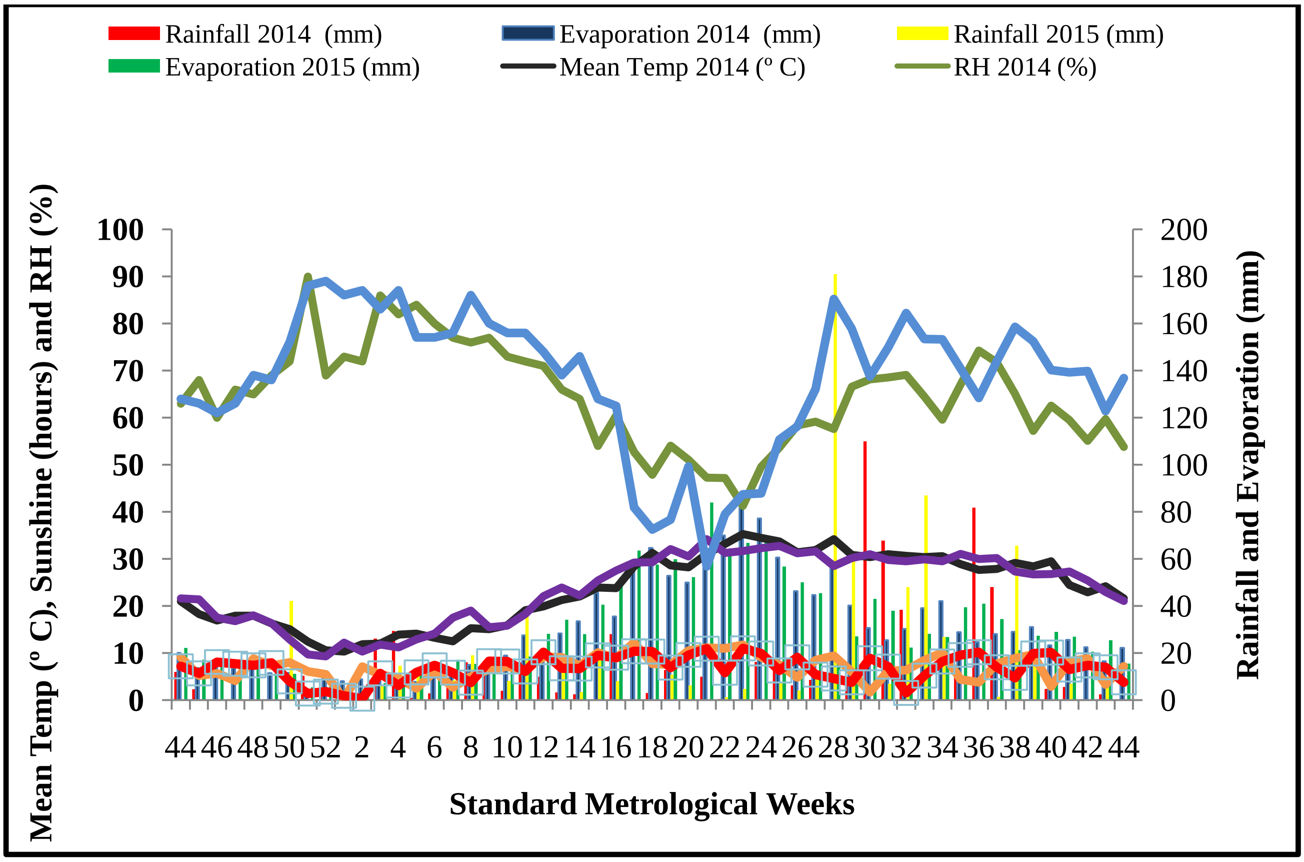

Fig. 1: Graphical presentation of mean temperature, sunshine, evaporation, rainfall and relative humidity during crop season for the year 2014 and 2015

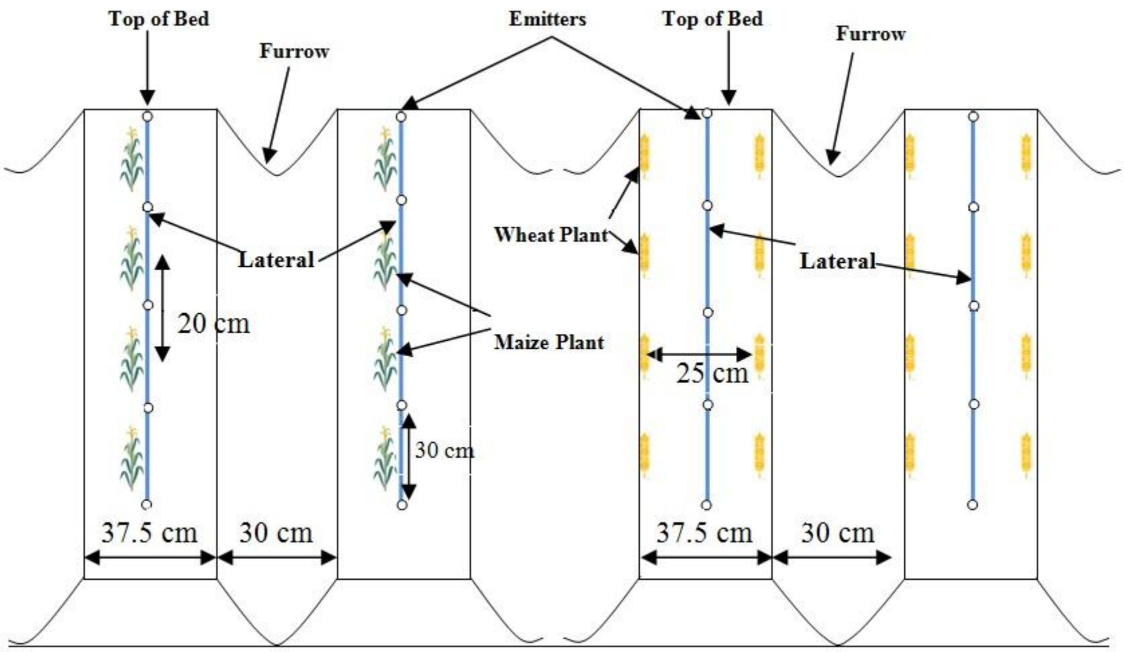

Fig 2: Layout of permanent raised beds and drip irrigation

Table 1: Detail of treatments for Experiment-I

Treatments	Symbol
Main Treatments: Tillage and straw management systems	
Permanent raised bed-residue removed-furrow irrigation	FIPB-R
Permanent raised bed -residue removed – fertigation	DIPB-R
Permanent raised bed -residue retained (maize 50% + wheat 25%) – fertigation	DIPB+R
Permanent raised bed -residue retained (maize 50% + wheat 25% + mungbean 100%) – fertigation	$DIPB_{Mb}$+R
Sub Treatments: Rates of N	
Zero- N	N_0
50% of recommended N (60 kg N ha^{-1})	$RN_{50\%}$
75% of recommended N (90 kg N ha^{-1})	$RN_{75\%}$
100% of recommended N (120 kg N ha^{-1})	$RN_{100\%}$
Nutrient expert (140 kg N ha^{-1})	NES

Table 2: Effect of residue, irrigation and N management on grain and straw yield of maize

Treatments	Grain yield (Mg ha^{-1})			Straw yield (Mg ha^{-1})		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
Irrigation and residue management						
FIPB-R	4.88	5.00	4.94	10.30	10.71	10.50
DIPB-R	5.41	5.57	5.49	11.42	11.70	11.56
DIPB+R	5.96	5.99	5.98	12.23	12.46	12.35
$DIPB_{MB}$+R	6.20	6.17	6.19	12.75	12.67	12.71
SEm±	**0.133**	**0.115**	**0.062**	**0.258**	**0.214**	**0.136**
LSD (P=0.05)	**0.469**	**0.406**	**0.175**	**0.909**	**0.756**	**0.382**
Nitrogen levels						
RN_0	3.46	3.40	3.43	7.64	7.59	7.62
$RN_{50\%}$	5.17	5.04	5.11	11.02	10.74	10.88
$RN_{75\%}$	6.23	6.43	6.33	12.90	13.42	13.16
$RN_{100\%}$	6.48	6.54	6.57	13.20	13.62	13.41
NES	6.73	6.89	6.81	13.61	14.03	13.82
SEm±	**0.094**	**0.083**	**0.070**	**0.210**	**0.198**	**0.152**
LSD (P=0.05)	**0.273**	**0.239**	**0.196**	**0.607**	**0.572**	**0.428**

Table 3: Effect of residue, irrigation and N management on grain and straw yield of wheat

Treatments	Grain yield (Mg ha^{-1})			Straw yield (Mg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Irrigation and residue management						
FIPB-R	3.79	3.94	3.87	4.77	4.89	4.83
DIPB-R	4.08	4.20	4.14	5.45	5.42	5.44
DIPB+R	4.35	4.38	4.37	5.50	5.49	5.49
$DIPB_{MB}$+R	4.40	4.54	4.47	5.55	5.79	5.67
SEm±	**0.061**	**0.054**	**0.037**	**0.124**	**0.100**	**0.057**
LSD (P=0.05)	**0.215**	**0.190**	**0.104**	**0.437**	**0.351**	**0.160**
Nitrogen levels						
RN_0	2.53	2.62	2.58	3.17	3.31	3.24
$RN_{50\%}$	3.69	3.78	3.74	5.02	4.78	4.90
$RN_{75\%}$	4.70	4.84	4.77	5.90	6.07	5.99
$RN_{100\%}$	4.84	4.98	4.91	6.06	6.23	6.17
NES	5.01	5.11	5.06	6.43	6.53	6.48
SEm±	**0.062**	**0.053**	0.041	**0.085**	**0.078**	0.064
LSD (P=0.05)	**0.178**	**0.154**	0.117	**0.246**	**0.225**	**0.179**

Table 4: Effect of residue, irrigation and N management on grain yield of maize, wheat and system productivity (wheat equivalent)

Treatments	Wheat (Mg ha^{-1})		Maize (Mg ha^{-1})		System Productivity (Mg ha^{-1})		
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	Pooled
Irrigation and residue management							
FIPB-R	3.79	3.94	4.88	5.00	8.20	8.28	8.24
DIPB-R	4.08	4.20	5.41	5.57	8.97	9.04	9.00
DIPB+R	4.35	4.38	5.96	5.99	9.73	9.60	9.67
$DIPB_{MB}$+R	4.40	4.54	6.20	6.17	12.4	12.32	12.36
SEm±	**0.061**	**0.054**	**0.133**	**0.115**	**0.122**	**0.130**	**0.061**
LSD (P=0.05)	**0.215**	**0.190**	**0.469**	**0.406**	**0.430**	**0.458**	**0.171**
Nitrogen levels							
RN_0	2.53	2.62	3.46	3.40	6.24	6.18	6.21
$RN_{50\%}$	3.69	3.78	5.17	5.04	8.96	8.76	8.86
$RN_{75\%}$	4.70	4.84	6.23	6.43	10.93	11.04	10.98
$RN_{100\%}$	4.84	4.98	6.48	6.54	11.30	11.37	11.34
NES	5.01	5.11	6.73	6.89	11.69	11.71	11.70
SEm±	**0.062**	**0.053**	**0.094**	**0.083**	**0.086**	**0.084**	**0.068**
LSD (P=0.05)	**0.178**	**0.154**	**0.273**	**0.239**	**0.249**	**0.242**	**0.191**

Table 5: Effect of residue, irrigation and N management on irrigation water productivity of wheat and maize

Treatments	Wheat IWP (kg ha^{-1} cm^{-1})			Maize IWP (kg ha^{-1} cm^{-1})		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
Irrigation and residue managementmanagement						
FIPB-R	131.55	147.65	139.60	172.55	174.06	173.30
DIPB-R	192.27	214.78	205.96	421.73	480.02	450.88
DIPB+R	224.07	237.98	230.63	634.05	591.93	612.99
$DIPB_{MB}$+R	226.98	245.72	242.72	659.82	609.89	634.86
SEm±	**2.234**	**3.014**	**2.167**	**9.332**	**9.188**	**5.272**
LSD (P=0.05)	**7.882**	**10.634**	**6.103**	**32.921**	**32.411**	**14.850**
Nitrogen levels						
RN_0	117.92	130.69	125.63	293.55	280.17	286.86
$RN_{50\%}$	172.36	187.33	181.71	440.47	417.20	428.84
$RN_{75\%}$	219.42	239.74	231.97	523.87	524.80	524.32
$RN_{100\%}$	225.67	246.83	238.66	540.63	540.03	540.33
NES	233.21	258.07	245.66	561.68	557.68	559.67
SEm±	**2.920**	**2.776**	**2.422**	**8.703**	**7.005**	**5.895**
LSD (P=0.05)	**8.449**	**8.032**	**6.823**	**25.185**	**20.272**	**16.603**

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Evaluation of N fertilization management strategies for increasing crop yields and nitrogen use efficiency in maize-wheat system under conservation agriculture

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ABSTRACT

Stagnation of agricultural productivity and degradation of soil and water resources of the IGP have compelled many agricultural scientists and policy makers to look towards a more sustainable path of conservation agriculture and resource conserving technologies. To this effect a two year field experiment was established with annual maize–wheat rotation in the north-western IGP of India to evaluate the effect of residue management and different method of nitrogen application on crop production and nitrogen use efficiency. Significantly higher grain and straw yield of maize and wheat was recorded in the residue retained plots i.e. FIRB+R as compared to the residue removed plots i.e. FIRB-R during both years, respectively. Maize yield under residue retained treatments was showed significant increases of 7.10% and 8.41% in yield compared to residue removed treatments in 2014 and 2015, respectively. Wheat yield was under residue retained treatments showed significant increases of 4.41% and 4.06% (with an average value of 4.23%) in yield compared to residue removed treatments in 2014 and 2015, respectively.The top placement of fertilizer was superior to the furrow application and broadcasting when taking into account grain and straw yield, nitrogen uptake at different growth stages and nitrogen use efficiency.The different N levels and application methods $RN_{75\%}$ -DOT results into significantly higher NUE (61.23 and 64.85 kg kg^{-1}) as compared to the $RN_{75\%}$ -B (53.56 and 56.93 kg kg^{-1}), $RN_{100\%}$ -DOT (56.45 and 56.06 kg kg^{-1}), $RN_{100\%}$-DIF (53.10 and 54.53 kg kg^{-1}) and $RN_{100\%}$ -B (48.70 and 50.99 kg kg^{-1}),during both years,respectively.

Key words: Conservation agriculture, Nitrogen use efficiency, Permanent beds, Residue management

1. Introduction

Inappropriate management practices in the past have led to the twin challenges of resource depletion and decelerating productivity growth of cereal crops (Jat et al. 2009). Future global food security relies not only on high production and access to food but also on the need to address the destructive effects of current agricultural production systems on ecosystem sustainability and increase the resilience of production systems to the effects of climate change (Foresight 2011). Declining soil fertility, erratic precipitation patterns, high input costs and unstable market conditions have all affected the profitability, sustainability and therefore, the livelihood of the small holder farming sector (Marongwet al. 2012). Nearly 94 percent (143 M ha) of the agriculturally suitable land is already under cultivation with limited scope for further horizontal expansion. Hence, the pressure on land will

increase to produce more from the same area under cultivation by increasing the input-use efficiencies and Good Agronomic Practices (Jat et al. 2016).During past half century, there has been a major main shift in agriculture from 'traditional animal-based subsistence' to 'intensive chemical and machinery-based' agriculture; this shift triggered the problems associated with deterioration of soil health and sustainability of natural resources. Soil organic carbon (SOC) contents less than 5 g kg-1 (<0.5%) in most cultivated soils compared with 15-20 g kg-1 (1.5–2.0%) in uncultivated virgin soils of India (Bhattacharyya et al. 2000), are attributed to intensive tillage, removal/burning of crop residues, mining of soil fertility and intensive monotonous cropping systems.

Stagnation of agricultural productivity and degradation of soil and water resources of the IGP have compelled many agricultural scientists and policy makers to look towards a more sustainable path of conservation agriculture (CA) and resource conserving technologies (Gupta and Sayre 2007, Erenstein and Laxmi 2008). Conservation agriculture (CA) based technologies (zero tillage (ZT), permanent raised beds, and crop intensification) have been advocated for increasing yields, reducing irrigation water input and production costs, and enhancing income and sustainability in different cropping systems (Kumaret al. 2013; Gathala et al. 2011; Ladhaet al. 2009; Jat et al. 2013;Saharawat et al. 2010; Sayre and Hobbs 2004).The CA based crop management practices found to be effective for increasing crop productivity (Jatet al.2013, Das et al. 2014, Parihar et al. 2016), profitability (Pariharet al.2016) and energy-use efficiency (Pariharet al. 2011). Furthermore, the intensivetraditional tillage practices led to reduction in soil organicmatter because of more oxidation and breakdown of organiccarbon and ultimately degrade soil properties (Biamahetal.2000, Gathala et al. 2011). Published experimental resultsacross the globe have shown increased productivity andsoil quality, mainly through SOM build-up (Ladhaet al.2009, Bhattacharyya et al. 2013) and higher SOC contentunder zero-tilled compared to conventionally tilled soils(West and Post 2002, Alvarez 2005, Parihar et al.2016a). Akbar et al. (2007) reported that there was about 36 percent water saving for broad-beds and about 10percentfor narrow-beds compared to flat sowing, and grain yield increased by 6percent for wheat and 33percent for maize. Devkota et al. (2013) reported that grain yields of wheat and maize after cotton increased by 12 and 42percent under PB than under CT, respectively. Under PB, water productivity increased by 27percent in wheat and 84 percent in maize compared to CT in irrigated lands of central Asia. Residue retention on PB increased the grain yield of wheat and maize by 5percent and 15percent compared to residue removed, respectively.

