Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)

Thesis

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By

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Pantnagar — ***(Pooja Pandey)***
July, 2017 — *Authoress*

CERTIFICATE

This is to certify that the thesis entitled **"Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)",** submitted in partial fulfillment of the requirements for the degree of **Doctor of philosophy** with major in **Horticulture (Vegetable Science)** and minors in **Soil Science** and **Genetics and Plant Breeding** of the College of Post-Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Ms. Pooja Pandey, Id.No. 42650** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Pantnagar
July, 2017

(Manoj Raghav)
Chairman
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We, the undersigned, members of the Advisory Committee of **Ms. Pooja Pandey, Id.No. 42650,** a candidate for the degree of **Doctor of Philosophy** with major in **Horticulture (Vegetable Science)** and minors in **Soil Science** and **Genetics and Plant Breeding**, agree that the thesis entitled **"Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)"** may be submitted in partial fulfilment of the requirements for the degree.

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(Ex Officio Member)

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	:	Per cent
2 % (Conc.)	:	(20 g l^{-1})
3 % (Conc.)	:	(30 g l^{-1})
/	:	Per
@	:	At the rate
°C	:	Degree Celsius
B: C	:	Benefit: cost ratio
C. D.	:	Critical difference
cm	:	Centimeter
cm^3	:	Cubic Centimeter
DAP	:	Days after planting
et al.	:	Etalia, Co-worker
g	:	Gram
ha	:	Hectare
ha^{-1}	:	Per hectare
i.e.	:	That is
K	:	Potash
kg	:	Kilogram
m^2	:	Square meter
mm	:	Millimeter
N	:	Nitrogen
NAR	:	Nitrogen apparent recovery
NUE	:	Nitrogen use efficiency
P	:	Phosphorus
ppm	:	Parts per million
q	:	Quintal
RBD	:	Randomized Block Design
RDF	:	Recommended dose of fertilizer
SEm±	:	Standard error of mean
t	:	Tonne
T.S.S.	:	Total soluble solids
viz.	:	Videlict (namely)
v/s	:	versus

Introduction

Chapter 1 INTRODUCTION

Potato is a non cereal major food crop in the world after rice, wheat and maize. Depending on the taxonomy, it belongs to the family Solanaceae and has about 5,000 varieties worldwide across nine species. The major species grown worldwide is *Solanum tuberosum* L., a dicotyledon herb about 60 cm in height having tetraploid genome with chromosome number 48. The probable center of origin of potato is Peru in South America. In 1565 the Spanish people brought potato from Peru to Spain and in 1586, Sir Francis Drake brought it to England. From Spain potato reached to Italy, Belgium, Germany, France, Holland and Northern Europe in the end of sixteenth century. In India, it is introduced from Europe in the seventeenth century by Portuguese. The first introduction of potato in India is mentioned in Terry's account of a banquet given by Asaph Khan to Sir Thomas Roe at Ajmer in 1615 (Shekhawat, 2010). Potato was first cultivated in plains then went to the hills where it became a cash crop and grown in off season. Now it has become popular among people of India after wheat and rice and cultivated throughout the country in different season.

The edible part of potato is the swollen portion of underground stem which is called a tuber and is designed to provide food for green leafy portion of the plant. It contains about 75% moisture, 20% dry matter, 22.6% carbohydrates, 1.6% protein and 97 kcal energy. It is rich in minerals like potassium (421 mg), phosphorus (40 mg) calcium (10 mg), iron (0.7 mg) and some vitamins *viz.,* thiamin (0.10 mg) and vitamin C (17 mg) per 100 g of fresh weight (Chakrabarti, 2010). Potato is an important crop for the high population areas of Asia because it produces more dry matter food, well-balanced protein and more calories per unit area of land and time than other major food crops. The problem of malnutrition can be largely solved if potato is accepted as a major food and not merely as a vegetable. Whether, mashed, fried, baked or roasted potatoes, people often consider it as comfort food. In India, several traditional dishes are prepared from potato like stuffed *paratha, kachouri, samosa, dum aloo* and sweets like *halwa*. Besides reducing malnutrition it has medicinal value like the juice of potato reduces gastrogenic problems. Potato also provides relief and heals burned skin wounds.

From the production point of view India is the world's second largest producer of potato next only to the China with the production of 48.0 million tons from 2.07 million hectare area. The productivity of potato is 23.1 t ha^{-1} and it occupies 21.7% of the total vegetable area and 28.32% of total vegetable production in country (Anonymous, 2015). Potatoes are available year-round in India as the country varied in climatic conditions according to the region. The major potato growing states in the country are Uttar Pradesh, West Bengal, Punjab, Bihar, Haryana, Madhya Pradesh, Gujarat and Maharashtra. More than 89% potato crop is grown in winter season (*Rabi*) under assured irrigation facility from October to March mostly in Indo gangetic plains (Banerjee *et al.*, 2015). The remaining 10% is being taken up during rainy season (Kharif) in Karnataka, Maharashtra, H.P., J & K, and Uttarakhand hills. In Uttarakhand, potato production is 452.50 thousand MT from 28.36 thousand hectare area (Anonymous, 2015). The major potato growing districts of the state are U.S. Nagar, Dehradun, Champawat, Pithoragarh and Haridwar. Hilly areas supply off season potato as well as quality seeds to the plains.