Among the fertilizers, nitrogen (N) is the most important nutrient for maize and wheat, and can improve grain yield and quality of both the crops (Ma et al. 2006). To obtain high yields of cereal crops, high rates of N fertilizer, especially manufactured N fertilizer, are applied by farmers in India. However, the increase of crop yields is not proportion with the large increase of consumption of N fertilizer (Shen et al. 2013). Excess inorganic N and inappropriate application methods have led to

low N use efficiency (NUE) and negativeenvironmental impacts (Shi et al. 2012).Leaching of nitrate below the root zone can be affected by a range of factors, including application rate, method of application and timing of application (Siyalet al. 2012). Continuous maize-wheat cropping with excessive application of fertilizer N may result not only in yield losses, but also in high soil nitrate concentrations, increasing potential contamination of both underground and surface water (Pei et al 2009, Yi et al. 2010). Efficient use of N fertilizer depends very much on timing, rates, resources and placement of N fertilizer application (Wang and Zhou 2013). The placement method of fertilizer N influences crop yield and N uptake by cereal crops (Duan et al. 2015).Placement of fertilizer plays an important role in nutrient uptake by plants and leaching of nutrients below the root zone. The precise fertilizer placement can make nutrients easily accessible to roots but without causing damage to the young seedlings, especially during the early stages of plant growth (Jones and Jacobsen 2009).Compared with placement of N fertilizer on the soil surface, N fertilizer applied in bands can reduce N loss via ammonia volatilization and improve NUE of plants. Banding of urea leads to high ammonium concentration in the fertilizer zone that can inhibit nitrifying bacteria, and so reduce N loss due to leaching (Yang et al. 2012). Additionally, placing N fertilizer into soil can reduce the immobilization of N by soil microorganisms and increases uptake by plants (Mooleki et al. 2010).Banding of N fertilizer can also improve the competition of crop with weeds compared to broadcast (Petersen 2001).Benjamin et al. (1998) showed that placing fertilizer in the non-irrigated furrow in alternate furrow irrigated systems increased fertilizer use efficiency and reduced fertilizer leaching. Waddell and Weil (2006) found that by placing fertilizer near the top of the bed, maize crop yields increased and the risk of N leaching decreased. Mailholet al.(2001) also reported that N fertilizer application near the top of the ridge has a beneficial impact on yield.

2 Material and methods

2.1. Experimental site and soil characteristics

Field experiment on maize-wheat system was conducted for two consecutive years (2013-14 and 2014-15) at Borlaug Institute for South Asia(BISA), Ladhowal (30.99◦N latitude, 75.44◦E longitude and at an elevation of 229 m above mean sea level), Punjab located in Trans-Gangetic alluvial plains of India. Before 2013, the field was undermaize-wheat system for the last three years and received recommended mineral fertilization for both crops.The soil (0–15 cm layer) of the experimental field wassandy loam in texture, with pH 8.6, Walkley-Black organic C5.40 g kg^{-1}, electrical conductivity 0.180dS m^{-1}, $KMnO_4$oxidizableN 156.8 kg ha^{-1}, 0.5 M $NaHCO_3$extractable P 28.56 kg ha^{-1}, and1N NH_4OAc extractable K 174 kg ha^{-1}.

2.2. Climate characteristics

Experimental site represented the sub-tropical climate with hotand dry (May–June) to wet summers (July–November) during the maize growing season and cool dry winters (December–April)during wheat growing season with mean annual rainfall of 680 mmand nearly 80% is received during the cotton season. The mean maximum and minimum temperatures show considerable variations during different months of the year. Temperature often exceeds 38^{o}C during summer and sometimes touches 45^{o}C with dry spells during May and June. Minimum temperature falls below 0.5^{o}C with some frosty spells during the winter months of December and January.The averageannual pan evaporation is about 850 mm. May and June are thehottest month (40-44.8◦C), while January is the coldest month (aslow as 1.6◦C). During crop season of 2013-14, the weakly mean temperature ranged between 10.3^{o}C in the 1st SMW (1-7 January) and 35.3^{o}C in the 23rd SMW, while in 2014-15, the weakly mean temperature ranged between 9.3^{o}C in the 52nd SMW (24-31 December) and 34.0^{o}C in the 21th SMW (Fig. 1).Wheat in2013-14 experienced lower minimum temperature in the month ofJanuary compared to that in 2014-15, while the trend in maximumtemperature was reversed during the same period. In 2013-14 rainfall of 635.3 mm was recorded during crop season with maximum rainfall of 110.0 mm received in 30th SMW, while in 2014-15 rainfall of 754.6 mm was recorded during crop season with maximum rainfall of 181.0 mm received in 28th SMW.

2.3. Treatments and experimental design

The experiment design consisted of two main treatments and seven sub treatments laid out in a split plot design with three replications. Two main treatments were the residue management system i.e residue removed and residue retained under permanent beds. The sub treatments were the combination from three levels of nitrogen i.e zero N, 75 and 100 percent of recommended N, and three methods of fertilizer application i.e. uniform broadcasting, drilled/placement on top of bed and drilled/placed in furrows.Each experimental unit was 108 m^{2} (5.4 m × 20 m) in gross.The treatment details are given in Table 1.

2.4. Formation o fpermanent raised beds

Before establishment of the cover crop at the start of experiment, the field was ploughed using disc plough to break hard pan if any. Thereafter, it was pulverized at the optimum moisture level (field capacity) with a cultivator and then levelled using a laser-assisted precision land levelling system attached with a 60- horsepower (hp) tractor. Permanent raised beds were made with a bed planter at a distance of 67.5 cm from top of the one bed to top of the second bed with 37.5 cm top and 30 cm furrow and bed height of 8 inch for sowing of crop, which can accommodate onerow of maize and two rows of wheat (Fig 2). These permanent beds were reshaped during sowing of succeeding crops with bed planter during both years.

2.5. Crop management

2.5.1. Maize

The maize hybrid PMH-1 was sown with one row on top of the raised beds at spacing of 67.5 cm between two beds and 20 cm plant to plant distance in all treatments by using the double-disc drilling machine. The seed rate of maize used was 20 kg ha^{-1}.Seed was treated with Gaucho (imidacloprid) 600 FS @ 6.0 ml per kg seed before planting for protection against attack of shoot fly and with Bavistin (carbendazim) @ 3g per kg seed for protection against various fungal diseases.Recommended doses of 120 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1}were applied as urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively, in both the years. While whole of the P and K was applied at the time of seeding, balance of fertilizer N (total minus added through DAP at the time of sowing) was applied in two equal splits. Half of the remaining N was applied at the knee heigh stage and the reaming was applied at the pre-tasseling stage as per the treatment through manual placement. Extra plants in the rows were thinned to maintain intra-row spacing at three weeks after sowing. The gap filling was accomplished immediately after the germination in order to maintain optimum and uniform plant population. Herbicide Atrataf 50 WP (Atrazine) was applied as pre-emergence @ 1.25 kg ha^{-1} using 500 litres of water with knap sack sprayer using flat fan nozzle for controlling the weeds. One inter-cultivation was done at knee high stage with the tractor operated reshaper, by hoeing the soil which besides checking weed growth provides good aeration to plant roots. One hand weeding was also done at 55 days after planting.Tank mix solution of chloropyriphos (20 EC) and endosulfan (Thiodone @ 0.03%) was sprayed once in the standing crop in order to control stem borer and termite infestation.

2.5.2. Wheat

Wheat variety HD-2967 was sown with a seed rate of 100 kg ha^{-1}insecond week of November. Seed was treated with chloropyriphos (20EC, 400 ml per100 kg seed mixed in 5 l of water) to control termiteattack. Recommended doses of 120 kg N, 60 kg P_2O_5 and 30 kg K_2O ha^{-1}were applied as urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively, in both the years.Nitrogen was applied as per treatment in each experimental unit through drilling with the help of double-disc seed cum fertilizer drill. Half dose of N and full dose of P_2O_5 and K_2O were applied at the time of sowing of wheat. Remaining half nitrogen was applied through drilling with the help of double-disc seed cum fertilizer drill at first irrigation at CRI stage. Tank mix solution of Total (sulfosulfuron + metsulfuron) at 16 g $ha^{-1}$was applied to control Phalaris minor weed at 25–30 DAS.

2.6. Irrigation management

The irrigation was applied to both maize and wheat as per the critical growth stages recommended in theregion by Punjab Agricultural University, but also depended on the rainfall event.

2.7. Crop residue management

Maize harvest manually at cob height and 50 % stover (below cob portion) was left standing in all residue management treatments except residue removed treatments, in which maize harvested at ground level and all maize stover removed from field. After wheat harvest, all the loose residues were removed and only the anchored wheat stubbles were retained after straw retrieval in residue retained treatments and remove of wheat stables after straw retrieval in case of residue removed treatments.

2.8. Yield measurement

At maturity, grain yield of maize and wheat was determined on an area of 13.5 m^2 (4 beds × 5 m long) in the middle of each plot. Grain yields of maize and wheat arereported at 14.5% and 12% grain moisture content, respectively.

2.9. Plant analysis for N uptake

The dry matter samples collected at different growth stages of maize and wheat, grain and cob cores of maize were collected at harvest, dried in sun and then in oven. Plant samples were ground in Wiley Mill and passed through 32 mesh size sieve. Grain samples were ground in small grinding mill.The samples were used for estimation of nitrogen content by modified Micro-Kjeldhal’s method (Subbiah and Asija 1956). The nitrogen uptake by dry matter samples at different growth stages, grains and cob cores were calculated by multiplying the per cent N content with their respective biomass yields.

3.0. Statistical analysis

The data recorded for different parameters were analysed withthe help of analysis of variance (ANOVA) technique (Gomez andGomez, 1984) for split plot design using SAS 9.1 software(SAS Institute, Cary, NC). Treatment differences were compared at 5%level of significance.

3. Results

3.1. Crop yields

Different rates and method of nitrogen application affected yield and yield attributes and nutrient uptake by plants significantly and thus has been discussed in detail along with the supporting studies. The various interaction effects were also not significant for various parameters. Hence, to avoid repetition have not been discussed under the individual parameters. Only the effects of main treatments and sub treatments have been discussed.

3.1.1. Maize

Among residue management plots significantly higher grain yield was recorded in the residue retained plots i.e. FIRB+R (5.43 and 5.80 Mg ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (5.07 and 5.35 Mg ha^{-1}) during both years, respectively (Table 2). Maize yield was under residue retained treatments showed significant increases of 7.10% and 8.41% (with an average value of 7.75%) in yield compared to residue removed treatments in 2014 and 2015, respectively. Nitrogen application method and N rate significantly affected the grain yield of maize. Among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher grain yield (6.53 and 6.73 Mg ha^{-1}) as compared to the control (2.91 and 3.22 Mg ha^{-1}), $RN_{75\%}$ -POT (5.51 and 5.84 Mg ha^{-1}), $RN_{75\%}$-PIF (5.09 and 5.45 Mg ha^{-1}), $RN_{75\%}$ -B (4.82 and 5.12 Mg ha^{-1}) and$RN_{100\%}$ -B (5.84 and 6.12 Mg ha^{-1}) during both years respectively. However no significant difference was observed between the grain yield of $RN_{75\%}$ -POT (5.51 and 5.84 Mg ha^{-1}) and $RN_{100\%}$ -B (5.84 and 6.12 Mg ha^{-1}), during both years respectively which ultimately results into the 25% saving in N fertilizer with change in only method of application. A reference to data presented revealed that the residue management brought significant effect on stover yield of maize. Higher stover yield was recorded under the residue retained plots i.e. FIRB+R (11.13 and 11.99 Mg ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (10.74 and 11.15 Mg ha^{-1}) during both years, respectively.Among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher straw yield (13.16 and 13.55Mg ha^{-1}) as compared to the control (6.65 and 7.34 Mg ha^{-1}), $RN_{75\%}$ -POT (11.33 and 11.95 Mg ha^{-1}), $RN_{75\%}$-PIF (10.80 and 11.34 Mg ha^{-1}) and $RN_{75\%}$ -B (10.27 and 10.73 Mg ha^{-1}).

3.1.2. Wheat

The data regarding grain yield presented in Table2 among residue management plots significantly higher grain yield was recorded in the residue retained plots i.e. FIRB+R (4.26 and 4.36 Mg ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (4.08 and 4.19 Mg ha^{-1}) during both years, respectively.Wheat yield was under residue retained treatments showed significant increases of 4.41% and 4.06% (with an average value of 4.23%) in yield compared to residue removed treatments in 2014 and 2015, respectively. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher grain yield (4.80 and 4.98 Mg ha^{-1}) as compared to the control (2.24 and 2.28 Mg ha^{-1}), $RN_{75\%}$ -DOT (4.45 and 4.53 Mg ha^{-1}), $RN_{75\%}$-DIF (4.35 and 4.37 Mg ha^{-1}), $RN_{75\%}$ -B (4.14 and 4.29 Mg ha^{-1}) and$RN_{100\%}$ -B (4.49 and 4.65 Mg ha^{-1}) but statically at par with the $RN_{100\%}$-DIF (4.68 and 4.83 Mg ha^{-1}), during both years respectively. However no significant difference was observed between the grain yield of $RN_{75\%}$ -DOT (4.45 and 4.53 Mg ha^{-1}) and $RN_{100\%}$ -B (4.49 and 4.65Mg ha^{-1}), during both years respectively. Significantly higher straw yield was recorded under the residue retained plots i.e. FIRB+R (5.30 and 5.46 Mg ha^{-1}) as compared to the residue removed plots i.e. FIRB-R (5.02 and 5.12 Mg ha^{-1}) during both years, respectively.Nitrogen application method and N rate significantly affected the straw yield of wheat. Among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher straw yield (5.86 and 56.09Mg ha^{-1}) as compared to the control (2.67 and 2.86 Mg ha^{-1}), $RN_{75\%}$ -DOT (5.46 and 5.60 t ha^{-1}), $RN_{75\%}$-DIF (5.41 and 5.35 Mg ha^{-1}) and $RN_{75\%}$ -B (5.26 and 5.28 Mg ha^{-1}) but statically at par with the $RN_{100\%}$-DIF (5.75 and 5.99 Mg ha^{-1}) and $RN_{100\%}$ -B (5.71 and 5.86 Mg ha^{-1}), during both years respectively.

3.2. Nitrogen uptake

The N uptake by maize and wheat crop at different growth stages was not significantly influenced due to residue management but significantly influenced by different N rates and application methods.

3.2.1*Nitrogen uptake at different growth stages of maize*

The N uptake by maize crop at different growth stages was not significantly influenced due to residue management but significantly influenced by different N rates and application methods. The data regarding N uptake presented in Table 3 showed that higher N uptake was recorded under the residue retained plots i.e. FIRB+Ras compared to the residue removed plots i.e. FIRB-R during both years at all growth stages. Among the different treatments at knee height stage higher N uptake was obtained inFIPB+R (35.34 and 39.89 kg ha^{-1}) as compared to the FIPB-R (30.74 and 33.50 kg ha^{-1}) during both years of study. Similarly at tasseling and silking stage higher N uptake was recorded under the FIPB+R as compared to the FIPB-Rduring both years of study. A perusal of data revealthat on quantitative basis nitrogen uptake followed the trend grain > stover > cob cores during both the years. Similarly In grain, straw and cob cores significantly higher nitrogen uptake was observed under FIPB+R as compared to FIPB-R during both years of study.At knee height stage among the different N levels and application methods $RN_{100\%}$-POT results into significantly higher N uptake (42.96 and 48.19 kg ha^{-1}) as compared to control (16.26 kg ha^{-1} and 18.46), $RN_{75\%}$ -POT (35.22 and 39.10 kg ha^{-1}), $RN_{75\%}$-PIF (31.41 and 34.42 kg ha^{-1}) and $RN_{75\%}$ -B (28.71 and 30.07 kg ha^{-1}), but statically at par with the $RN_{100\%}$-PIF (37.85 and 48.19 kg ha $^{-1}$) during both years respectively. Similarly at tasseling and silking stage higher N uptake was observed under the top placement of fertilizer as compared to furrow application and broadcasting. Maximum N uptake in grain and stover was with the $RN_{100\%}$-POT(92.99, 100.62 and 75.74, 81.27 kg ha^{-1}), which was statistically at par with $RN_{100\%}$-PIF(83.95, 91.14 and 64.64, 76.93 kg ha^{-1}) but significantly higher than control (31.82, 37.16 and 20.86, 24.36 kg ha^{-1}), $RN_{75\%}$ -POT (74.17, 81.28 and 56.35, 60.92 kg ha^{-1}), $RN_{75\%}$-PIF (64.44,71.02 and 45.82,52.93 kg ha^{-1}) and $RN_{75\%}$ -B (60.46, 67.46 and 39.43 and 45.79kg ha^{-1}) and $RN_{100\%}$-B (78.89, 84.20 and 61.45, 68.23 kg ha^{-1}) , respectively during both years of study. Similarly, the maximum N uptake in cob cores was observed under $RN_{100\%}$-DOTwhich was statistically at par with that recorded under $RN_{100\%}$-PIF and $RN_{100\%}$-Bbut significantly higher than observed undercontrol, $RN_{75\%}$-PIFand $RN_{75\%}$ -B.

3.2.2 *Nitrogen uptake at different growth stages of wheat*

The data regarding N uptake presented in Table 4 showed that higher N uptake was recorded under the residue retained plots i.e. FIRB+Ras compared to the residue removed plots i.e. FIRB-R during both years at all growth stages. At maximum tillering stage higher N uptake was obtained inFIPB+R (34.51 and 33.59 kg ha^{-1}) which was statistically similar with FIPB-R (33.05 and 31.26 kg ha^{-1}). Similarly, N uptake by grain and straw was higher under the FIPB+R (78.91, 76.82 and 24.20, 26.29 kg ha^{-1}) as compared to the FIPB-R (73.06, 72.63 and 21.94, 23.43 kg ha^{-1}), respectively in both the years but not statistical difference was observed.However the N levels and method of application had significant effect on N uptake at all the observations i.e. at maximum tillering stage, at panicle imitation stage and at maturity in grain and straw. At maximum tillering stage among the different N levels and application methods $RN_{100\%}$-DOT results into significantly higher N uptake (42.88 kg ha^{-1}) as compared to the all other treatments during the first year, but in the second year N uptake under $RN_{100\%}$-DOT (41.10kg ha^{-1}) was significantly higher than the control (13.59 kg ha^{-1}), $RN_{75\%}$ -DOT (32.95 kg ha^{-1}), $RN_{75\%}$-DIF (30.19 kg ha^{-1}) and $RN_{75\%}$ -B (30.00 kg ha^{-1}), but statically at par with the $RN_{100\%}$-DIF (39.15 kg ha $^{-1}$) and $RN_{100\%}$ -B

(38.64 kg ha^{-1}). Similarly at panicleinitiation stage higher N uptake was observed under the top placement of fertilizer as compared to furrow application and broadcasting. At maturity stage the $RN_{100\%}$-DOT results into significantly higher N uptake in grain (100.59 and 97.33 kg ha^{-1}) as compared to the $RN_{75\%}$ -DOT (76.51 and 76.85 t ha^{-1}), which was significantly at par with the $RN_{100\%}$-B during the second year. Similarly, N uptake by straw was significantly higher under the $RN_{100\%}$-DOT as compared to the $RN_{75\%}$ -DOT which is statically at par with the$RN_{100\%}$-B and $RN_{100\%}$-DIF during both the years.

3.3. Nitrogen use efficiency

The ability of crops to use the applied N depends on the uptake and utilization efficiency. Residue management and, different N levels and method of N application brought significant differences in the NUE by the maize. The data regarding NUE presented in Table 5**.** Significantly higher NUE was recorded under the residue retained plots i.e. FIRB+R (56.04 and 59.74 kg kg^{-1}**)** residue removed plots i.e. FIRB-R (52.23 and 54.89 kg kg^{-1}**).** Among the different N levels and application methods $RN_{75\%}$ -DOT results into significantly higher NUE (61.23 and 64.85 kg kg^{-1}) as compared to the $RN_{75\%}$ -B (53.56 and 56.93 kg kg^{-1}), $RN_{100\%}$ -DOT (56.45 and 56.06 kg kg^{-1}), $RN_{100\%}$-DIF (53.10 and 54.53 kg kg^{-1}) and $RN_{100\%}$ -B (48.70 and 50.99 kg kg^{-1}),during both years,respectively. However among the 100% recommended fertilizer re rate significantly higher NUE was observed under the $RN_{100\%}$ -DOTas compared to the $RN_{100\%}$-DIF and $RN_{100\%}$ -B.

4. Discussion

Continuous adoption of rice-wheat cropping system in the Indo-Gangetic plains (IGP) of the Indian sub-continent has led to a number of adverse effects including deterioration of soil health (Bhandari et al. 2002), severe ground water depletion(Hira et al. 2004), air pollution (Bijay-Singh et al. 2008) and emergence of new insect-pests, diseases and weeds which warrants the need for crop diversification.Stagnation of agricultural productivity and degradation of soil and water resources of the IGP have compelled many agricultural scientists and policy makers to look towards a more sustainable path of conservation agriculture (CA) and resource conserving technologies (Gupta and Sayre 2007, Erenstein and Laxmi 2008).Conservation agricultureis increasingly being seen as a farming system that can reduce the negative impacts of some of the factors that are limiting agricultural productivity(Marongwe et al. 2012).

Our results showed that significantly higher grain and straw yield of maize and wheat was recorded in the residue retained plots i.e. FIRB+R as compared to the residue removed plots i.e. FIRB-R during both years, respectively.The significantly higher grain and straw yield of maize and wheat under FIPB+R in comparison to FIPB-R was may also attributed to increase in yield attribute of wheat and maize which was enhanced by optimum and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of the crop residues(Gursoy et al. 2010). Ram et al. (2010) also reported higher yields under ZT withresidue due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture, tillers, grains ear^{-1} and 1000-grain weight than no-residue application under ZT and CT practices.

Das et al. (2014) reported significantly higher yields of wheat from ZT, PNB (70 cm) and PBB (140 cm) than CT onasandy clay loam soil. They also observed beneficial effect of retaining crop residues on cotton yield over no residues. Devkota et al. (2013) also recorded significant increases in yieldand water productivity of wheat and maize after cotton under PBB than under CT. Parihar *et al* (2016) also showed the positive effects of PB and residue retention on grain yield of maize. Naresh et al. (2012) reported that PB with residue retention increased yield by 11-17% in maize and 12-15% in wheat as compared to conventional practices. The crop residues retained as surface mulch would have helped in regulating the soil temperature and moisture. Lafond (1999) reported that surface residues in a no-till system helped to buffer soil temperature and that, during winter, soil temperature (at 5 cm depth) with residue removal and conventional tillage was on average 0.29 °C lower than that with no tillage and surface retained residues. Sepat and Rana (2013) also reported that zero till-raised bed with crop residue retention and conventional till -raised bed with crop residue incorporation recorded 25% higher yield and yield attributes in maize as compared to conventional till-flat without residue retention.

Among the different N levels and application methodsthe higher grain and straw yield was obtained in the top placement of fertilizer as compared to the furrow application and broadcasted might be due tothe effect of higher ammonium ion concentration in the fertilizer zone that can inhibit the nitrifying bacteria and so as reduce the N loss due to leaching and increases the NUE, which ultimately affects the grain yield (Hartmann et al. 2015).also reported that placement of N significantly improved the grain and straw yield of wheat over broadcast application of N. The increase with placement of N was 8.1% for grain and 7.4% for straw yield over broadcast. Hassan et al. (2013) reported that band placement of nitrogen produced a grain yield of 6.49 and 5.60 t ha^{-1} whereas nitrogen applied broadcastproduced 5.78 and 4.95 t ha^{-1} during 2006 and 2007, respectively. The increase in grain yield of maize by band placement was probably due to more N uptake and its continuous supply to maize plants near plant roots throughout the growing period and improved all physiological characteristics of the plant that led to better yield attributes and grain yield. Siyal et al. (2012) also reported that N leaching can be reduced to zero percent by placing the fertilizer on the top of bed, which was due to the direct contact of the fertilizer with infiltrating water that will lead to more N leaching. Waddell and Weil (2006) reported that the placement of N fertilizer as compared to surface application through broadcasting results into less ammonia volatilisation and nitrous oxide emission which ultimately increases the NUE.Chen et al. (2016)reported higher grain yield with band placement of fertilizer as compared to the broadcasting..

The ability of crops to use the applied N depends on the uptake and utilization efficiency. Residue management and, different N levels and method of N application brought significant differences in the NUE for the wheat and maize crop.The improved NUE in residue retained plots as compared to the residue removed plots might be due to the compound effects of additional nutrients (Blanco-Canqui and Lal 2008), lesser weed population, improved soil physical health (Jatet al. 2013, Singh et al. 2016), better water regimes (Govaerts et al. 2009) and improved nutrient use efficiency by the crop.Nitrogen use efficiency is greater when the yield response to N is high. Therefore, this efficiency is generally high with low N rates and decreases in accordance with the rate increase of applied N (Gauer et al. 1992). Similar results were obtained by Rahman et al. (2000).

5. Conclusions

The study showed that maize and wheat yields were significantly improved with the residue retention at the soil surface. The top placement of fertilizer was superior to the furrow application and broadcasting when taking into account grain and straw yield, nitrogen uptake at different growth satges and nitrogen use efficiency.

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References

Akbar G, Hamilton G, Hussain Z, Yasin M (2007) Problems and potentials ofpermanent raised bed cropping systems in Pakistan. Pakistan J Water Res 11:11–21.

Alvarez R (2005) A review of nitrogen fertilization and conservation tillage effects on soil C storage. Soil Use Manage21**:** 38–52.

Benjamin JG, Porter LK, Duke HR, Ahuja LR and Butters G (1998) Nitrogen movement with furrow irrigation method and fertilizer band placement. Soil Sci Soc Am J 62**:** 1103-08.

Bhattacharyya R, Das TK, Pramanik P, Ganeshan V, Saad AA and Sharma AR (2013) Impacts of conservation agriculture on soil aggregation and aggregate-associated N under an irrigated agroecosystem of the Indo-Gangetic Plains. Nutr Cycl Agroecosyst 96:185–202.

Bhattacharyya R, Das TK, Pramanik P, Ganeshan V, Saad AA and Sharma AR (2000) Impacts of conservation agriculture on soil aggregation and aggregate- associated N under an irrigated agroecosystem of the Indo-Gangetic Plains. Nutr Cycl Agroecosyst http://dx.doi.org/10.1007/s10705-013-9585.

Biamah EK, Rockstrom J and Okwack G (2000) Conservation tillage for dryland farming: Technological options and experiences in Eastern and Southern Africa. Regional Land Management Unit, RELMA/Sida, ICRAF, House, Gigiri, Nairobi, Kenya.

Bijay-Singh, Shan YH, Johnson-Beebout SE, Yadvinder-Singh, Buresh RJ, Donald LS (2008) Crop residue management for lowland rice-based cropping systems in Asia. Adv Agron Academic Press, 117–199.

Blanco-Canqui H and Lal R (2008) No-tillage and soil-profile carbon sequestration: An on-farm assessment. Soil Sci Soc America J 72: 693-701.

Das TK, Bhattacharyya R, Sudhishri S, Sharma AR, Saharawat YS, Bandyopadhyay KK, Sepat S, Bana RS, Aggarwal P, Sharma RK, Bhatia A, Singh G, Datta SP, Kar A, Singh B, Singh P, Pathak H, Vyas AK and Jat ML (2014) Conservation agriculture in an irrigated cotton–wheat system of the western Indo-Gangetic Plains: Crop and water productivity and economic profitability. Field Crops Res158**:** 24–33

Devkota M, Martius C, Lamers JPA, Sayre KD, Devkota KP, Gupta RK(2013)Combining permanent beds and residue retention with nitrogen fertilizationimproves crop yields and water productivity in irrigated arid lands undercotton wheat and maize. Field Crops Res. 149: 105–114.

Duan W, Shi Y, Zhao J, Zhang Y and Yu Z (2015) Depth of nitrogen fertiliser placement affects nitrogen accumulation, translocation and nitrate nitrogen content in soil of rain fed wheat. Int J Plant Prod 9:237–256.

Erenstein O and Laxmi V (2008) Zero tillage impacts in India's rice-wheat systems: a review. Soil Till Res100**:** 1-14.

Foresight (2011) The future of food and farming. Published by Government Office for Science.

Gathala M K, Ladha J K, Saharawat Y S, Kumar V, Kumar V and Sharma P K (2011) Effect of tillage and crop establishment methods on physical properties of a medium-textured soil under a seven-year rice–wheat rotation. Soil Sci Soc America J 75: 1851-1862.

Govaerts B, Sayre K.D, Goudeseune B, De Corte P, Lichter K, Dendooven Land Deckers J (2009) Conservation agriculture as a sustainable option for the central Mexican highlands. Soil Till Res 103: 222-230.

Gupta RK and Sayre K (2007) Conservation Agriculture in South Asia J Agri Sci Cambridge145**:** 207-214.

Gursoy S, Sessiz A and Malhi SS (2010) Short-term effects of tillage and residue management following cotton on grain yield and quality of wheat. Field Crops Res 119: 260-268

Hassan UlMahmood, Ehsan Ahmad RiazUllah and Saqib Muhammad (2013) Response of maize to nitrogen application methods and row configuration.SarhadJ. Agric. 29:341-349

Hira GS, Jalota SK and Arora VK (2004) Efficient Management of Water Resources for Sustainable Cropping in Punjab.Research Bulletin.Department of Soils, Punjab Agricultural University, Ludhiana, Punjab-INDIA.

Jat HS, Jat RK, Yadvinder-Singh, Parihar CM, Jat SL, Tetarwal JP, Sidhu HS and Jat ML (2016) Nitrogen Management under Conservation Agriculture in Cereal-based Systems. Indian J Fertilisers12**:** 76-91.

Jat M L, Gathala M K, Saharawat Y S, Tetarwal J P, Gupta R and Yadvinder-Singh (2013) Double no-till and permanent raised beds in maize–wheat rotation of north-western Indo-Gangetic plains of India: Effects on crop yields, water productivity, profitability and soil physical properties. Field Crops Res149**:** 291–99

Jat ML, Gathala MK, Ladha JK, Saharawat YS, Jat AS, Kumar V, Sharma SK, Kumar V and Gupta, RK (2009) Evaluation of precision land levelling and double zero-till systems in the rice–wheat rotation: water use, productivity, profitability and soil physical properties. Soil Till Res105**:** 112–21.

Kumar V, Saharawat YS, Gathala MK, Jat AS, Singh SK, Chaudhary N and Jat ML (2013) Effect of different tillage and seeding methods on energy use efficiency and productivity of wheat in Indo-Gangetic plains. Field Crops Res 142: 1-8.

Ladha JK, Singh Y, Erenstein O and Hardy B (eds.) (2009) Integrated Crop and Resource Management in the Rice–Wheat Systems of South Asia. International Rice Research Institute, Los Banos, Philippines, pp. 395.

Ma L, Peterson GA, Ahuja LR, Sherrod L, Shaffer MJ and Rojas KW (1999) Decomposition of surface crop residues in long-term studies of dry land agroecosystems. Agron J 91: 401-409.

Mailhol JC, Ruelle P and Nemeth I (2001) Impact of fertilisation practices on nitrogen leaching under irrigation. Irri Sci 20: 139-147.

Marongwe LS, Nyagumbo I, Kwazira K, Kassam A and Friedrich T (2012) Conservation agriculture and sustainable crop intensification: A Zimbabwe case study. Integ Crop Manage17**:** 1-44.

Mooleki SP, Malhi SS, Lemke RL, Schoenau JJ, Lafond G and Brandt S (2010) Effect of form, placement and rate of N fertilizer, and placement of P fertilizer on wheat in Saskatchewan. Canadian J Plant Sci 90: 319–337.

Parihar CM, Jat SL, Singh AK and Jat ML (2011) Energy scenario and water and productivity of maize based cropping system under conservation agriculture practices in south Asia. In: Abstracts of 5th world congress on conservation agriculture, incorporating the 3rd farming system design conference held at Brisbane, Australia from 26th to 29th Sept. Page: 144–150.

Parihar CM, Jat SL, Singh AK, Kumar B, Yadvinder-Singh, Pradhan S, PooniyaV, Dhauja A, Chaudhary V, Jat ML, Jat RK and Yadav OP (2016) Conservation agriculture in irrigated intensive maize-based systems of north-western India: effects on crop yields, water productivity and economic profitability. Field Crops Res 193:104-116.

Parihar CM, Yadav MR, Jat SL, Singh AK, Kumar B, Pradhan S, Chakraborty D, Jat ML, Jat RK, Saharawat YS, and Yadav OP. (2016a) Long term effect of conservation agriculture in maize rotations on total organic carbon, physical and biological properties of a sandy loam soil in north-western Indo-Gangetic Plains. Soil Till Res161: 116-128.

Pei XX, Wang XB, He P, Zhang XZ, Li KJ, Zhou W, Liang GQ and Jin JY (2009) Effect of postponing N application on soil N supply, plant N uptake and utilization in winter wheat. Plant Nut Fert Sci 15: 9–15 (in Chinese).

Petersen J, Mortensen JV (2002) Dry matter production and 15N recovery in spring wheat as affected by placement geometry of the fertilizer band [J]. Communications in soil science and plant analysis 33: 163–178.

Ram H, Kler DS, Singh Yand Kumar K. (2010) Productivity of maize (*Zea mays*)–wheat (*Triticumaestivum*) system under different tillage and crop establishment practices.Indian J Agro 55: 185-190.

Naresh RK, Singh SP and Pankaj Chauhan (2012) Influence of conservation agriculture, permanent raised bed planting and residue management on soil quality and productivity in maize-wheat system in western Int. J. Life Sci Bt & Pharm Res 1:27-34.

Saharawat YS, Singh B, Malik RK, Ladha JK, Gathala M, Jat ML, Kumar V (2010) Evaluation of alternative tillage and crop establishment methods in a rice–wheat rotation in North Western IGP. Field Crops Res116: 260–67.

Sayre K and Hobbs P (2004) The raised-bed system of cultivation for irrigated production conditions. In: Lal R, Hobbs P, Uphoff N and Hansen D O (Eds.) Sustainable agriculture and the Rice-Wheat system. Ohio State University, Columbia, Ohio, USA, 337-55

Shen J, Li C, Mi G, Li L, Yuan L and Jiang R (2013) Maximizing root/ rhizosphere efficiency to improve crop productivity and nutrient use efficiency in intensive agriculture of China. J Exp Bot 64:1181–1192.

Shi Z, Li D, Jing Q, Cai J, Jiang D, Cao W (2012) Effects of nitrogen applications on soil nitrogen balance and nitrogen utilization of winter wheat in a rice–wheat rotation. Field Crops Res 127:241–247.

Singh VK, Yadvinder-Singh, Dwivedi BS, Singh SK, MajumdarK, Jat M, Mishra RP and Rani M (2016) Soil physical properties, yield trends and economics after five years of conservation agriculture based rice-maize system in north-western India. Soil Till Res155:133-148.

Siyal AA, Bristowc KL and Simunek J (2012) Minimizing nitrogen leaching from furrow irrigation through novel fertilizer placement and soil surface management strategies. Agric Water Manage115: 242-250.

Waddell JT and Weil RR (2006) Effect of fertilizer placement on solute leaching under ridge tillage and no till. Soil Till Res 90: 194-204.

Wang H and Zhou J (2013) Root zone fertilization- A key and necessary approach to improve fertilizer use efficiency and reduce nonpoint source pollution from the cropland Soils 05:785–790 (In Chinese)

West TO and Post WM (2002) Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Sci Soc America J 66: 1930–46.

Yang J, Li X, Xu L, Hu F, Li H, Liu M (2012) Influence of the nitrification inhibitor DMPP on the community composition of ammonia oxidizing bacteria at micro sites with increasing distance from the fertilizer zone. Biol Fert Soils 49:23–30.

Yi Q, XZ Zhang, P He, L Yang and GY Xiong (2010) Effect of reducing nitrogen application on crop nitrogen uptake, utilization, and soil nitrogen balance in rice-wheat rotation system. Plant Nut Fert Sci16: 1069–77 (in Chinese).