Potato is a short duration, high yielding and nutrient exhaustive crop. So, use of balanced fertilizers with best management practices is necessary and pre-requisite for getting better and higher yield of this crop. Nitrogen (N) is one of the foremost management priorities in potato cropping systems (Stark *et al*., 2004). It determines the quantity and structure of potato yield, its chemical composition and tuber quality (Kolodziejczyk, 2014). It primarily influences tuber size, dry matter and sugar contents. The supply is managed according to the market classes (table stock, French fries and potato chips) which require different quality parameters. Sound management of nitrogen for potato makes good economic sense. Optimal nitrogen application in potato is essential for achieving commercial tuber yield and size requirements which results in the maximum economic return. It also represents an effective and practical means for producers to reduce greenhouse gas emissions which makes good environmental sense. Widely fluctuating N levels result in irregular tuber growth and often end in the formation of internal (brown center and hollow heart) and external (misshapen) tuber deformities (Taysom *et al.*, 2007). On the other hand, excess nitrogen can result in reduced yield and delayed tuber set (Alva, 2004). It also increases environmental losses of nitrogen, including nitrate leaching to groundwater and emissions of nitrous oxide, a greenhouse gas to the atmosphere (Blumenthal *et al*., 2008). However, when nitrogen is deficient, potato leaves become pale yellow/green, small in size and drop prematurely. The plant is stunted in growth with only a few thin stems and few tubers which lead to the lesser yield. On an average, a 90 days potato crop producing 20 tons tubers per hectare requires about 100 kg nitrogen to be removed in the form of tuber and haulm (Das *et al.*, 2015). Nitrogen uptake on per day basis is sometime even more than 1.5 kg ha^{-1} during active growth period (Kumar and Trehan, 2012). Agronomic research on macronutrient management aspect showed that some newly released potato cultivars for processing requires approximately 150% higher nitrogen and potassium over current table-purpose potato cultivars. Recent diagnostic survey also indicates that to maintain crop productivity in many intensively cultivated areas, farmers have resorted to use of greater than the recommended dose of fertilizer (RDF), particularly N (Das *et al.*, 2015).

Mostly nitrogen is made available from soil to plants in one of the two forms: NH_4^{++}-N and NO_3^- -N. Commonly used N fertilizer sources available in India are urea, ammonium nitrate and ammonium sulphate. Urea is the most frequently used cheapest nitrogenous fertilizer globally and contains nitrogen in amide form. Before utilization, it has to be converted to ammonium and finally into the nitrate. Therefore, nitrogen recovery by plant from applied urea is always less because of the heavy losses of the applied nitrogen in ammonia (NH_3) volatilization, leaching, runoff and dinitrification. Such high N losses from applied urea lower the fertilizer use efficiency and thus represent both economic and agronomic losses (Khan *et al*., 2014). In addition this lost nitrogen increases nitrate contamination of water and gas emissions from greenhouse. Crop nitrogen-use efficiency can be enhanced by reducing such type of losses. Synchronous application of N fertilizer with plant growth stages is an option to minimize these losses. Data from N uptake studies show that 80 to 90% of the total potato N is taken up within 60 days after emergence (Munoz *et al.*, 2005; Horneck and Rosen 2008). While, N applied later than 60 to70 days after emergence is unlikely to contribute to tuber production (Vos, 1999). Fertilizer application at suitable growth stage of plant also provides better yield and quality by proper translocation of food material in edible organ. Casa *et al.* (2005) reported to split the nitrogen applications, giving initially to the crop a fraction of the optimal N dose calculated according to a balance method. Crop N status monitoring is then required in order to assess whether it is necessary to complement the dose with a second dressing.

The growth, yield, quality and nitrogen use efficiency also depend upon the application methods such as band placement, broadcasting, foliar spray etc. Banded fertilizer nitrogen is used more efficiently than broadcast. The above said effects of N availability patterns on tuber growth, yield and quality have led to recommendations for split N applications, with lower levels applied pre-plant (Stark and Westermann, 2001). Nitrogen needs of potatoes are best met by split applications of N fertilizers during the vegetative period. This involves applying some of the N fertilizer pre-plant or at planting with the remainder of the crop's N needs applied with irrigation water. Split application of N fertilizer can improve the efficiency of crop nitrogen use in sandy soils that are susceptible to leaching. Whereas, it has not been found to improve tuber yield in medium-textured soils, and may reduce yield potential in years with dry soil conditions early in the growing season (Zebarth *et al*., 2007). After application immediate incorporation in the soil also enhances nitrogen use efficiency when urea is taken as fertilizer source. Surface application of urea causes ammonia emission. Warm weather, some soil properties (soil type, content and composition of organic matter, biological activity, high pH) and windy weather increase nitrogen loss to as much as 47% (Watson, 2005).

Another effective application method *i.e.* foliar spray of nutrients is an important additional way to mitigate the nutrient deficiency immediately and a good tool in crop management to maximize yields of crops. In soil fertilization, plants absorb nutrients by root and they are translocated to the upper parts while in foliar application, nutrients enter the leaf cuticle and then in the cells. Thus, crop shows immediate response in less time in case of foliar sprays (Fageria *et al.,* 2009). The beneficial effects of foliar urea applications expressed as an increase in yield and an improvement of crop quality were reported in many vegetable species such as cabbage, onion, cucumber, squash (Kolota and Osinska, 2001). In an experiment Qadri *et al*. (2015) observed that foliar application of fertilizer is far better than soil application not only for improving plant yield and quality but also nutrient efficiency. However, at earlier stage of growth when plant is small with no sufficient foliage respond better to basal or band placement. So, combination of broadcast and foliar application observed better for yield and quality than the sole method (Kumar, 2015). Foliar application of urea is more beneficial as it depends less on soil conditions and in saline or dry soils when root nitrogen uptake is impaired, plants can easily take nitrogen from foliar application. It can also enhance yield of tuber as it provides an opportunity to fertilize the crop late in the season. The interest in foliar fertilizers arose due to the multiple advantages of foliar application methods such as rapid and efficient response to the plant needs, less product needed, and independence of soil conditions. It is also recognized that supplementary foliar fertilization of nitrogen during crop growth can improve the mineral status of the plants and increase the crop yield (Kolota and Osinska, 2001). A high penetration rate is one of the pre-requisites for efficient foliar nutrition. Urea, due to its intrinsic characteristics like small molecular size, non-ionic nature and high solubility, is usually taken up rapidly through the leaf cuticle. Urea can be supplied to plants through the foliage, facilitating optimal nitrogen management, which minimizes nitrogen losses to the environment (Witte *et al*., 2002). Rizk *et al.*, (2013) observed that beside of vegetative growth and yield urea as foliar spray also influence the nutritional content such as protein, N, P, K, Mn, Zn and Cu in potato.