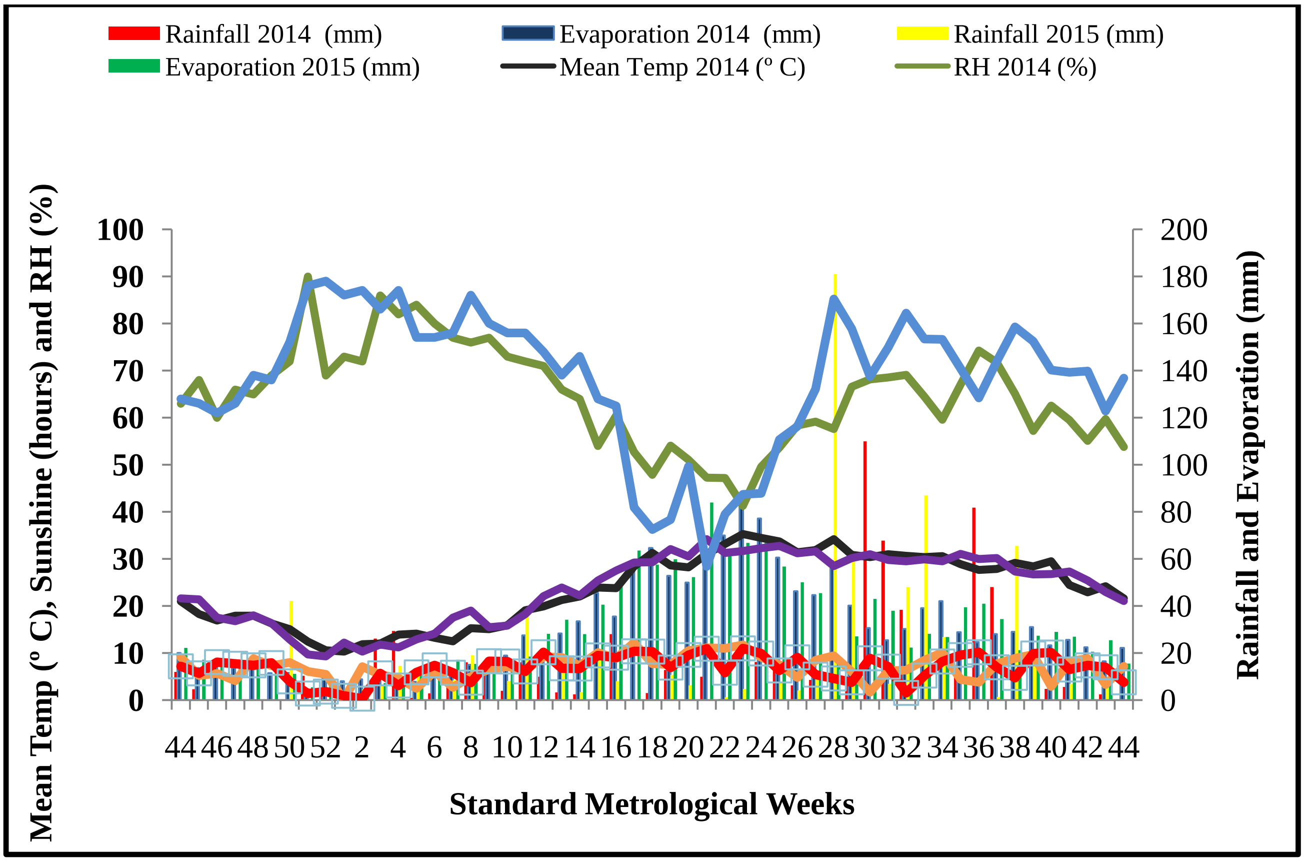

Fig. 1: Graphical presentation of mean temperature, sunshine, evaporation, rainfall and relative humidity during crop seasonfor the year 2014 and 2015

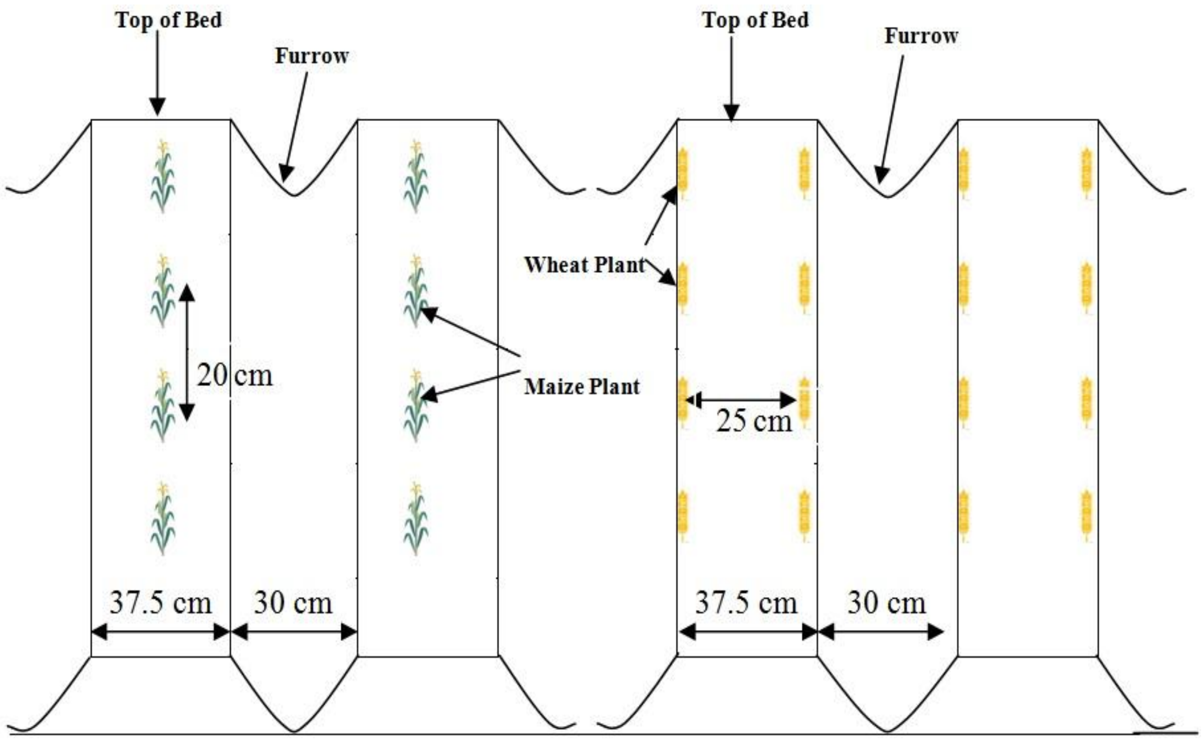

Fig 2: Layout of permanent raised beds

Table 1: Detail of treatments

Treatments	Symbol
Main Treatments: Tillage and straw management systems	
Permanent bed -Residue Removed	FIPB-R
Permanent raised bed -Residue Retained (maize 50% + wheat 25%)	FIPB+R
Sub Treatments: Nitrogen rate and application methods	
Zero – N control	N_0
75% of recommended N-Uniform broadcasting	$RN_{75\%}$-B
75% of recommended N-Drilled/Placement on top of bed	$RN_{75\%}$ -POT
75% of recommended N-Drilled/Placed in Furrow	$RN_{75\%}$-PIF
100% of recommended N-Uniform broadcasting	$RN_{100\%}$ -B
100% of recommended N- Drilled/Placement on top of bed	$RN_{100\%}$ -POT
100% of recommended N- Drilled/Placed in Furrow	$RN_{100\%}$-PIF

Table 2: Effect of residue and N management on grain and straw yield of wheat and maize

Treatments	Maize Grain Yield (Mg ha^{-1})		Maize Straw yield (Mg ha^{-1})		Wheat Grain Yield (Mg ha^{-1})		Wheat Straw yield (Mg ha^{-1})	
	2014	**2015**	**2014**	**2015**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
Residue management								
FIPB-R	5.07	5.35	10.74	11.15	4.08	4.19	5.02	5.12
FIPB+R	5.43	5.80	11.13	11.99	4.26	4.36	5.30	5.46
SEm±	**0.022**	**0.071**	**0.042**	**0.110**	**0.013**	**0.024**	**0.029**	**0.039**
LSD (P=0.05)	**0.141**	**0.462**	**0.278**	**0.722**	**0.084**	**0.155**	**0.192**	**0.256**
Nitrogen levels and method of application								
RN_0(Control)	2.91	3.22	6.65	7.34	2.24	2.28	2.67	2.86
$RN_{75\%}$ -B	4.82	5.12	10.27	10.73	4.14	4.29	5.26	5.28
$RN_{75\%}$-POT	5.51	5.84	11.33	11.95	4.45	4.53	5.46	5.60
$RN_{75\%}$-PIF	5.09	5.45	10.80	11.34	4.35	4.37	5.41	5.35
$RN_{100\%}$ -B	5.84	6.12	12.01	12.61	4.49	4.65	5.71	5.86
$RN_{100\%}$-POT	6.53	6.73	13.16	13.55	4.80	4.98	5.86	6.09
$RN_{100\%}$-PIF	6.04	6.54	12.30	13.41	4.68	4.83	5.75	5.99
SEm±	**0.123**	**0.109**	**0.271**	**0.232**	**0.091**	**0.074**	**0.142**	**0.113**
LSD (P=0.05)	**0.486**	**0.320**	**0.795**	**0.682**	**0.269**	**0.217**	**0.415**	**0.331**

Table 3: Effect of residue and N management on nitrogen uptake at different growth stages of maize

Nitrogen uptake (kg ha^{-1})												
Treatments	**At knee height stage**		**At tasseling stage**		**At silking stage**		**Grain**		**Stover**		**Cob cores**	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Residue management												
FIPB-R	30.74	33.50	101.22	110.82	108.112	119.36	66.08	71.38	49.94	55.22	11.22	12.64
FIPB+R	35.34	39.89	110.08	121.77	123.071	130.14	72.99	80.88	54.14	62.05	12.15	13.86
SEm±	**1.210**	**2.593**	**3.853**	**5.006**	**2.533**	**5.455**	**1.325**	**2.439**	**1.203**	**1.504**	**0.761**	**0.213**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application												
RN_0(Control)	16.26	18.46	46.64	48.03	49.97	57.57	31.82	37.16	20.86	24.36	6.02	7.14
$RN_{75\%}$ -B	28.71	30.07	92.26	105.39	102.19	114.38	60.46	67.46	39.43	45.79	10.17	11.28
$RN_{75\%}$-POT	35.22	39.10	113.09	124.66	125.25	133.02	74.17	81.28	56.35	60.92	12.36	14.58
$RN_{75\%}$-PIF	31.41	34.42	103.58	115.26	113.75	123.58	64.44	71.02	45.82	52.93	10.79	13.35
$RN_{100\%}$ -B	37.85	41.84	119.40	130.30	131.64	137.58	78.89	84.20	61.45	68.23	13.38	14.89
$RN_{100\%}$-POT	42.96	48.19	136.69	150.13	149.08	160.41	92.99	100.62	75.74	81.27	15.58	16.58
$RN_{100\%}$-PIF	38.89	44.77	127.90	140.28	137.26	146.69	83.95	91.14	64.64	76.93	13.50	14.96
SEm±	**1.454**	**3.052**	**5.143**	**5.390**	**4.383**	**5.895**	**3.335**	**3.850**	**4.181**	**3.539**	**0.746**	**0.811**
LSD (P=0.05)	**4.270**	**8.961**	**15.101**	**15.826**	**12.871**	**17.308**	**9.791**	**11.306**	**12.277**	**10.392**	**2.191**	**2.381**

Table 4: Effect of residue and N management on nitrogen uptake at different growth stages of wheat

Nitrogen uptake (kg ha^{-1})								
Treatments	At maximum tillering Stage		At panicle initiation Stage		At Maturity			
					Grain		Straw	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Residue Management								
FIPB-R	33.05	31.26	91.52	91.31	73.06	72.63	21.94	23.43
FIPB+R	34.51	33.59	95.98	93.06	78.91	76.82	24.20	26.29
SEm±	**0.463**	**0.545**	**1.394**	**6.109**	**3.341**	**1.320**	**0.716**	**1.500**
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogen levels and method of application								
RN_0(Control)	14.93	13.59	31.02	33.79	32.89	33.15	9.22	9.39
$RN_{75\%}$ -B	31.27	30.00	87.45	84.36	68.89	66.76	20.72	23.01
$RN_{75\%}$-DOT	35.55	32.95	94.17	96.12	76.51	76.85	24.51	26.66
$RN_{75\%}$-DIF	33.33	30.913	90.47	90.36	70.72	73.38	22.77	23.90
$RN_{100\%}$ -B	39.42	38.64	114.21	113.92	89.27	84.52	27.37	30.10
$RN_{100\%}$-DOT	42.88	41.70	122.83	117.28	100.59	97.33	29.76	31.70
$RN_{100\%}$-DIF	39.10	39.15	115.82	109.45	93.03	91.09	27.12	29.24
SEm±	**0.907**	**1.645**	**6.099**	**6.481**	**3.980**	**3.399**	**1.609**	**2.280**
LSD (P=0.05)	**2.664**	**4.829**	**17.908**	**19.029**	**11.687**	**9.981**	**4.725**	**6.695**

Table 5: Effect of residue and N management on nitrogen use efficiency of maize and wheat

Treatments	Maize NUE (kg kg^{-1})		Wheat NUE (kg kg^{-1})	
	2014	2015	2013-14	2014-15
Residue Management				
FIPB-R	52.23	54.89	42.72	43.61
FIPB+R	56.04	59.74	44.04	45.39
SEm±	**0.944**	**1.125**	**0.239**	**0.127**
LSD (P=0.05)	**1.394**	**4.9125**	**NS**	**0.702**
Nitrogen levels and method of application				
RN_0	-	-	-	-
$RN_{75\%}$ -B	53.56	56.93	45.99	47.73
$RN_{75\%}$-DOT	61.23	64.85	49.47	50.25
$RN_{75\%}$-DIF	56.57	60.53	48.35	48.55
$RN_{100\%}$ -B	48.70	50.99	37.45	38.76
$RN_{100\%}$-DOT	56.45	56.06	40.04	41.47
$RN_{100\%}$-DIF	53.10	54.53	38.98	40.23
SEm±	**4.336**	**6.700**	**0.890**	**0.702**
LSD (P=0.05)	**2.508**	**3.118**	**2.543**	**2.085**

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Decomposition rate and nutrient release pattern of different crop residues as affected by method of placement

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ABSTRACT

To maintain current soil organic carbon stocks and ensure future soil productivity and agricultural sustainability, it is important to maximize crop residue contribution to soil organic carbon. Crop residues are an important source of plant nutrients and are the primary source of organic matter that available in large quantities which is not being fully utilized. To manage residues for their maximum benefits while minimising problems associated with their retention, decomposition is a key process in the nutrient cycling and formation of soil organic matter.The experiment was conducted on a sandy loam soil during 2013-14 to 2014-15 at research platform of the Borlaug Institute for South Asia (BISA), Ladhowal (Ludhiana), Punjab. Type of residue and method of placement had a strong influence on N, P and K releasing behaviour. In both $MT_{50\%}$ and $ML_{50\%}$treatment of maize residueplaced sub-surface release more N, P and K as compare to surface placed residue at different stages. Total N, P and K releasedat the end of decomposition period was more in $ML_{50\%}$ i.e. 31.66 kg N ha^{-1} 2.91 kg P ha^{-1} and 56.12 kg K ha^{-1} as compare to $MT_{50\%}$ 21.6 kg N ha^{-1}, 1.62 kg P $ha^{-1}$and 46.2 kg K $ha^{-1}$when residue is placed sub-surface. Similarly in wheat and moong-bean residues N,P and K release was higher in sub-surface placed residue as compare to surface placed residue through out to decomposition period irrespective to type of residue. At the end of decomposition period release of total N was maximum in $MB_{100\%}$, followed by $WL_{25\%}$+ $MB_{100\%}$ >$WT_{75\%}$ >$WL_{25\%}$ (32.02 kg N ha^{-1}, 16.07 kg N ha^{-1} 13.71 kg N $ha^{-1}$and 6.53 kg N ha^{-1} respectively). Total P release from the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ was about 3.16 kg P ha^{-1}, 1.70 kg P ha^{-1}, 3.48 kg P ha^{-1} and 2.84 kg P ha^{-1}respectively. At the end of decomposition cycle both in surface and sub surface placed residue most (99%) of the K (31- 45 kg K ha-1) was released from the different type of residues.

Key words: Nutrient release, crop residues, Decomposition rate, Placement effect

Introduction

India has achieved a record food grain production of 257 million tonnes in 2014-15 and hence the crop residues, a by-product of crop production system, have increased proportionately. Total removal of plant nutrients by different crops is significantly higher than additions through fertilizer nutrients in India, resulting in continuous depletion of soil fertility. The maintenance of high soil nutrients levels fulfil the nutritional demand of cultivated plants possible only through the application of organic and inorganic fertilizers (Ranjbar and Jalali, 2012). Application of organic materials as soil amendments is an important management strategy that can improve and uplift soil-quality characteristics and alter the nutrient cycling through mineralization or immobilization turnover of added materials (Campos *et al.,* 2013, Baldi and Toselli 2014, Novara *et al.,* 2013, Hueso-González *et al.,* 2014, Oliveira *et al.,* 2014). Use of local organic materials derived either from livestock or plants have been attaining worldwide support for improving the fertility and productivity potential of degraded and nutrient-poor soils (Abbasi *et al.,* 2015, Tejada and Benítez, 2014).

Crop residues are an important source of plant nutrients and are the primary source of organic matter (as C constitutes more than 40% of the total dry biomass), are available in large quantities, and are not being fully utilized. The economic value of crop residues mainly focuses on the equivalent fertilizer cost of the nutrients that they contain (Rezig *et al.,* 2014). To maintain current soil organic carbon stocks and ensure future soil productivity and agricultural sustainability, it is important to maximize crop residue contribution to soil organic carbon (Stewart *et al*., 2015). Incorporating plant residues into agricultural soils can sustain organic carbon content, readily available C and N, improve soil physical properties, enhance biological activities and increase nutrient availability (Hadas *et al* ., 2004, Cayuela *et al.,* 2009, Murungu *et al.,* 2011). Adopting the principles of conservation agriculture (CA) together with 'Best-Bet' crop-management practices would improve system productivity and overall resource-use efficiency, resulting in a higher profitability as well as long-term sustainability of different crops and cropping systems.

The crop residue in the system accounts about 35% to 40% N, 10% to 15% of P, and 80% to 90% of K removal by different crops (Sharma and Sharma 2004). It is estimated that in India, annually different crops generate a gross quantity of 686 million tonnes crop residues (Hiloidhari *et al*., 2014). Crop residues may affect several factors that influence yield, including plant establishment, soil temperature, water infiltration and evaporation, disease and pest populations and nutrient availability. The challenge is to manage residues in a way that maximises the benefits while minimising problems associated with their retention. A thorough knowledge of the factors affecting decomposition is a pre-requisite to develop best management practices for crop residues. Decomposition is a key process in the nutrient cycling and formation of soil organic matter (Berg and McClaugherty 2002). Decomposition is primarily influenced by the environmental conditions in which decay takes place, the chemical quality of leaf litter, and the nature and abundance of decomposing organisms present (Polyakova and Billor, 2007). Soil and environmental factors such as soil texture, pH, nutrient availability, moisture and temperature, and biochemical composition of the residue are very important because they can modify decomposition rates due to their effects on microbial activity (Heal *et al*., 1997, Yadvinder-Singh *et al.,* 2005, Vahdat *et al.,* 2011, Abera *et al.,* 2012). The initial N content of plant residues is one of the crucial factors accelerating or inhibiting residue decay, as it determines the turnover of the microbial mass mineralizing the residues (Heal *et al.,* 1997). Due to more favourable conditions for microbial activity, soil-incorporated residues normally decompose at a faster rate than residues on the soil surface (Yadwinder-Singh *et al.*, 2010, Wang *et al.*, 2001). Soil microenvironments for biological and chemical processes differ in surface placed residues than their incorporation thereby influencing the nature and extent of organic matter dynamics and nutrient cycling (Beare 1997, Cookson *et al.*, 1998). Many researchers have studied the decomposition of crop residues under different environments (Stroo *et al.*, 1989, Ghidey and Alberts 1993, Schomberg *et al.*, 1996).

Residue decomposition may be determined either by measuring mass loss (e.g. Douglas and Rickman 1992, Beare *et al.*, 2002) or by measuring CO_2-C evolution from decaying residue (e.g. Bremer *et al.,* 1991, Jensen *et al.*, 1997, Berg and McClaugherty 2003). Because of operational simplicity, mass loss using a litter bag technique has been the preferred method in many decomposition studies (Heal *et al.*, 1997). Crop residue, contained in fibreglass mesh bags, is placed in the soil at a depth of 0.15 or 0.20 m and undecomposed residue measured by recovering the litter bag containing the remaining material (Beare *et al.*, 2002). Bags subsequently sampled and periodically examined for loss in litter-weight as an index of decomposition (Carsky 1989).

Although the effects of placement on decomposition of different residues under field conditions other than maize and moongbean are known, information is lacking in the maize-wheat-moongbean system, a world's most important cropping system. There is a need to study decomposition and nutrient dynamics in the crop residues of these crops under field conditions. Keeping in mind the beneficial effects of plant residues on soil–plant systems, the present work aims to (1) predict decomposition and release of N, P and K from maize, wheat and moonbean residue; and (2) analyze the effects of placement on residue decomposition and nutrient dynamics.

Methods and materials

Site description

The experiment was conducted on a sandy loam soil during 2013-14 to 2014-15 at research platform of the Borlaug Institute for South Asia (BISA), Ladhowal (Ludhiana), Punjab. Geographically, BISA platform is located 20 km east of Ludhiana at 30˚ 99' North latitute, 75˚ 44' East longitude and at an altitude of 229 metres above mean sea level. The place located in Trans Gangetic agro climatic zone and represents the Indo-Gangetic alluvial plains. The climate is sub-tropical, with hot, dry to wet summers (June–October) and cool, dry winters (November–April). The mean maximum temperature in June, which is the hottest month of the year, ranges from 40° to 44.8°C, while the mean minimum temperature in the coldest month of January is as low as 1.6°C. The mean annual rainfall is about 696 mm, of which nearly 80 per cent is received during the monsoon period from July to September and the rest during the period between October and May. The mean daily U.S. Weather Bureau Class 'A' open pan evaporation value reaches as 6.8 mm in the month of June and as low as 0.32 mm in the month of January. The annual pan evaporation is about 850 mm. Mean relative humidity attains the maximum value (85 to 90% or even more) during the south-west monsoon and the minimum (30 to 40%) during the summer months. The meteorological data for the cropping season as recorded at meteorological observatory of the Borlaug Institute for South Asia, Ladhowal (Punjab).

Residue decomposition and nutrient release

The experiment was established in November 2013 after the harvest of maize as the cover crop. Maize, wheat and moongbean residue used in the experiment was collected from on-going field experiment involving permanent bed tillage-residue management and N fertilizer treatments. The trial was laid out as randomized block design with three replicates of six different type of residues and two methods of placement. The treatments were: (1) Maize top 50% ($MT_{50\%}$); (2) Maize lower 50% ($ML_{50\%}$); (3) Wheat top 75% ($WT_{75\%}$); (4) Wheat lower 25% ($WL_{25\%}$); (5) Moongbean 100% ($MB_{100\%}$); (6) Wheat lower 25% + Moongbean 100% ($WL_{25\%}$ + $MB_{100\%}$) and two methods of placement (1) Surface placed (2) Sub surface placed. The maize residues were placed during the wheat crop cycle after the harvest of maize crop and, wheat and moongbean residues were placed during maize crop cycle after the harvest of wheat and relay moong. The initial composition of the residues is given in Table 1 and 2. The straws were air-dried and cut into 1-2 cm lengths before use in the experiment. The kinetics of residue decomposition and the subsequent release of N, P and K release were studied using a nylon mesh bag technique (Beare *et al.*, 2002). Bags containing maize residues were placed in the field on 30 November 2013 after the sowing of wheat and the bags containing wheat and moonbean residues were palced in the field on 07 July 2014 after the sowing of maize. Nylon mesh bags containing different residues were sampled 7 times (30, 60, 90, 120, 150, 270 and 365 days after placement) during the growing season of maize and wheat. Fifty gram of residue (cut into 1-2 cm size) was placed in each nylon bag (1 mm mesh). On seven permanent beds each of 20 m long six sealed nylon mesh bags for i.e three on soil surface and three on sub surface (10-12 cm deep) for three replicate in each treatment were placed horizontally at equal distance. The position of each nylon bag was marked with nylon thread tied to a wooden stick. Six nylon mesh bags from each bed were removed at regular intervals on each of seven samplings for each treatment. Residue remaining on each sampling date was taken out from the bag, shaken gently over a sieve (1 mm) to remove bulk of soil and finally washed off closely with distilled water. Samples were then oven-dried at 60˚C for 48 h, weighed, and ground to pass through 1 mm sieve. The loss in residue mass of the residue in a bag was considered as decomposed. Total N in residues was determined by Kjeldahl method (Keeney and Nelson 1982). For determination of P and K content, residue was wet-digested with a mixture HNO_3–H_2SO_4–$HClO_4$ (10:4:1). Phosphorous in the wet digest was measured calorimetrically by the molybdate yellow colour method using spectrophotometer (Olsen *et al.*, 1954) and K by flame photometry (Brown and Warencke 1998). Total N, P and K of the residue was calculated by multiplying % N, P and K by the weight remaining at each sampling period. The change in the N, P and K contents of the decomposing residue represented the amount that had mineralized/immobilized during the period.

Calculations and statistical analysis

Exponential decomposition models were used to describe the decomposition of litter in litter bags (Patricio *et al.*, 2012):

$$Y_t = Y_O \exp^{-kt}$$

where Y_t is residue remaining (%) at time t (expressed in days); Y_O is initial condition (i.e., % mass remaining at t = 0); and k is the relative decomposition rate. The nutrient release was then calculated as under:

Initial amount of nutrient in the residue, kg ha^{-1}(assuming a load of 4.45 Mg ha^{-1}, 7.08 Mg ha^{-1}, 3.81 Mg ha^{-1}, 2.52 Mg ha^{-1}, 3.20 Mg ha^{-1} and 2.79 Mg ha^{-1} for $MT_{50\%}$, $ML_{50\%}$, $WT_{75\%}$, $WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ respectively) = % initial mean nutrient concentration multiplied by residue load (Mg ha^{-1}) say N_t, P_t and K_t for N, P and K, respectively. Total biomass remaining at a given time (Mg ha^{-1}) was calculated as initial mass (Mg ha^{-1}) × % mass remaining (see above), say 'x'.

Total N in the residue remaining at a given time (kg ha^{-1}) = a *1000x

Where, a = Total Nitrogen (%) content in the reaming residue

Total N released (kg) = $N_t - (a * x)$

N released (% of initial) = $\{N_t - (a * x)\}/N_t * 100$

Similar calculations were carried out for P and K release. Statistical analysis software (SAS 1985) was used to test variations between treatments and least significant difference (LSD, ≤ 0.05) was used to determine differences between treatment means.

Results and discussion

Residue decomposition

A rapid decrease in the weight was observed during the initial time in both the residues (Table 3). However this decrease was not significantly different between two types of residues mainly because of same residue quality. After 60 days of placement of bags, $MT_{50\%}$ had lost 27.07% of its initial mass and $ML_{50\%}$ had lost 31.28% of its initial irrespective of the method of placement. Nearly 50% of the initial weight was lost from the bags after 120 days of placement of bags and, at the end of the decomposition cycle $MT_{50\%}$ had lost 93.50% of its initial mass and $ML_{50\%}$ had lost 94.78% of its initial irrespective of the method of placement (Fig 1 and 2). Decomposition was significantly affected by method of placement as surface placed residue lost about 11.59% of initial mass after the

30 DAP, where as sub-surface placed residue lost about 30.78% of initial mass irrespective of type of residue. Throughout the decomposition cycle, the percent decrease in weight was significantly higher from the surface placed residue as compared to subsurface placed residue. In surface placed residue, the 50% of the initial weight lost after the 150 DAP, whereas in sub-surface placed residue the 50% of the initial weight lost after the 90 DAP. At the end of the decomposition cycle (365 DAP), the percent weight remaining was of the order 8.31% and 3.14% of surface placed and sub-surface palced respectively.

Similarly, in wheat and moongbean residues rapid decrease of litter mass at the beginning decomposition for all treatment irrespective of method of placemecnt was observed (Table 7). After 30 days of placement of bags, $M_{100\%}$ had lost 57.60% of its initial mass, while $WT_{75\%}$, $WL_{25\%}$ and $WL_{25\%}+M_{100\%}$ had lost 38.41%, 30.79% and 46.11% respectively. At the end of the decomposition cycle all the residues had lost about 93-95% of their initial mass. Moongbean residue decompose more rapidly than the other residue at the early stage of decomposition, but the percentages of residue weight left trended to constant after an initial period of rapid decomposition. The initial more weight loss of moongbean residue was mainly due to the high total N contents of the legume residues compared to the other non-legumes legume residues. Increased residue decomposition with greater inherent litter N has been also observed in other studies (Cornwell *et al.*, 2008, Hobbie *et al.*, 2012). It has been reported that N availability may control the decomposition of plant residues, particularly those with low N content such as cereals, when the N requirements of the soil decomposers are not met by the residue or soil N contents (Vahdat *et al.*, 2011). The decomposition of the surface and subsurface placed residue observed in this study are quite similar to the ones reported by other authors. Decomposition was significantly affected by method of residue placement as sub-surface placed residue lost 74.63% of initial weight after the 150 DAP, where as surface placed residue lost about 82.99% of initial mass irrespective of type of residue.

The initial phase of decomposition is characterized by rapid loss of hydrosoluble compounds, high microbial activity, availability of limiting elements such as N and P and leaching/release of nutrients), whereas in late stages carbon loss has been related to elements required to decompose recalcitrant components such as lignin that accumulate in the remaining litter (Gusewell and Gessner 2009, Berg *et al.*, 2010, Hobbie *et al.*, 2012, Loranger *et al.*, 2002 and Nyberg *et a.,l* 2002). Nevertheless, our findings of weight loss were comparable to the findings of Ngatia *et al* (2014), who reported 50-65% weight loss of savanna grasses in East Africa in a study period of the 20 weeks. Liu et al (2011) reported that about 36–55% Cynodon dactylon (L.) Pers. (Bermuda grass) organic matter was lost within 18 weeks of study period in Florida. Decomposition rates of sub-surface placed residues faster than those of surface placed residues as a result of greater soil–residue contact, a more favourable and stable microenvironment, particularly soil moisture regime, and increased availability of exogenous N for decomposition by microorganisms (Cogle *et al.*, 1987, Schomberg *et al.*, 1994). Decomposition rates for many different residue types have consistently been 2-4 times faster in sub-surface placed than in surface-placed (Beare *et al.*, 2002, Ghidey and Alberts 1993, Varco *et al.*, 1993).

Nutrient change pattern during residue decomposition

Nitrogen and K contents were significantly affected both by type of residue as well as method of placement (Table 4 & 6). After 30 DAP of bags the percent residue N increased by 19.23% and 13.96% in MT50% and ML50%, respectively. In maize residues after 90 days of placement, the N content was increased by fifty per cent of its initial content irrespective of method of placement. However no significant difference was observed at the end of season, which might be due to the fact that whole of the organic carbon at the end was lost from the residue with 365 days of placement. The percent residue N increased by 5.4% in surface placed residue and 28% in sub-surface placed residue by 30 DAP, irrespective of type of residue. The increase in N concentration was greater in sub-surface placed residues than placed at surface due to more loss of organic C in the former. For example, at the end of 150 DAP; N concentration was 106.6% in surface placed residue as compared to 64% in sub-surface placed residue.

Similarly in wheat and moongbean residues statistical analysis showed that there were highly significant differences between the different residues in relative N depending upon the initial N concentration. The percent residue N increased by 202.5%, 258.4%, 109.3% and 141.7% in $WT_{75\%, WL25\%,}$ $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ residues respectively over the initial content irrespective of method of placement at the end of the decomposition cycle (Table 8). Irrespective of type of residue increase in percent N was significantly different in surface and sub surface placed residue, as increase percent N content was more in subsurface placed residue as compared to surface placed residue due to greater loss of organic C in the former.

The increase in litter N over the study period was in accordance with the findings of several previous studies (Dubeux *et al.*, 2006, Hamadi *et al.*, 2000 and Liu *et al.*, 2011), which reported increased nitrogen masses over the study period. Apart from greater release of carbon (though not measured directly) which is evident from large mass loss, increase in N concentration in the residue may also be attributed due to faster leaching of other non-nitrogenous compounds (Ghidey and Alberts 1993).

However the method of placement and type of residue showed no significant effect on P content in maize residues (Table 5). Like N, P content also increased continuously and was 85-90% higher than its initial P content in surface and sub-surface placed residue. Similarly in wheat and moongbean residues, the P content was increasing linearly with time and statistical analysis showed that, there were significant differences in P content at each sampling time in all type of residue irrespective of method of placement (Table 9). The percent residue P increased by 83.0%, 94.7%, 128.0% and 131.3% in $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ residues respectively over the initial content irrespective of method of placement at the end of the decomposition cycle (365 DAP). (Tian *et al.*, 1992) reported an increase of P concentration in rice residue during the initial period of decomposition. Many studies showed accumulation of P as well as N during decomposition (Staaf and Berg 1982, O'Connell 1988). In some cases, P accumulation was faster than N during decay of forest debris (Lambert *et al.*, 1980) indicating that the dependence of decomposer activity for phosphorus. In another study O'Connell (2004) showed that, there was four-fold increase in the amount of P in mesh bags after five years of decomposition.

The change in K in the residue was significantly affected by method of placement as well as type of residue. In maize residues, K in residue decreased markedly from initial level to 70-80% after 150 days of placement irrespective of placement method. However in wheat an moongbean residues, there were also significant differences between the different residues with respect to percent K remaining in litter at each sampling time, with greatest decrease in $WL_{25\%}$ with 74.3% decrease followed by $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ with 66.4 and 65.2% respectively after 30 days of placement irrespective of method of placement (Table 10). The pattern of decrease in K content can be clearly divided into two stages. In the first stage (30 DAP) there was a rapid decrease in potassium content and was found to be almost 50% of initial content (Table 6). During the second stage (60 DAP onwards), it was observed that K content decreased steadily and decrease in K content was 80-85% after 365 days of placement in both type of residue irrespective of method of placement. The high loss of initial K is mainly because k is not a structural element, it is susceptible to high initial loss by leaching, Staaf (1980). Other workers have reported that, higher leaching losses of K from residues since K is not embedded to the tissues of plants (Berg 1984, Saini 1989 and Reddy and Venkataiah 1989). The slow release of K observed here in the second stage might be due to the little change in soil exchangeable cation contents, supported by the studies of (Lupwayi and Haque, 1998 and Ahlam, 2004).

Release of nutrients during residue decomposition

Type of residue and method of placement had a strong influence on N releasing behaviour. In surface placed residue total N release from $MT_{50\%}$ residue by 60 DAP was about 2.73 kg N ha^{-1} (11.78% of initial) and 6.08 kg N ha^{-1} (17.88% of initial) from ML50%. (Fig 7 & 9).The higher N release from $ML_{50\%}$ as compared to $MT_{50\%}$ was may be due to the more weight lost in former at each sampling time. In both type of residue the amount of N release from the sub surface placed residue was higher than the surface placed residue, as in $MT_{50\%}$ residue by 120 DAP N release increased to 7.86 kg N ha^{-1} (33.93% of initial) from sub surface placed residue in comparison to 3.40 kg N ha^{-1}(14.67% of initial) in surface placed residue (Fig). Similarly in $ML_{50\%}$ residue by 120 DAP N release increased to 13.35 kg N ha^{-1} (39.26% of initial) from sub surface placed residue in comparison to 7.45 kg N ha^{-1} (21.92% of initial) in surface placed residue (Fig 9). At the end of decomposition period the total amount of N release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 21.6 kg N ha^{-1} (91.76% of initial) and 31.66 kg N ha^{-1} (93.12% of initial) respectively.

Similarly in wheat and moongbean residues, N release was high in the initial 120 days of decomposition. In surface placed residue after 120 days of placement DAP the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ release 5.79 kg N ha^{-1}, 1.82 kg N ha^{-1}, 18.08 kg N ha^{-1} and 6.78 kg N ha^{-1} (37.99%, 22.61%, 52.31% and 37.95% of initial) respectively (Fig 11,14, 17 & 20). In all type of residue the amount of N released from the sub surface placed residue was higher than the surface placed residue, as in $WL_{75\%}$ residue by 150 DAP, N release increased to 9.52 kg N ha^{-1} (62.44% of initial) from sub surface placed residue in comparison to 8.40 kg N ha^{-1} (55.09% of initial) in surface placed residue (Fig 11). At the end of decomposition period in sub surface placed the total amount of N released from the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ was about 13.71 kg N ha^{-1}, 6.53 kg N ha^{-1}, 32.02 kg N ha^{-1} and 16.07 kg N ha^{-1} (89.95%, 80.96%, 92.64% and 89.95% of initial) respectively. The amount of N released followed the order $MB_{100\%}$ > $WL_{25\%}$+ $MB_{100\%}$ > $WT_{75\%}$ >$WL_{25\%}$ through out the decomposition period, which is mainly due the high initial N concentration of the $MB_{100\%}$.