To obtain good yield and enhance the nutrient recovery it is important to supply proper amount of nitrogenous fertilizer at accurate time by suitable and efficient application method when there is a need of the crop. The time of fertilizer application should be adjusted in such a way that the requisite amount of N is made available at aforesaid critical periods. It should also be economic to the farmer. Keeping in view the above facts and considering the potential of potato in *tarai* region and also to ensure environment safety and economic security of farmers, a field experiment was conducted at Vegetable Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand with the following objectives:

- to standardize the nitrogen scheduling in potato for yield and processing attributes
- to estimate nitrogen apparent recovery in the treatments and
- to workout the crop profitability under different nitrogen scheduling

Review of Literature

Potato is one of the most important crops in the world while in a few countries it is consumed as staple food. Due to bulk of the nutrients and energy potato is also considered as malnutrition reduction food. In India, it is grown in a wide area including hills and Indogangetic plains. It is estimated that by 2020 India will have 1.3 billion populations and to fulfil its potato requirement country will need to produce about 49 million tons of potato. For this much production there will be a need of best management practices including water, soil, seed, and fertilizer with proper post harvest practices. Potato is a nutrient exhaustive crop and usually requires more nitrogen for optimum yield and quality. Excess amount of nitrogen induces the vegetative growth and lower level reduces the size of the tuber, ultimately both the conditions lead to the fewer tuber yields. However, sometimes it may be additionally supplied through irrigation systems during early tuber growth.

Application of nitrogen, at right time, in right amount, at right place by right method is a critical issue as nitrogen is highly leached and volatile element and is considered as pollutant either goes to ground water or volatilize in atmosphere. According to Blumenthal *et al*. (2008) adequate nitrogen usually improves tuber yield, quality, size, maturity, dry matter and sugar content as nitrogen primarily influences these characters. Regarding importance of nitrogen in potato a brief review of literature pertaining to the proposed study on potato is reviewed as under following sub-heads:

2.1 Effect of nitrogen on growth characters

2.2 Effect of nitrogen on yield and yield contributing characters

2.3 Effect of nitrogen on quality characters

2.4 Effect of nitrogen on soil and plant analytical characters

2.5 Effect of nitrogen on economics

2.1 Effect of nitrogen on growth characters

To determine the most appropriate dose and time of nitrogen application for potato (*Solanum tuberosum* L.) an experiment was conducted by Elkashif *et al.* (2000)

at the Gezira University Farm. They applied nitrogen in the form of urea at the rate of 83 kg/ha to potato cultivars (Spunta, Draga and Diamant). Application was either a whole dose before planting, whole dose after emergence, half the dose before planting and the other half after emergence, half the dose after emergence and the other half three weeks later. They observed that application of the whole dose before planting resulted in the highest emergence percentage and the most vigorous vegetative growth compared with other treatments. However, the lowest emergence percentage, the poorest vegetative growth was recorded in application of half the dose after emergence and the other half three weeks later.

In an experiment Gathungu *et al*. (2000) investigated the effect of different sources of nitrogen (CAN, ASN and Urea), time of application (early application, split application with half of the fertilizer at planting and half applied 5 weeks after emergence & late application with 5 weeks after emergence) and method of application (placement and broadcast within the furrow) on growth and development of potato over two seasons using the cultivar Dutch Robjyn. They noticed that early application of N followed by split applied fertilizer led to a fast early growth (shoot, tuber, root and total dry matter, Leaf Area Index (LAI) and plant height) particularly where CAN or ASN was applied. They also reported that late N application (later in the growth season) with urea enhanced growth of the shoots (leaves and plant height).

While assessing the effect of supplemental light and urea application methods (spraying at 0.1% after true leaf formation at alternate days until transplanting; and drenching at 0.1% after true leaf formation at alternate days until transplanting) on the growth and yield of seed potato, Wadhwa *et al.* (2000) recorded that spraying with 0.1% urea improved survival, seedling establishment, plant height number of branches and leaves, haulm weight and tuber yield, while drenching did not.

In an experiment regarding influence of the method of urea application on the yield and quality of potato tubers Trawczynski and Grzeskiewicz (2000) observed that split application plays an important role to escape the detrimental effect of urea on crop emergence and yield of potato.

Martin *et al*. (2001) evaluated different methods to fulfil potato crop nitrogen requirement by measuring petiole diameter, total plant nitrogen content and leaf area of cultivar Russet Burbank at Lincoln. The nitrogen treatments were 0, 150 kg N ha^{-1} at planting time, 300 kg N ha^{-1} (150 kg at planting+ 150 kg at moulding), 275 kg N ha^{-1} (100 kg at planting time+ 25 kg at moulding and 12.5 kg in ten split doses) in the form of urea. They found that the leaf area index was declined quickly in case of no nitrogen, while it is increased earlier and decreased to zero during later growing season in other treatments. They also noticed a close relationship between nitrogen content of the plant and plant fresh weight but the relationship depends upon the rate and schedule of fertilizer application.

In an experiment regarding evaluation of five different methods of urea application Chowdhury *et al*. (2002a) found that application of 100% urea as basal dose cause adverse effect on plant emergence because the concentrations of free ammonia and nitrite was likely to be more near the seed tubers than those of the other treatments. Split application of urea, however, reduced this adverse effect on plant emergence. The potato plant reached at the maximum height and foliage coverage per hill (64.17 cm and 78.17% respectively) at 50% basal + 50% top dressing of urea and the minimum (57.40 cm and 73.90% respectively) at 100% basal. The maximum number of haulm (3.87) was found at 50% basal + 50% top dressing of urea and the minimum (3.13) at 100% basal. They explained that decrease in number of main stem might be due to the toxicity produced by the basal application of urea which ultimately killed the sprouts. In their study method of application of urea did not affect fresh and dry weight of haulm.