The highly significant positive correlation between net N mineralization and the residue N content confirms the previous results (Nourbakhsh and Dick 2005, Vahdat *et al.,* 2011, Abbasi *et al.,* 2015), indicating that residue N concentration can be considered a better tool to predict mineralization of added organic residues compared to the C=N ratio. As indicated in a previous study (Trinsoutrot *et al.,* 2000), the net accumulation (whether positive or negative) of mineral N in soil during decomposition of organic residues is directly related to the residue N content. Kumar and Goh, (2003) also reported net nitrogen mineralization (% of added N) from different organic materials during 110 days of incubation was in the range of 35% in *Triticum aestivum* (wheat) residues to 81% in *Trifolium repens* (white clover) residues. The results indicated that there was no period of N immobilization throughout the decomposition period for the two types of residues. This was clearly observed as % N remaining in each sampling did not exceed 100%.Since N application after maximum tiller stage has less effect on the grain yield of wheat, the additional amount of N released after boot stage may not be absorbed by growing wheat and remains unutilized. Both residue N (and also other chemical composition parameters such as lignin, cellulose and phenol contents), residue load and timely release of N are critical factors for residue to be considered a reliable source of N for crop production (Clement *et al.,* 1995). If both the recycling of N in the soil microbial biomass and possible losses of N mineralized (i.e., leaching, denitrification, and volatilization) are considered, the average total N content of maize residue is not enough to significantly reduce the N fertilizer rate applied to wheat and the following maize crop over a short-term. Possible management alternatives that need to be evaluated are adjusting residue incorporation and N fertilizer application times to improve the synchronicity between maize residue decomposition and wheat N uptake.

During the initial period of decomposition (by 90 DAP), P was immobilized against net mineralization. The higher P release from $ML_{50\%}$ as compared to $MT_{50\%}$ was may be due to the more weight lost in former at each sampling time. In maize residue the amount of P release from the sub surface placed residue was higher than the surface placed residue, as in $MT_{50\%}$ residue by 270 DAP, P release increased to 1.44 kg P ha^{-1} (73.68% of initial) from sub surface placed residue in comparison to 1.25 kg P ha^{-1} (63.59% of initial) in surface placed residue. Similarly in $ML_{50\%}$ residue by 270 DAP, P release increased to 2.75 kg P ha^{-1} (88.27% of initial) from sub surface placed residue in comparison to 2.37 kg P ha^{-1} (76.07% of initial) in surface placed residue. At the end of decomposition period the total amount of P release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 1.62 kg P ha^{-1} (82.77% of initial) and 2.91 kg P ha^{-1} (93.40% of initial) respectively.

During the first 60 DAP about 30-50% of initial P was released from different wheat and moongbean residues irrespective of method of placement. By 60 DAP, the amount of P released followed the order $MB_{100\%}$ > $WL_{25\%}$+ $MB_{100\%}$ > $WT_{75\%}$ >$WL_{25\%}$ which was mainly due the fast decomposition in moongbean residues (Fig 12, 15, 18 &21). The percentages of P released trended to constant after an initial period of rapid increase. As expected P release was lower from surface placed residue than the sub surface placed residue throughout the decomposition period. In all type of residue the amount of P release from the sub surface placed residue was higher than the surface placed residue, as in $WT_{75\%}$ residue by 120 DAP, P release increased to 2.45 kg P ha^{-1} (73.04% of initial) from sub surface placed residue in comparison to 1.75 kg P ha^{-1} (52.34% of initial) in surface placed residue (Fig 12). At the end of decomposition period in sub surface placed residue the total amount of P released from the $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ was about 3.16 kg P ha^{-1}, 1.70 kg P ha^{-1}, 3.48 kg P ha^{-1} and 2.84 kg P ha^{-1} (94.38%, 89.76%, 92.05% and 90.71% of initial) respectively. The release of P and K depends on the nutrient concentration of the organic matter and the C-to-nutrient ratio (Nygaard Sorensen & Thorup-Kristensen 2011). Lupwayi *et al.*, (2007) found that the percentages of residue P released were positively correlated with P concentration. As the P mineralization starts by 120 DAP of maize residue, so residue P may not significantly contribute to the nutrition of the wheat crop and may incorporated into the soil as a organic P forms. Gupta *et al* ., (2007) reported that crop residual recycling increased soil P supply to wheat after 4 year in rice–wheat system. Studies by McLaughlin *et al.*, (1988) however, indicated that crop residue P may not significantly contribute to the nutrition of the subsequent crop over short-term, but becomes incorporated into organic P forms.

The results showed that large percentage of K release from the maize residue occurs by 30 DAP. At initial period of decomposition i.e up to 90 DAP irrespective of type of residue about 65-75% of K was released from surface placed residue and about 80-85% was released from sub surface placed residue. At the end of decomposition period the total amount of K release from $MT_{50\%}$ and $ML_{50\%}$ sub surface placed residue was about 46.22 kg K ha^{-1} (98.78% of initial) and 56.12 kg K ha^{-1} (99.02% of initial) respectively (Fig 8 & 10) similar to the study of Lupwayi *et al* (2006), where 92–

99% of the K in green manure and 65–95% of the K in the other residues was released. Similarly in wheat and moongbean residues, rapid K release was observed and most of the K (70-90%) from different residues was released by 30 DAP irrespective of method of placement. In sub surface placed residue after 30 days of placement, $WT_{75\%}$,$WL_{25\%}$, $MB_{100\%}$ and $WL_{25\%}$+ $MB_{100\%}$ release 25.97 kg N ha^{-1}, 32.39 kg N ha^{-1}, 40.98 kg N ha^{-1} and 26.74 kg N ha^{-1} (82.46%, 84.29%, 89.87% and 85.13% of initial K content) respectively (Fig 13,16, 19 & 22). At the end of decomposition cycle i.e by 360 DAP both in surface and sub surface placed residue most (99%) of the K (31-45 kg K ha-1) was released from the different type of residues. Similar trend was reported by (Ventura *et al.*, 2010) and Tagliavini *et al.*, (2007) who concluded that high release of litter K occurred from the early stage of litter decomposition, which was attributed to the fact that K was not bound to organic matter. As K is not associated with structural components of plants (Marschner 1995), its release from crop residues will depend less on microbiological decomposition of the residues than N or P release. Thus, the extent and rate of K release from crop residues is usually greater than residue decomposition and N or P release (Lupwayi *et al.*, 2006). Approximately 93% of the potassium present in plant residues after mechanized harvest becomes bioavailable after 12 months, which largely contributes to improvement of crop productivity (Flores *et al.*, 2014). Potassium does not remain incorporated in the straw with the carbon chain. Consequently, after senescence or harvest of the plants, this nutrient is quickly released to the soil solution and is readily bio available to plants (Prado, 2008).

Conclusions

Throughout the decomposition cycle, the percent decrease in weight was significantly higher from the surface placed residue as compared to subsurface placed residue. In different types of residues, residue placed sub-surface release more N, P and K as compare to surface placed residue at different stages.

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References:

Abbasi, M. K., Tahir, M. M., Sabir, N. and Khurshid, M. 2015. Impact of the addition of different plant residues on nitrogen mineralization–immobilization turnover and carbon content of a soil incubated under laboratory conditions. *Solid Earth* 6, 197-205.

Abera, G., Wolde-meskel, E. and Bakken, L. R. 2012. Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents. *Biology and Fertility of Soils* **48**, 51–66.

Baldi, E. and Toselli, M. 2014. Mineralization dynamics of different commercial organic fertilizers from agro-industry organic waste recycling: an incubation experiment. *Plant Soil and Environment* **60**, 93–99.

Beare, M. H., Wilson, P. E., Fraser, P. M., Butler, R. C. 2002. Management effects of barley residue decomposition, nitrogen release, and crop production. *Soil Science Society of American Journal* **66**, 848-56.

Berg, B. and McClaugherty, C. 2003. *'Plant litter: Decomposition, humus formation, carbon Sequestration.'* Springer: Berlin, Gemany.

Berg, B., Davey, M., De, Marco A., Emmett, B., Faituri, M., Hobbie, S., Johansson, M.B., Liu, C., McClaugherty, C., Norell, L., Rutigliano, F., Vesterdal, L. and De, Virzo Santo A. 2010. Factors influencing limit values for pine needle litter decomposition: a synthesis for boreal and temperate pine forest systems. *Biogeochemistry* **100**, 57-73.

Campbell, C. A. and Zentner, R. P. 1993. Soil organic matter as influenced by crop rotations and fertilization. *Soil Science Society of American Journal* **57**, 1034-40.

Campos, A. C., Etchevers, J. B., Oleschko, K. L. and Hidalgo, C. M. 2013. Soil microbial biomass and nitrogen mineralization rates along an altitudinal gradient on the cofre de perote volcano (Mexico): the importance of landscape position and land use. *Land Degradation and Development* **25**, 581-93.

Carsky, R. J. 1989. *Estimating availability of nitrogen from green manure to subsequent maize crop by using buried bag technique.* Ph.D Thesis, Cornell University, Ithaca, NY-USA.

Cayuela, M L, Sinicco T and Mondini V (2009) Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil. *Applied Soil Ecology* **48:** 118-27.

Christensen, B. T. 1986. Barley residue decomposition under field conditions: Effect of placement and initial nitrogen content on weight loss and nitrogen dynamics. *Soil Biology and Biochemistry* **18**, 523-29.

Clement, A., Ladha, J. K. and Chalifour, F. P. 1995. Crop residue effects on nitrogen mineralization, microbial biomass, and rice yield in submerged soils. *Soil Sci Soc Am J* **59**, 1595-603.

Cookson, W. R., Beare, M. H. and Wilson, P. E. 1998. Effects of prior crop residue management on microbial properties and crop residue decomposition. *Applied Soil Ecology* **7**,179-88.

Cornwell, W. K., Cornelissen, J. H. C., Amatangelo, K., Dorrepaal, E., Eviner, V.T., Godoy, O., Hobbie, S. E., Hoorens, B., Kurokawa, H., Pe´rez-Harguindeguy, N., Quested, H. M., Santiago, L. S., Wardle, D. A., Wright, I. J., Aerts, R., Allison, S. D., Van, Bodegom P., Brovkin, V., Chatain, A., Callaghan, T. V., Dı´az, S., Garnier, E., Gurvich, D. E., Kazakou, E., Klein, J. A., Read, J., Reich, P. B., Soudzilovskaia, N. A., Vaieretti, M. V. and Westoby, M. 2008. Plant species traits are the predominant control on litter decomposition rates within biomes worldwide. *Ecology Letter* **11,** 1065-071

Curtin, D., Selles, F., Wang, H., Campbell, C. A. and Biederbeck, V. O. 1998. Carbon dioxide emissions an transformation of soil carbon and nitrogen during wheat straw decomposition *Soil Science Society of American Journal* **62**, 1035-041.

Douglas, C. L. J. and Rickman, R. W. 1992. Estimating crop residue decomposition from air temperature, initial nitrogen content, and residue placement. *Soil Science Society of American Journal* 56, 272-78.

Dubeux, J. C. B., Sollenberger, L. E., Interrante, S. M., Vendramini, J. M. B. and Stewart, R. L. 2006. Litter decomposition and mineralization in Bahia grass pastures managed at different intensities. *Crop Science* **46**, 1305-10.

Flores, R. A., Mello, Prado R., Pancelli, M. A., Almeida, H. J., Moda, L. R., Borges, M. N., Melo, B. and Souza, Junior J. P. 2014. Potassium nutrition in the first and second ratoon sugarcane grown in an oxisol by a conservationist system. *Chilean Journal of Agriculture Research* **74**, 83-88.

Frey, S. D., Elliot, E. T., Paustian, K. and Peterson, G. A. 2000. Fungal translocation as a mechanism for soil nitrogen inputs to surface residue decomposition in a no-till ecosystem. *Soil Biology and Biochemistry* **32**, 689-98.

Ghidey, F. and Alberts, E. E. 1993. Residue type and placement effects on decomposition: field study and model evaluation. *Transaction of the American Society of Agricultural Engineers* **36**,1611-17.

Gupta, R. K .and Sayre, K. 2007. Conservation Agriculture in South Asia. *The Journal of Agricultural Sciences Cambridge* **145**, 207-14.

Gusewell, S. and Gessner, M. O. 2009. N: P ratios influence litter decomposition and colonization by fungi and bacteria in microcosms. *Functional Ecology* **23**, 211-19.

Hadas, A., Kautsky, L., Goek, M. and Kara, E. E. 2004. Rates of decomposition of plant residues and available nitrogen in soil, related to residue composition through simulation of carbon and nitrogen turnover. *Soil Biology and. Biochemistry* **36**, 255-66.

Hamadi, Z., Steinberger, Y., Kutiel, P., Lavee, H. and Barness, G. 2000. Decomposition of Avena sterilis litter under arid conditions. *Journal of Arid Environments* **46**, 281-93.

Heal, O. W., Anderson, J. M. and Swift, M. J. 1997. Plant residue quality and decomposition: An historical overview. In: Cadisch G and Giller K E (Eds.) *Driven by nature: plant Residue Quality and Decomposition.* CAB Int, Cambridge, pp 3–30.

Hiloidhari, M., Das, D. and Baruah, D. C. 2014. Bioenergy potential from crop residue biomass in India. *Renewable and Sustainable Energy Reviews* **32**: 504–12.

Hobbie S E, Eddy W C, Buyarski C R, Adair E C, Ogdahl M L and Weisenhorn P (2012) Response of decomposing litter and its microbial community to multiple forms of nitrogen enrichment. *Ecological Monographs* **82**, 389-405

Honeycutt, C. W. and Potaro L. J. 1990. Field evaluation of heat units for predicting crop residue carbon and nitrogen mineralization. *Plant Soil* **125**, 213–220.

Hueso-González, P., Martínez-Murillo, J. F. and Ruiz-Sinoga, J. D. 2014. The impact of organic amendments on forest soil properties under Mediterranean climatic conditions. *Land Degradation and Development* **25**, 604-12.

Keeney, D. R., Nelson, D. W. 1982. Nitrogen—Inorganic forms. In: Page A L, Miller R H and Keeney D R (eds) *Methods of soil analysis.* Part 2. 2nd edn. Agron. Monogr. 9. ASA and SSSA, Madison, WI, pp 643-98

Kumar, K. and Goh, K. M. 2003. Nitrogen release from crop residues and organic amendments as affected by biochemical composition, *Communications in Soil Science and Plant Analysis* **34**, 2441-60.

Liu, K., Sollenberger, L. E., Silveira, M. L., Vendramini, J. M. B. and Newman, Y. C. 2011. Grazing intensity and nitrogen fertilization affect litter responses in 'Tifton 85% Bermuda grass pastures: II. Decomposition and nitrogen mineralization. *Agronomy Journal* 103, 163-68.

Loranger, G., Ponge, J. F., Imbert, D. and Lavelle, P. 2002. Leaf decomposition in two semi-evergreen tropical forests: influence of litter quality. *Biology and Fertility of Soils* **35**, 247-52.

Lupwayi, N. Z., Clayton, G. W., O'Donovan, J. T., Harker, K. N., Turkington, T. K. and Soon, Y. K. 2007. Phosphorus release during decomposition of crop residues under conventional and zero tillage. *Soil Tillage Research* **95**, 231-39.

Ma, L., Peterson, G. A., Ahuja, L. R., Sherrod, L., Shaffer, M. J. and Rojas, K. W. 1999. Decomposition of surface crop residues in long-term studies of dryland agroecosystems. *Agronomy Journal* **91**, 401-09.

Mclaughlin, M. J., Alston, A. M., Martin, J. K. 1988. Phosphorus cycling in wheat-pasture rotations. I. The source of phosphorus taken up by wheat. *Australian Journal Soil Research* **26**, 323-32

Mishra, B., Sharma, P. K., Bronson, K. F. 2001. Decomposition of rice residue and mineralization of carbon, nitrogen, phosphorous and potassium in wheat field soil in Western Uttar Pradesh. *Journal of Indian Society of Soil Science* **49**, 419-24.

Murungu, F. S., Chiduza, C., Muchaonyerwa, P. and Mnkeni, P. N. S. 2011 Decomposition, nitrogen, and phosphorus mineralization from residues of summer-grown cover crops and suitability for a smallholder farming system in South Africa. *Communications in Soil Science and Plant Analysis* **42**, 2461-72.

Ngatia, L. W., Reddy, R. L., Nair, P. K. R., Pringle, R. M., Palmer, T. D. and Turner, B. L. 2014. Seasonal patterns in decomposition and nutrient release from East African savanna grasses grown under contrasting nutrient conditions. *Agriculture, Ecosystems and Environment* **188,** 12-19.

Nourbakhsh, F. and Dick, R. P. 2005. Net nitrogen mineralization or immobilization potential in a residue-amended calcareous soil. *Arid Land Research Management* **19**, 299-06.

Novara, A., Gristina, L., Rühl, J., Pasta, S., D'Angelo, G., La, Mantia T. and Pereira, P. 2013. Grassland fire effect on soil organic carbon reservoirs in a semiarid environment. *Solid Earth* **4,** 381-85.

Nyberg, G., Ekblad, A., Buresh, R. and Hogberg, P. 2002. Short-term patterns of carbon and nitrogen mineralization in a fallow field amended with green manures from agroforestry trees. *Biology and Fertility of Soils* **36**, 18-25.

Nygaard, Sorensen J. and Thorup-Kristensen, K. 2011. Plant-based fertilizers for organic vegetable production. *Journal of Plant Nutrient and Soil Science* **174**, 321-32.

Oliveira, S. P., Lacerda, N. B., Blum, S. C., Escobar, M. E. O. and Oliveira, T. S. 2014. Organic carbon and nitrogen stocks in soils of northeastern brazil converted to irrigated agriculture. . *Land Degradation and Development* **26**, 9–21.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939. U.S. Gov. Print Office,Washington.

Ordpnez-Fernandz, A., Rodrı´guez-Lizana, A., Carbonell, R., Gonza´lez, P. and Perea, F. 2007 Dynamics of residue decomposition in the field in a dryland rotation under mediterranean climate conditions in southern Spain. *Nutrient Cycling in Agroecosystems* **79**, 243-53.

Prado ,R .M . 2008. *Nutrição de plantas. UNESP, São Paulo*. 407 pp.

Ranjbar, F. and Jalali, M. 2012. Calcium, magnesium, sodium, and potassium release during decomposition of some organic residues. *Communications in Soil Science and Plant Analysis* **43**, 645-59.

Rezig, F. A. M., Elhadi, E. A. and Abdalla, M. R. 2014. Decomposition and nutrient release pattern of wheat (Triticum aestivum) residues under different treatments in desert field conditions of Sudan. *International Journal of Recycling Organic Waste and Agriculture* **3**, 1-9.

Rodrı´guez-Lizana, A., Carbonell, P., Gonza´lez, R., Ordo´n˜ez, R. 2010. N, P and K released by the field decomposition of residues of a pea–wheat–sunflower rotation. *Nutrient Cycling in Agroecosystems* **87**,199-208.

Schomberg H H and Steiner J L (1997) Comparison of residue decomposition models used in erosion prediction. *Agron omy Journal* **89:** 911-19.

Schomberg, H. H., Steiner, J. L., Evett, S. R. and Moulin, A. P. 1996. Climatic influence on residue decomposition prediction in the wind erosion prediction system. *Theoretical and applied climatology* **54:** 5-16.

Stewart, C. E., Pratibha, M., Follett, R. F. and Halvorson, A. D. 2015. Lignin biochemistry and soil N determine crop residue decomposition and soil priming. *Biogeochemistry* **124**, 335-51.

Stroo, H. F., Bristow, K. L., Elliott, L. F., Papendick R I and Campbell G S (1989) Predicting rates of wheat residue decomposition.*Soil Science Society of American Journal* **53:** 91-99.

Tejada, M. and Benítez, C. 2014. Effects of crushed maize straw residues on soil biological properties and soil restoration. *Land Degradation and Development* **25**, 501-09.

Tian, G., Kang, B. T., Brussaard, L. 1992. Biological effects of plant residues with contrasting chemical compositions under humid tropical conditions - decomposition and nutrient release. *Soil Biology and Biochemistry* **24**,1051-60.

Trinsoutrot, I., Recous, S., Mary B and Nicolardot, B. 2000. C and N flux of decomposing 13C and 15N *Brassica napus* L.: effect of residue composition and N content. *Soil Biology and Biochemistry* **32**, 1717-30.

Vahdat, E., Nourbakhsh, F. and Basiri M. 2011 Lignin content of range plant residues controls N mineralization in soil. *European Journal Soil and Biology* **47**, 243-46.

Van, Vliet P. C. J., Gupta, V. V. S. R. and Abbot, L. K. 2000. Soil biota and crop residue decomposition during summer and autumn in south-western Australia. *Applied Soil Ecology* **14**,111-14.

Varco JJ, Frye WW, Smith MS, MacKown CT 1993. Tillage effects on legume decomposition and transformation of legume and fertilizer nitrogen-15. *Soil Science Society American Journal* **57**, 750–756.

Wang, H., Curtin, D., Jame, Y. W., McConkey, B. G. and Zhou, H. F. 2001. Simulation of soil carbon dioxide flux during plant residue decomposition. *Soil Science Society American Journal* **66,** 1304-10.

Yadvinder-Singh, Bijay-Singh and Timsina J 2005. Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. *Advances in Agronomy* **85**,269-07.

Yadvinder-Singh, Gupta, R. K., Jagmohan Singh, Gurpreet Singh, Gobinder Singh and Ladha, J. K. 2010. Placement effects on rice residue decomposition and nutrient dynamics on two soil types during wheat cropping in rice–wheat system in north-western India. *Nutrient Cycling in Agroecosystems* **88**, 471-80

Table 1: Initial weight taken and initial nutrient content in different type of residues

Type of Residue	Weight (g)	N (%)	P (%)	K (%)
Maize Res T50%	50	0.52	0.044	1.050
Maize Res L50%	50	0.48	0.044	0.800
Wheat Res T75%	50	0.40	0.088	1.250
Wheat Res L25%	50	0.32	0.075	1.525
MungRes 100%	50	1.08	0.118	1.425
MR100%+WRL25%	50	0.64	0.112	1.125

Table 2: Quality parameters of different type of residues

Type of Residue	Neutral Detergent Fibre (NDF) %	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Silica (%)
Maize Res T50%	82	33	41	7	1
Maize Res L50%	82	35	38	6	3
Wheat Res T75%	84	29	42	9	4
Wheat Res L25%	86	19	45	17	5
MungRes 100%	74	15	44	14	1
MR100%+WRL25%	82	23	41	16	2

Table 3: Periodic weight (g) remains in $MT_{50\%}$ and $ML_{50\%}$residuesas affected by method of placement

Treatments	Days after placement						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue	**Weight (g)**						
MR $T_{50\%}$	39.568^a	36.463^a	29.948^a	25.922^a	17.650^a	7.510^a	3.250^a
MR $L_{50\%}$	39.246^a	34.359^a	26.906^a	21.473^a	15.202^a	4.404^a	2.611^a
SEM±	**0.658**	**0.309**	**0.569**	**1.350**	**0.609**	**0.429**	**0.378**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Method of placement	**Weight (g)**						
SP	44.205^a	40.698^a	32.157^a	27.408^a	21.193^a	7.917^a	4.158^a
SSP	34.610^b	30.123^b	24.698^b	19.987^b	11.658^b	3.998^b	1.705^b
SEM±	**0.658**	**0.833**	**0.569**	**1.350**	**0.609**	**0.429**	**0.378**
LSD (p = 0.05)	**2.322**	**2.940**	**2.008**	**4.762**	**2.149**	**1.513**	**1.334**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table 4: Periodic N (%) content in MT$_{50\%}$ and ML$_{50\%}$ residuesas affected by method of placement

Treatments	Days after placement						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue	**Nitrogen (%)**						
MR T$_{50\%}$	0.620[a]	0.640[a]	0.783[a]	0.830[a]	0.947[a]	1.033[a]	1.157[a]
MR L$_{50\%}$	0.547[b]	0.580[b]	0.720[b]	0.767[b]	0.933[a]	0.997[a]	1.117[a]
SEM±	**0.011**	**0.012**	**0.018**	**0.014**	**0.037**	**0.042**	**0.084**
LSD (p = 0.05)	**0.037**	**0.042**	**0.064**	**0.049**	**NS**	**NS**	**NS**
Method of placement	**Nitrogen (%)**						
SP	0.527[b]	0.540 [b]	0.697 [b]	0.737 [b]	0.820 [b]	1.050[a]	1.163[a]
SSP	0.640[a]	0.697 [a]	0.807 [a]	0.860 [a]	1.033 [a]	0.980 [a]	1.110 [a]
SEM±	**0.011**	**0.012**	**0.018**	**0.014**	**0.037**	**0.042**	**0.084**
LSD (p = 0.05)	**0.037**	**0.042**	**0.064**	**0.049**	**0.131**	**NS**	**NS**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table 5: Periodic P (%) content in MT$_{50\%}$ and ML$_{50\%}$residuesas affected by method of placement

Treatments	Days after placement						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue	**Phosphorus (%)**						
MR T$_{50\%}$	0.065[a]	0.061[a]	0.081[b]	0.076[a]	0.083[a]	0.094[a]	0.136[a]
MR L$_{50\%}$	0.078[a]	0.068[a]	0.092[a]	0.085[a]	0.081[a]	0.094[a]	0.109[a]
SEM±	**0.005**	**0.005**	**0.005**	**0.010**	**0.005**	**0.007**	**0.009**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Method of placement	**Phosphorus (%)**						
SP	0.069[a]	0.057[a]	0.083[a]	0.074[a]	0.081[a]	0.089[a]	0.123[a]
SSP	0.074[a]	0.071[a]	0.090[a]	0.087[a]	0.083[a]	0.099[a]	0.122[a]
SEM±	**0.005**	**0.005**	**0.005**	**0.010**	**0.005**	**0.007**	**0.009**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table 6: Periodic K (%) content in $MT_{50\%}$ and $ML_{50\%}$residuesas affected by method of placement

Treatments	Days after placement						
	30	60	90	120	150	270	365
Type of residue	**Potassium (%)**						
MR $T_{50\%}$	0.404[b]	0.346[b]	0.279[b]	0.250[b]	0.221[a]	0.192[a]	0.158[a]
MR $L_{50\%}$	0.488[a]	0.408[a]	0.338[a]	0.288[a]	0.246[a]	0.183[a]	0.154[a]
SEM±	**0.017**	**0.015**	**0.016**	**0.010**	**0.011**	**0.010**	**0.011**
LSD (p = 0.05)	**0.061**	**0.051**	**0.055**	**0.037**	**NS**	**NS**	**NS**
Method of placement	**Potassium (%)**						
SP	0.521[a]	0.450[a]	0.383[a]	0.321[a]	0.279[a]	0.204[a]	0.167[a]
SSP	0.371[b]	0.304[b]	0.233[b]	0.217[b]	0.188[b]	0.171[a]	0.146[a]
SEM±	**0.017**	**0.015**	**0.016**	**0.010**	**0.011**	**0.010**	**0.011**
LSD (p = 0.05)	**0.061**	**0.051**	**0.055**	**0.037**	**0.038**	**NS**	**NS**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table7: Periodic weight (g) remains in different residues as affected by method of placement

Treatments	Days after placement						
	30	60	90	120	150	270	365
Type of residue	**Weight (g)**						
Wheat Res T75%	30.793[b]	24.935[a]	17.607[bc]	14.402[b]	10.015[bc]	6.725[b]	2.550[b]
Wheat Res L25%	34.603[a]	26.997[a]	20.543[a]	16.582[a]	12.123[a]	8.842[a]	3.497[a]
MungRes 100%	21.202[d]	19.010[c]	16.445[c]	12.820[c]	9.165[c]	5.960[b]	2.540[b]
MR100%+WRL25%	26.943[c]	22.337[b]	18.617[b]	16.395[a]	11.073[ab]	7.413[ab]	2.923[ab]
SEM±	**0.720**	**0.747**	**0.614**	**0.497**	**0.762**	**0.546**	**0.239**
LSD (p = 0.05)	**2.205**	**2.287**	**1.879**	**1.522**	**1.651**	**1.674**	**0.731**
Method of placement	**Weight (g)**						
Surface placed	31.792[a]	26.811[a]	21.150[a]	17.566[a]	12.685[a]	8.630[a]	3.792[a]
Sub surface placed	24.979[b]	19.828[b]	15.456[b]	12.533[b]	8.503[b]	5.840[b]	1.963[b]
SEM±	**0.509**	**0.528**	**0.434**	**0.352**	**0.539**	**0.386**	**0.169**
LSD (p = 0.05)	**1.559**	**1.617**	**1.329**	**1.077**	**1.167**	**1.183**	**0.517**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table8: Periodic N (%) in different residues as affected by method of placement

Treatments	Days after placement						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue	**Nitrogen (%)**						
Wheat Res T75%	0.480[c]	0.557[c]	0.680[c]	0.733[c]	0.827[c]	0.975[c]	1.210[c]
Wheat Res L25%	0.377[d]	0.427[d]	0.543[d]	0.687[c]	0.773[c]	0.977[c]	1.147[c]
MungRes 100%	1.523[a]	1.607[a]	1.727[a]	1.850[a]	2.087[a]	2.177[a]	2.260[a]
MR100%+WRL25%	0.787[b]	0.870[b]	0.993[b]	1.127[b]	1.337[b]	1.460[b]	1.547[b]
SEM±	**0.027**	**0.014**	**0.025**	**0.039**	**0.042**	**0.045**	**0.046**
LSD (p = 0.05)	**0.083**	**0.043**	**0.077**	**0.120**	**0.128**	**0.138**	**0.142**
Method of placement	**Nitrogen (%)**						
Surface placed	0.737[b]	0.808[b]	0.935[b]	1.050[b]	1.197[a]	1.375[a]	1.500[a]
Sub surface placed	0.847[a]	0.922[a]	1.037[a]	1.148[a]	1.315[a]	1.419[a]	1.582[a]
SEM±	**0.019**	**0.010**	**0.018**	**0.028**	**0.030**	**0.032**	**0.033**
LSD (p = 0.05)	**0.059**	**0.031**	**0.055**	**0.085**	**0.090**	**NS**	**NS**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table 9: Periodic P (%) in different residues as affected by method of placement

Treatments	Days after placement						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue	**Phosphorus (%)**						
Wheat Res T75%	0.091[c]	0.101[b]	0.105[c]	0.112[b]	0.121[b]	0.138[c]	0.161[b]
Wheat Res L25%	0.080[d]	0.089[c]	0.094[d]	0.103[b]	0.112[b]	0.126[d]	0.146[c]
MungRes 100%	0.122[a]	0.131[a]	0.176[a]	0.200[a]	0.233[a]	0.254[a]	0.269[a]
MR100%+WRL25%	0.115[b]	0.125[a]	0.160[b]	0.191[a]	0.223[a]	0.237[b]	0.259[a]
SEM±	**0.002**	**0.002**	**0.003**	**0.004**	**0.004**	**0.004**	**0.003**
LSD (p = 0.05)	**0.005**	**0.006**	**0.010**	**0.013**	**0.012**	**0.012**	**0.011**
Method of placement	**Phosphorus (%)**						
Surface placed	0.101[a]	0.111[a]	0.134[a]	0.124[a]	0.168[a]	0.187[a]	0.209[a]
Sub surface placed	0.103[a]	0.112[a]	0.133[a]	0.132[a]	0.177[a]	0.190[a]	0.208[a]
SEM±	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.003**	**0.002**
LSD (p = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

Table10: Periodic K (%) in different residuesas affected by method of placement

Treatments	Days after placement						
	30	**60**	**90**	**120**	**150**	**270**	**365**
Type of residue	**Potassium (%)**						
Wheat Res T75%	0.471[ab]	0.367[abc]	0.254[bc]	0.229[ab]	0.204[d]	0.133[b]	0.108[c]
Wheat Res L25%	0.392[b]	0.296[c]	0.254[c]	0.225[ab]	0.175[bc]	0.146[b]	0.096[c]
MungRes 100%	0.479[a]	0.421[a]	0.350[a]	0.271[b]	0.163[cd]	0.108[b]	0.092[c]
MR100%+WRL25%	0.392[b]	0.333[bc]	0.263[bc]	0.200[b]	0.138[d]	0.117[b]	0.083[c]
SEM±	**0.025**	**0.015**	**0.018**	**0.016**	**0.013**	**0.013**	**0.007**
LSD (p = 0.05)	**0.076**	**0.047**	**0.054**	**0.049**	**0.041**	**NS**	**NS**
Method of placement	**Potassium (%)**						
Surface placed	0.465[a]	0.402[a]	0.308[a]	0.273[a]	0.200[a]	0.127[a]	0.100
Sub surface placed	0.402[b]	0.306[b]	0.252[b]	0.190[b]	0.140[b]	0.125[a]	0.090
SEM±	**0.018**	**0.011**	**0.012**	**0.011**	**0.010**	**0.009**	**0.005**
LSD (p = 0.05)	**0.054**	**0.034**	**0.038**	**0.035**	**0.027**	**NS**	**NS**

SEM±, standard error of the mean; LSD, least significant difference; DAP, Days after Placement

Means with same letter are not significantly different

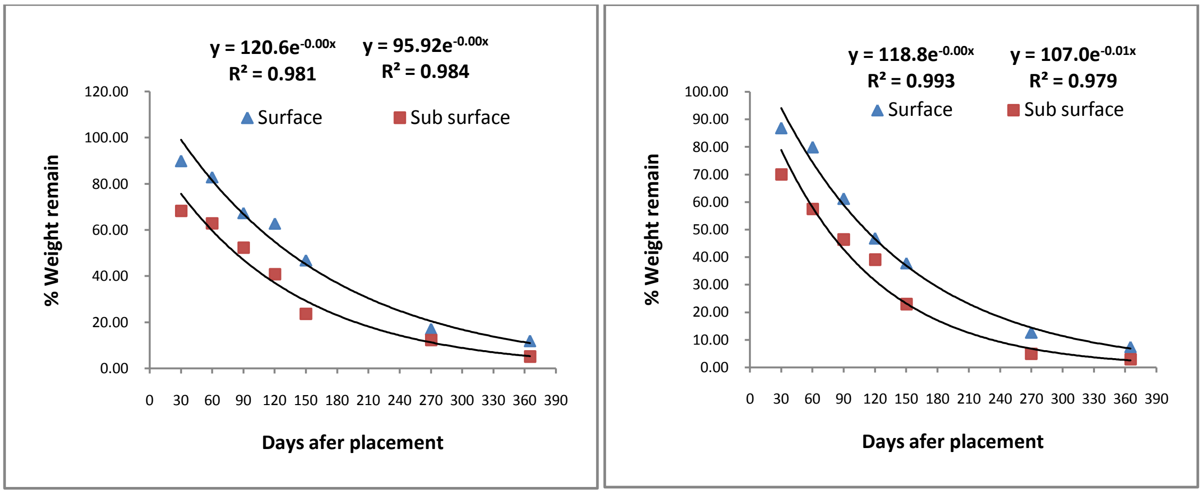

Fig 1&2: Percent weight remaining of $MT_{50\%}$ and $ML_{50\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

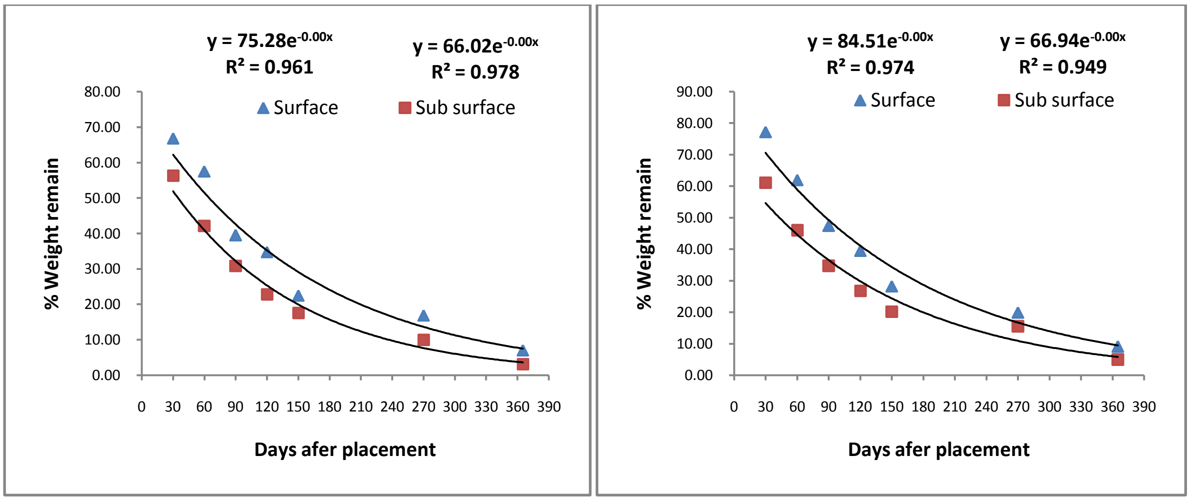

Fig 3&4: Percent weight remaining of $WT_{75\%}$ and $WL_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