Another experiment to find out the appropriate method of urea application and its effect on different growth characters was done by Chowdhury *et al*. (2002b) at Horticulture Farm of Bangladesh Agriculture University. The four doses of nitrogen (0, 60, 120, 180 kg ha^{-1}) supplied through urea with five different application methods at same time *i.e.* basal, 30 and 50 days after planting. They recorded minimum time for 80% emergence in 0% nitrogen. However, maximum plant height, number of haulms per hill and foliage coverage was measured in 180 kg ha^{-1} nitrogen applied 50% as basal and 50% in two split doses at 30 and 50 DAP. Maximum fresh weight of haulm was recorded in 180 kg ha^{-1} nitrogen applied as 75% basal and 25% as split doses at 30 and 50 DAP while dry weight was found maximum in 180 kg ha^{-1} nitrogen completely applied as basal.

Bulking rate of Russet Burbank potatoes at three nitrogen regimes (deficient, adequate or recommended and excessive nitrogen) was assessed by Kleinkopf *et al*. (2003)

during the growing seasons. The effect of these treatments clearly indicated that nitrogen fertilization in excess amount than the recommended rate increases the vine length above that necessary to maximize bulking rate. Leaf area index of 3 to 3.5 facilitates the interception of proper sunlight. On that basis they suggested that any vine size that produces a leaf area index greater than 3.5 remain limited in growth rate by available sunlight. They also noticed that under high nitrogen programmes tuber initiation is delayed by 10 to 14 days.

In a field experiment conducted in Ethiopia Agu (2004) observed that leaf area index, leaf area growth rate and the number of shoots and leaves per stand were highest when nitrogen was applied at sowing, and decreased with delay in the application.

A research work with a red potato variety Symphonia was done by Ayyub *et al.* (2006) to explore various nitrogen application techniques like broadcast, side dressing and foliar with different split doses at research farm of Faisalabad, Pakistan. Tuber emergence percentage, number of aerial stems, leaves per plant, plant height, were found maximum when urea (250 kg ha^{-1}) was applied half dose at planting by broadcast method + half at 30 days after planting by placement method followed by half dose of nitrogen at planting as broadcast method + half dose of nitrogen 30 days after planting as broadcast method.

Chadha *et al.* (2006) evaluated effect of split doses of N, K and FYM on the productivity of seed potato (Kufri Jyoti) in cold desert of Himachal Pradesh. The treatments were consisted of 60 kg ha^{-1} N each at planting and earthing up (45 DAP), 40 kg ha^{-1}N each at planting, earthing up and 60 DAP and 30 kg ha^{-1}N each at planting, earthing up, 60 DAP and 75 DAP. On the basis of experiment results they observed that split application was advantageous especially at higher dose. In their study plant height, number of shoots per hill was increased significantly with increase in number of splits of nitrogen from 2 to 4.

To observe nitrogen efficacy for split application of urea (250 kg ha^{-1}) to potato cultivar named PARS-70 a field experiment was conducted by Nasir *et al.* (2006). Various growth characteristics like germination, number of stems/plant, plant height, number of compound leaves per plant, number of tuber per plant, less mortality percentage were recorded highest in treatment which received the total amount of nitrogen in 5 splited applications while only basal dose of nitrogen, produced minimum of all the above parameters.

Majic *et al.* (2007) observed that 300 kg N ha^{-1} dose increased few growth traits such as number of haulm and dry matter content etc. A good response of potato varieties at split nitrogen application was also recorded by them.

To estimate the precising nitrogen requirement for two table potato cultivars at different growth periods a trial was conducted by Kumar *et al*. (2008). Growth, yield and economic characters were calculated for their response to four nitrogen rates (0, 90, 180 and 270 kg N ha^{-1}). Plant emergence was 98% in all the treatments which remained unaffected to the nitrogen doses. Other growth characters *viz*, plant height, stem number and number of compound leaves positively responds to nitrogen fertilization. Plant height and marketable tuber number was increased with increment in nitrogen dose upto 180 kg ha^{-1} whereas, significant increase in number of compound leaves per plant was restricted the growth parameters. They observed a quadratic response to nitrogen application for total and marketable graded tuber.

In a field experiment regarding spacing, crop duration and N rates on potato Kumar *et al.* (2011) observed that prolonged growth, N application time and crop geometry did not influence emergence, plant height, haulm number, leaf number and leaf area index.

Rizk *et al*. (2013) carried out two field trials during two experimental seasons of 2010-2011 and 2011-2012 to study the response of potato plants to the foliar spray of urea (2% and 3%) sprayed three times starting 45 days after planting and with 10 days intervals and to the addition of humic acid with irrigation water at the rates of 0, 10, 20 and 30 centimole/l applied three times starting 45 day after planting and with 15 days intervals. They observed that urea as foliar spray resulted in vigorous potato plant, *i.e.* the tallest plants and that carried largest number of leaves, fresh and dry weight of leaves and stems. Moreover, the better plant growth was recorded with 3% urea application.

Increment in potato growth parameters as both the fertilizer application rate and fertilizer split application frequency was explained by Banjare *et al.* (2014) who reported the increase in growth parameters like plant height, number of leaves and shoot per plant, fresh and dry weight of shoot per plant increased with increase in nitrogen levels.

Kumar (2015) conducted an experiment to evaluate different nitrogen application methods including basal, topdressing and foliar on potato crop during 2012-13 and 2013-2014 at GBPUAT, Pantnagar. He measured longest plants (54.11cm), maximum number of haulms per hill (5.84), stem girth (8.65) number of leaves (42.15), leaf area index (5.47) and fresh weight of plant (246.11) when 160 kg ha-1 nitrogen was applied as 50% basal + 25% as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP.