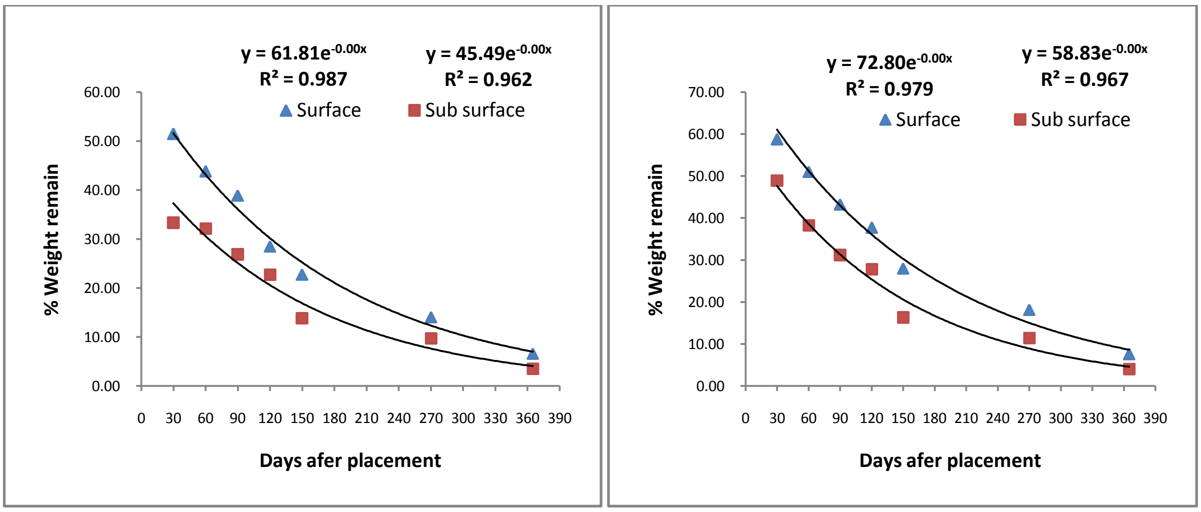

Fig 5&6: Percent weight remaining of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

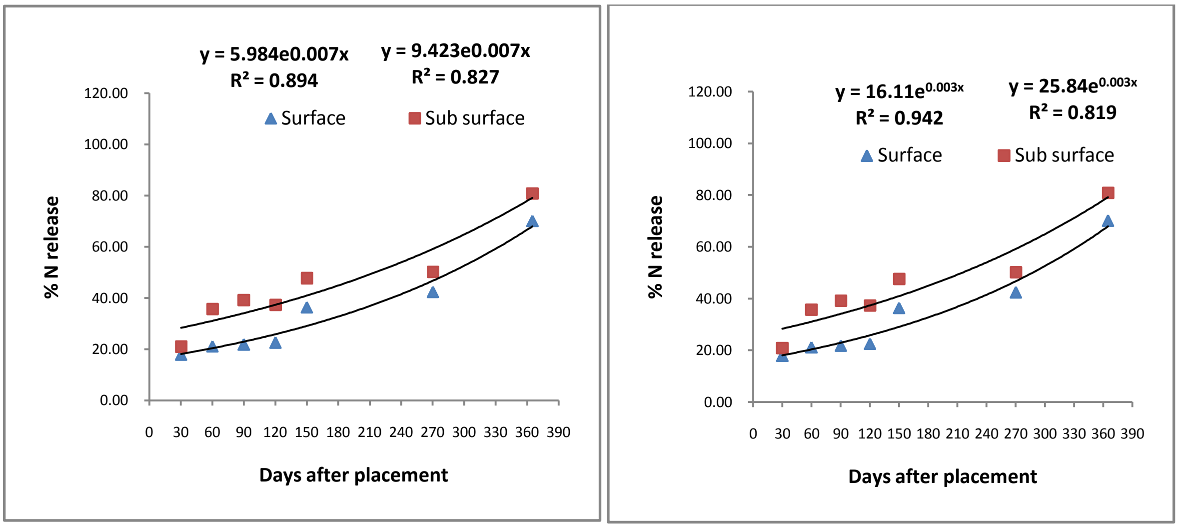

Fig 7&8: Nitrogen release during decomposition of $MT_{50\%}$ and $ML_{50\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

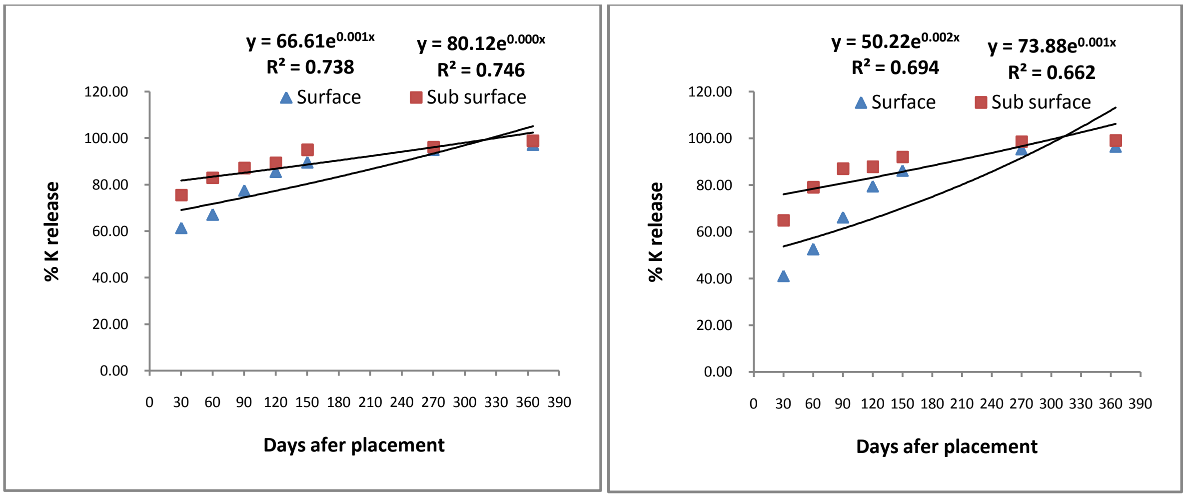

Fig 9&10: Potassium release during decomposition of $MT_{50\%}$ and $ML_{50\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

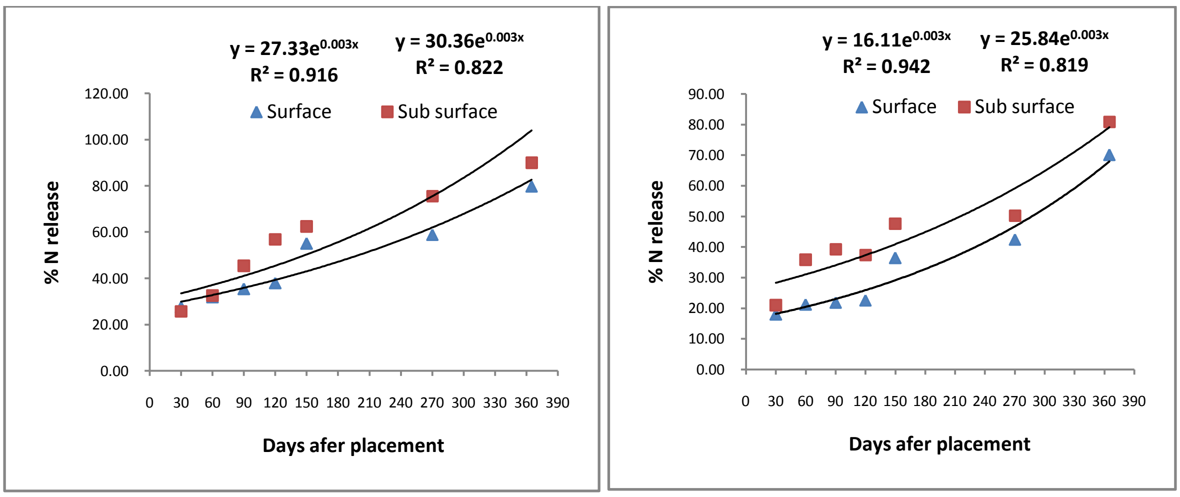

Fig 11&12: Nitrogen release during decomposition of $WT_{75\%}$ and $WL_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

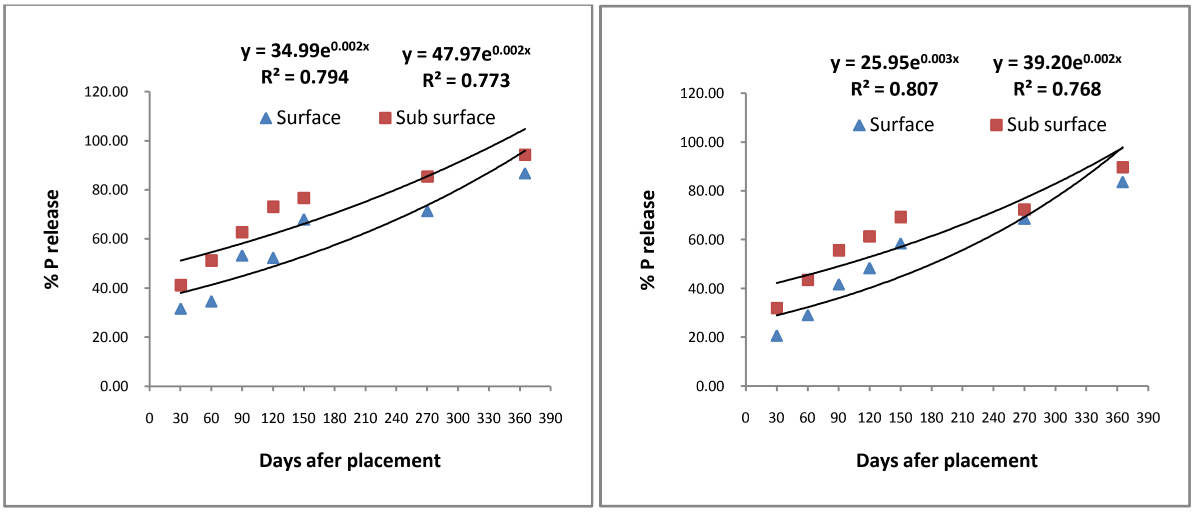

Fig 13&14: Phosphorus release during decomposition of $WT_{75\%}$ and $WT_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

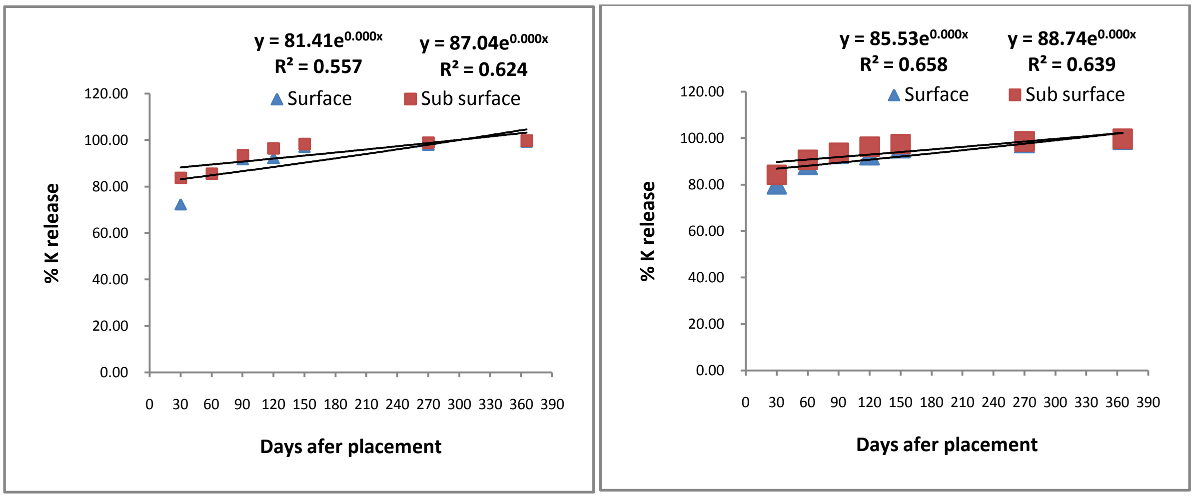

Fig 15&16: Potassium release during decomposition of $WT_{75\%}$ and $WT_{25\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

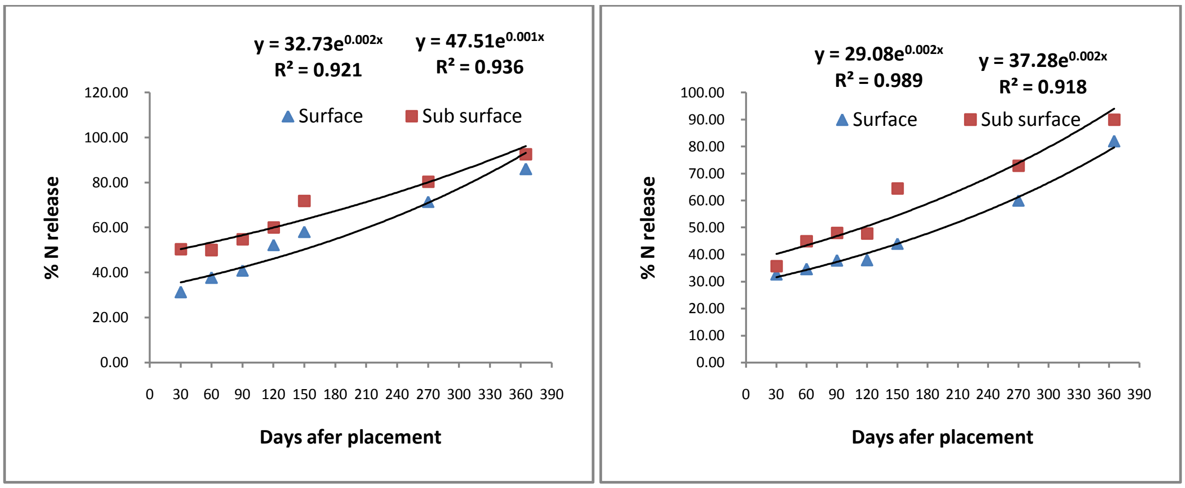

Fig 17&18: Nitrogen release during decomposition of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

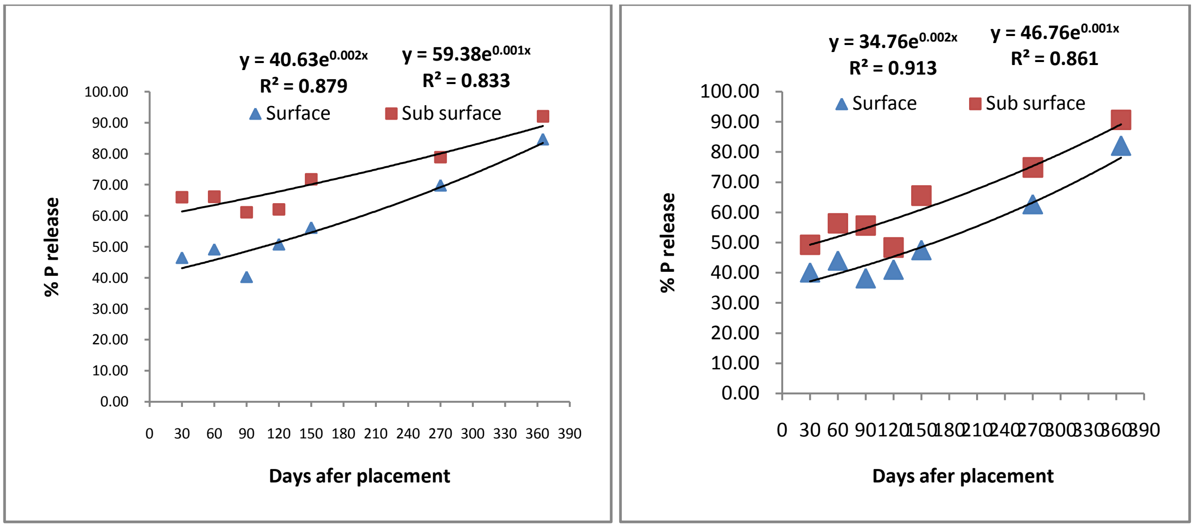

Fig 19&20: Phosphorus release during decomposition of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

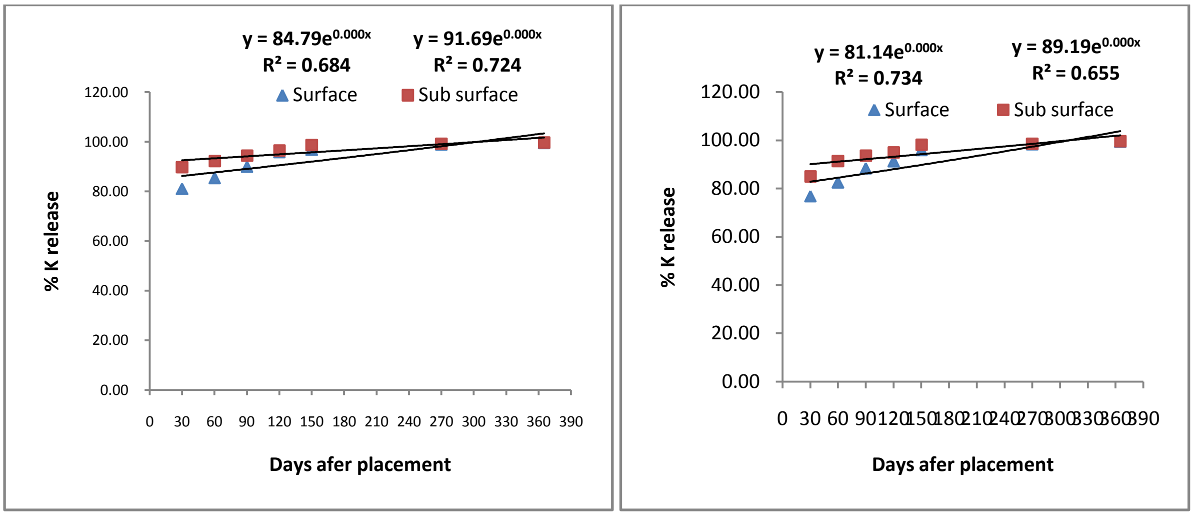

Fig 21&22: Potassium release during decomposition of $M_{100\%}$ and $WL_{25\%}+M_{100\%}$ residue throughout the decomposition cycle as a function of days after placement as affected by method of placement

VITA

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