Effect of nitrogen (urea) and phosphorous (DAP) application on growth and yield characters of potato was evaluated by Qadri *et al*. (2015). DAP fertilizer was applied as basal and foliar sprays of urea were given after 30 DAP with one week interval in five split doses They reported that maximum growth characters were recorded in the treatment of DAP 120 + urea 8 kg acre^{-1}. The results indicated that foliar nitrogen increased leaf nitrogen content which strengthens source sink relationship.

To see the effects of nitrogen form and its application time on potato plant growth, tuber formation and tuber yield of two potato cultivars Kexin 1 and Favorita a trial was conducted under sand cultural condition by Suyala *et al.* (2016). They found that plant height, leaf area, leaf SPAD value, plant dry matter accumulation and tuber weight were not significantly influenced by nitrite (NO_3-N) or ammonia (NH_4-N) applied before tuberization.

2.2 Effect of nitrogen on yield and yield contributing characters

Elkashif *et al*. (2000) applied nitrogen in the form of urea at the rate of 83 kg/ha to potato cultivars (Spunta, Draga, and Diamant) with four different application timing *viz.* whole dose before planting, whole dose after emergence, half the dose before planting and the other half after emergence, half the dose after emergence and the other half three weeks later. They observed that application of the whole dose before planting resulted highest tuber yield as compared with other treatments.

Gathungu *et al*. (2000) noticed significant difference between the time of application of N on yield of potato. They found that early application of N followed by split applied fertilizer showed the highest tuber yield. Late application of fertilizer had the lowest tuber yield but the highest total N accumulation in both leaves and tubers.

Kolota and osinska (2001) recorded beneficial effects of foliar application of urea in yield enhancement and quality improvement of different vegetable crops such as cabbage, onion, cucumber and squash. They reported that the interest in foliar fertilizers arose due to the multiple advantages of foliar application like rapid and efficient response to the plant needs, less product needed and independence of soil conditions. They also recognized that during crop growth supplementary foliar fertilization can improve the mineral status of plants and crop yield.

While assessing the effect of urea application methods on potato yield and yield related parameters Chowdhury *et al*. (2002a) found maximum number of tuber per hill, weight of tuber per hill and yield of tubers per plot (6.97, 387.33 g and 12.54 kg respectively) at 50% basal + 50% top dressing of urea and the minimum (6.10, 311.67 g and 9.75 kg respectively) at 100% basal application of urea which ultimately affect the tuber yield per hectare. In their study the highest percentage (33.17) of Grade A tuber (dia. 55mm) was recorded at 100% basal application of urea and lowest (28.17) at 100% top dressing.

Similarly in another experiment of nitrogen rate and application methods Chowdhury *et al*. (2002b) observed highest yield of potato tuber in the treatment of 180 kg ha^{-1} urea split as 50% basal and 50% topdressing at 30 and 50 DAP.

To compare the different methods of fertilizer application viz. placement, banding and broadcast, two research trial were conducted by Mahmood *et al.* (2002) at NARC, Islamabad with the cultivar Desiree. The half dose of nitrogen, full dose of phosphorus and potassium was applied at planting time and remaining dose of nitrogen was applied at the time of earthing up of the crop. They recorded yield increment by 20.24 and 35.55% using banding and placement method of fertilizer application over broadcasting.

To observe the effects of the rate and timing of N fertilization on yield and processing quality of Russet Burbank potato under rainfed production a trial was conducted by Zebarth *et al* (2004) in New Brunswick, Canada. The different fertilizer N rates (0-160 kg N ha-1 in 1999 and 0-200 kg N ha-1 in 2000 and 2001) were applied either at planting according to normal grower practice, or at hilling, the latest time that granular fertilizer can practically be applied. They recorded that timing of N application had little effect on tuber yield, size distribution or processing quality under adequate soil moisture conditions. However, under dry soil conditions, split N application reduced tuber yield and tuber size.

The effect of four levels of nitrogen fertilizer with different splitting methods on vegetative growth and tuber yield of potato was studied by Al-Moshileh *et al*. (2005). The field experiments were carried out during autumn season at the Experimental Farm of College of Agric. &Vet. Med., Al-Qassim University. They observed that application of N improved potato tuber yield, increasing N rates to 300 kg N ha^{-1} increased tuber yield. However, higher N rate of 450 kg N ha^{-1} resulted a drop in tuber yield. They calculated highest potato yield with 300 kg N ha^{-1} equally split in three doses at 0, 45, and 60 days after planting.

In a field trial Ayyub *et al.* (2006) found more number of tubers, more fresh & dried weight of tubers and maximum tuber yield ha^{-1} when urea was broadcasted as half dose at the time of planting + half dose was given at 30 days after planting by placement method.

Chadha *et al.* (2006) evaluated effect of split doses of N, K and FYM on the productivity of seed potato (Kufri Jyoti) in cold desert of Himachal Pradesh. The treatments were consisted of 60 kg ha^{-1} N each at planting and earthing up (45 DAP), 40 kg ha^{-1}N each at planting, earthing up and 60 DAP and 30 kg ha^{-1}N each at planting, earthing up, 60 DAP and 75 DAP. They recorded tuber yield is increased by 23.1 and 13.4% in 4 splits of nitrogen application over its 2 and 3 splits, respectively.

To observe nitrogen efficacy for split application of urea (250 kg ha^{-1}) to potato cultivar named PARS-70 a field experiment was conducted by Nasir *et al.* (2006). They found treatment of total amount of Nitrogen in 5 splited applications produced best results regarding weight of tubers per plant (g), and per plot (kg), tuber yield per acre (tons) and per hectare (Tons), total Biomass per plant (g), foliage fresh weight per plant (g), foliage dry weight per plant (g), tuber dry weight per plant (g). However, only basal dose of Nitrogen, produced minimum of all the above parameters.

To assess the effect of rates and application times of mineral fertilizers (N and K) on the production and quality of potato (cv. Vivaldi) tubers an experiment was conducted by Cardoso *et al.* (2007) in Bahia, Brazil. Fertilizers were applied at 100% during planting, one-third during planting and two-third during tuberization, 50% during planting and 50% during tuberization, one-third during planting, one-third during tuberization and one-third at 25 days after tuberization, one-fourth during planting, one-fourth during tuberization, one-fourth at 25 days after tuberization and one-fourth at 50 days after tuberization. In their study split application of N and K fertilizers (50% during planting and 50% during tuberization) favoured higher tuber productivity in relation to the total fertilizer application.

Evaluation of seven levels of Nitrogen (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) and three methods of application (Broadcasting, Banding and Placement) in potato variety, Desiree was done by Khan *et al.* (2007) at Agricultural Research Station (North) Mingora, Swat. The treatments were replicated thrice in Randomized Complete Block Design (RCBD). Maximum number of tubers (170.33) $plot^{-1}$, tuber size (63.33 mm) maximum per cent ground cover (59.33%), and tuber yield $hectare^{-1}$ (19.28 t) were recorded in plots, which received fertilizer through banding. In case of interaction, best results were recorded in plots where nitrogen at the rate of 150 kg ha^{-1} was applied through banding. The result lead to the conclusion that “Banding” is the most efficient and economical method of fertilizer application in potato and 150 kg N ha^{-1} is the promising level of nitrogen for excellent results in potato crop under the agroclimatic conditions of Mingora, Swat.

In an experiment Poljak *et al.* (2007) found that high potato tuber yields can only be obtained with the application of optimal nutrient doses in balanced proportions.

In a study regarding effects of application time, amount and forms of nitrogenous fertilizer to total and different sized of tuber yields of potato in Erzurum conditions Ozturk *et al.* (2007) found application time and amounts of nitrogenous fertilizer significantly affected yield related parameters except medium tuber yield. They also observed that to get more tuber yield and reduce the labour and time consumption, nitrogenous fertilizer should be applied before planting.

Management of nitrogen fertilization, in terms of rate, timing, and method of application, influence the yield and quality of potatoes Alva (2004). According to him maintaining adequate supply of N availability in the soil is particularly important through the bulking stage of the tuber.

Essah and Delgado (2009) concluded that tuber yield and quality severely affected by over and under fertilization. In their study maximum tuber yield and quality for Canela Russet variety of potato was recorded in 157 kg N ha^{-1} split as 90 kg N ha^{-1}

applied at planting time and three fertigations of 22 kg N ha^{-1} applied biweekly after tuber initiation. However, for cultivar Sangre maximum tuber yield and quality was observed in 90 kg N ha^{-1} applied at planting time. According to them it is important that site specific nutrient management practices are developed for cultivars physiological response to total nitrogen application as well as to that physiological stage when the nitrogen is applied to maximize tuber yield, quality and economics while reducing nitrogen losses to the atmosphere.

Vos (2009) reported that when N is applied late in the season or at high rates in potato crop it can delay tuber bulking and plant maturation

Jamaati *et al.* (2010) reported importance of split application of nitrogen on nutrient use efficiency and yield parameters. He recorded dividing total nitrogen into two or more applications would assist in promoting yield, reduce loss of nutrients hence enhancing nutrient use efficiency and yield bigger size potato.

A field trial was conducted by Kumar *et al*. (2011) at Modipuram (India) during 2005–2007 on potato cultivar Kufri Chipsona-1. The duration of the crop was 110 and 120 days in main plot, while sub-plot consisted of combination of four time of N application (2 split, 3 split, 3 split + 1 foliar spray, and 2 split + 2 foliar spray) with two spacings (67.5 × 20 and 67.5 × 25 cm). They observed that total and process grade tuber number, yield and process grade tuber weight remained unaffected by crop duration and time of N application.

In order to study of the effects of three levels of nitrogen fertilizer, 4 different of application times of the fertilizer and interaction of these treatments on yield and yield components of Agria cultivar of potato an experiment was conducted by Etemad and Sarajuoghi (2012) in Ghorveh, Kordestan, Iran. They observed significant differences between main treatments and interactions between them. In their study the maximum tuber yield, the maximum tuber number and the maximum dry weight of tubers were recorded in condition that third part of Nitrogen fertilizer used at first and the rest used after Earthing up.

To test impacts of N rate (0, 67, 134, 201, and 268 kg N ha^{-1}), N application timing (100% applied with planter, 2-way split (30% with planter and 70% band applied approximately 30 days after planting at dragoff), and three-way split (30% with planter, 50% band applied prior to drag-off, and 20% band applied at bloom initiation), and additions of the growth regulator maleic hydrazide (MH-30) on “Goldrush” and “Norkotah” Russet potato varieties Reiter *et al.* (2012) was conducted an experiment at Mid-Atlantic Region (Virginia). They observed that Maleic hydrazide and N application timing had little consistent effect on any tested parameter. They also found treatments that one would expect to have higher N use efficiency (more N splits) and higher N rates had more tuber rots.

To assess the effects of N application time on marketable tuber ratio, dry matter concentration and specific gravity of the Chinese cultivar KX 13 an experiment was conducted by Sun *et al*. (2012) with four treatments. They achieved 30 t ha^{-1} of marketable tuber yield with 100 kg N ha^{-1} applied at planting and 50 kg N ha^{-1} applied 1 week before tuber bulking stage (35 DAE), while 23 t ha^{-1} marketable yield was achieved by applying all 150 kg N ha^{-1} at planting. Both the treatment significantly increased harvest index (HI) from 0.76 to 0.86 and marketable tuber ratio from 64.8% to 79.2%. In their study high marketable tuber ratio (74%) and HI (0.86) was recorded with N application at planting with topdressing at 20 DAE, but the lower total tuber yield led to a lower marketable tuber yield. They also observed that treatment without N application at planting, N dressing did not increase the yield and HI.

Banjare *et al.* (2014) reported increase in potato yield ha^{-1} as both the fertilization rate and fertilizer split application frequency increased. Increase in yield attributing traits like stolon number, fresh and dry weight of tuber per plant was recorded with increase in nitrogen fertility. They also observed that overall increase in fresh and dry tuber weight, nitrogen and nitrate concentration and decreased specific gravity with increase in nitrogen levels.

An experiment was done by Kelling *et al.* (2015) to see the interactive effects of different hill shapes and distribution of in-season N fertilizer application at various timings in a 3-year potato (*Solanum tuberosum* L. cv. Russet Burbank) in central Wisconsin. Different hill shape (standard, shaped-plateau, or pointed) as the main plots and 202 kg N ha^{-1} divided into two, three, or four applications as the split plots were designed in SPD. The results of their study indicated that splitting the N into three in-season applications (emergence, early tuberization, and tuberization + 20 days) increased tuber yield by about 4% or tuber size by 19% in years where rain increased leaching potential on this sandy soil, but further splitting increased the proportion of small tubers that passed a 5.1 cm screen.

In a field trial conducted at GBPUAT, Pantnagar Kumar (2015) recorded maximum number of tubers with application of 160 kg ha^{-1} nitrogen when applied as 50% basal + 50% as top dressing at 25 DAP with one foliar spray of 2% urea at 40 DAP which was statistically at par with same dose of nitrogen applied as 50% basal + 25% as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP. However, total tuber yield and marketable tuber yield was recorded highest in 50% basal + 25% as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP. He also noticed an increase in aggregate number of tuber with mode of application of nitrogen (basal + topdress + foliar spray) or (basal + 3 foliar spray). In their study he found the highest number of >75g and 51-75 g grade tubers in treatment 50% basal + 25% as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP compared to treatment 50% basal + one foliar spray of 2% urea at 25 DAP which have maximum number of grade 26-50 g and 0-25 g tubers.

Peter *et al*. (2015) were carried out an experiment to determine the effects of split nitrogen application and different rates of nitrogen fertilizer on the productivity of Irish potatoes (*Solanum tuberosum* L.) in smallholder farming in Zimbabwe. The experiment was laid out in RBD with three nitrogen application levels (15 g m^{-2}, 30 g $m^{-2}$and 45 g m^{-2}) and three split application levels (1, 2 and 3) replicated three times. On the basis of data they found that nitrogen rate had a significant effect on number of tubers, tuber size and on the tuber yield of the potato. The highest tuber yield was obtained in 30 g N m^{-2} with the 15g N m^{-2} producing the least. They also observed that split application had a significant effect ($p<0.05$) on number of tubers, size of tubers as well as the overall yield of the potatoes. From the findings they concluded that compared to the other treatments three split applications applied at 30g m^{-2} had the potential to increase the yield. They also recommended top dressing of nitrogenous fertilizer in three treatments to ensure a higher productivity of Irish potatoes.

Rens *et al*. (2015) reported that to maintain sustainable and economical potato production optimum nitrogen fertilizer management is necessary. The study was conducted with grower collaboration on three farms for two consecutive years (2011 and 2012) to determine the effect of N-fertilizer rate and timing of application on plant biomass, tuber marketable yield and quality of chipping potato irrigated by subirrigation. All experimental plots received at the rate of 56 kg ha^{-1} N as ammonium nitrate approximately 40 days before planting, a common grower practice. Nitrogen fertilizer treatments were 0, 56, 112 or 168 kg ha^{-1} given at plant emergence (Nemerg) combined with 56 or 112 kg ha^{-1} of N given as a sidedress at tuber initiation (Ntuber init). Across all sites mean marketable tuber yield ranged from 19.2 to 39.7 t ha^{-1} with the lowest yield when rainfall occurred in a large amount prior to harvest at one site. Marketable yield responded quadratically to increase N-fertilizer rates applied at plant emergence, with optimum yield calculated at Nemerg rate between 88 and 113 kg ha^{-1}. They also observed that marketable yield did not increased when N was applied more than 56 kg ha^{-1} at tuber initiation.

With the objective to determine the effect of the N fertilizer rate and timing of application on N use efficiency (NUE) and yield of chipping potato 'FL1867' a study was done by Zotarelli *et al.* (2015) with grower collaboration for two years (2011 and 2012) on three commercial farms using subirrigation on course textured soils of Florida. All treatments replicated four times received 56 kg ha^{-1} of N as ammonium nitrate applied 40 days before planting (Npre-pl) as a band. Liquid urea ammonium nitrate was also applied as band at 0, 56, 112, or 168 kg ha^{-1} during plant emergence (Nemerg) followed by 56 or 112 kg ha^{-1} side-dressed at tuber initiation stage (Ntuber init). Average tuber yield ranged from 25.6 to 47.2 t ha^{-1}, with the lowest yields recorded when heavy rainfall close to harvest increased yield loss to decay. They also noticed that tuber yield was either not influenced by N application or responded quadratically peaking at Nemerg levels between 95 and 125 kg ha^{-1}. Above this range N application rates decreased yield and NUE.

In an experiment regarding effects of nitrogen form and its application time on tuber yield of potato Suyala *et al.* (2016) observed that the plants treated with NO_3-N before tuber initiation produced more tubers per plant than those treated with NH_4-N. On the basis of results they found that potato nitrogen management including N fertilizer form and its application time should be adjusted according to the aim of commercial potato production or seed potato propagation.

2.3 Effect of nitrogen on quality characters

In an experiment Chowdhury *et al.* (2002a) observed that dry weight of tuber was significantly affected by the methods of urea application. They recorded 50% basal + 50% top dressing and 25% basal + 75% top dressing produced the maximum dry weight (18.20%) while minimum dry weight (17.50%) was recorded in 100% basal application.

In another similar study Chowdhury *et al*. (2002b) recorded maximum dry matter of tuber (18.37%) with 180 kg of nitrogen applied as 75% basal and 25% in two split doses at 30 and 50 DAP and same dose at 50% as basal and 50% in two split doses at 30 and 50 DAP.

Increase in fertilizer rates decreased specific gravity and starch content of potato tuber. Protein and nitrate content were positively related with nitrogen application, while the effect on ascorbic acid content was relatively small. Ascorbic acid was significantly reduced only at the highest nitrogen level which also led to drastic yield depression. Since nitrate is considered phloem-immobile and xylem transport into the tubers is restricted (because of the tuber's low transpiration rate), the pathway of nitrate translocation into the tubers is unclear (Lin *et al*., 2004).

Ayyub *et al.* (2006) recorded some of the tuber qualitative characters like TSS, specific gravity and dry matter contents better in case of initially broadcasted or later on side dressed nitrogen as compared to full basal dose (broadcasted or side dressed) and foliar application of nitrogen. On the other hand some qualitative characters like tuber's moisture, nitrogen, phosphorus, potassium and crude protein contents were improved in case of foliar application of nitrogen, followed by initially side dressed or full basal single dose of nitrogen as compared to better performing treatments for all other quantitative characters.

During assessing the effect of rates and application times of mineral fertilizers (N and K) on the production and quality of potato (cv. Vivaldi) tubers in Bahia, Brazil Cardoso *et al*. (2007) observed that application time and rates of N and K did not promote significant responses in the dry mass, total titrable acidity, soluble solids and content of reducing sugars in potato tubers.

Ciecko *et al*. (2010) observed that the highest average content of total nitrogen and protein nitrogen was determined in potato tubers which had received exclusive nitrogen fertilization, both as foliar sprays and to soil. In their experiment they found highest increment in the total and protein nitrogen content in potato tubers at 10% contribution of foliar nitrogen application.

Kumar *et al.* (2011) conducted a research trial to see the effect of spacing, crop duration and N rates on tuber quality at Modipuram during 2005–2007 on potato cultivar Kufri Chipsona-1. The duration of the crop was 110 and 120 days in main plot, while sub-plot consisted of combination of four time of N application (2 split, 3 split, 3 split + 1 foliar spray, and 2 split + 2 foliar spray) with two spacings (67.5 × 20 and 67.5 × 25 cm). For all treatment combinations, processing attributes like chip colour and reducing sugars were within acceptable range, although tuber specific gravity and dry matter lowers by excess soil or foliar N application applied late in the season.

While assessing the effects of N application time on dry matter accumulation in foliage and tubers, Sun *et al.* (2012) observed that treatments with N dressing had no significant effect on specific gravity or dry matter concentration of tubers.

In a study Wei *et al.* (2013) used potato variety Hezuo-88 to investigate the effects of foliage supplement fertilizers on the dry matter accumulation, nutrient status and soil nutrient, including spraying 0.5% urea, 0.3% KH2PO4 and their combination solution after squaring, all of which were treated by applying equal amount of fertilizer. The results of the study revealed that spraying 0.5% urea or 0.5% urea +0.3% KH2PO4 particularly increased dry matter accumulation and biomass yield of plant.

Cambouris *et al*. (2016) examined that tuber specific gravity and culls (unmarketable tubers) were influenced by N rate, but the response was depend upon soil and climatic conditions. Their results suggested that, under humid conditions with irrigation, a one-time application of PCU in potato cultivation can minimize the risk of N loss without reducing tuber yield and quality.

Kumar (2015) noticed that less amount of nitrogen and split application give high dry matter content with high specific gravity and which were decreased with increase in nitrogen dose. However, in case of protein it is increased with high nitrogen application. The highest dry matter was observed in 25% basal + 25% as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP while specific gravity was recorded maximum with no application of nitrogen. Maximum protein content was analysed in 50% basal + 25% as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP.

In an experiment Rens *et al*. (2015) noticed that more than 56 kg ha^{-1} of N application at tuber initiation did not increase tuber specific gravity or tuber quality. Nitrogen rate treatments above 112 kg ha^{-1} at emergence, and 56 kg ha^{-1} at tuber initiation did not improve potato marketable yield or tuber quality.

2.4 Effect of nitrogen on soil and plant analytical characters

Witte *et al*. (2002) observed that urea, due to its intrinsic characteristics such as non ionic nature, small molecular size and high solubility is usually taken rapidly through the leaf cuticle. It can be supplied to the plants through foliage, facilitating optimal nitrogen management, which reduces nitrogen losses to the environment. Most of the plants absorb applied urea rapidly and hydrolyze it in the cytosole.

To determine optimum N rates and application timings for 7 potato cultivars an experiment was were carried out by Atkinson *et al*. (2003) at two sites, including Aberdeen, ID and Parma ID. At Nitrogen was applied either 1) 2/3 pre-plant + 1/3 in-season (early treatment), or 2) 1/3 pre-plant + 2/3 in-season (late treatment).Nitrogen timing had relatively little effect on N utilization by cultivar Bannock Russet and Gem Russet, but early N was used more efficiently than late N by cultivar Russet Burbank and Summit Russet. Cultivar Alturus and Ranger also preferred split N applications with most of the N applied prior to planting. However, A8893-1 performed best with most of the N applied during tuber bulking.

A study was done by Zebarth *et al*. (2004) regarding rate and timing of N fertilization effects on the N use efficiency characteristics of rainfed Russet Burbank potato suggested that under rainfed potato production in Atlantic Canada, timing of N fertilization has no significant effect on N use efficiency of Russet Burbank potato in years of adequate soil moisture, but NUpE may be decreased by split application of N in dry years.

An experiment was conducted by Trawczynski, (2004) in Poland regarding effect of foliar urea application, during the vegetation period of the potato cultivar Sante, on the content of nitrogen mineral form in the soil and potato yield. They found that supplementary rates of N (15 and 30 kg N ha-1) provided as foliar-applied urea can be used to adjust N nutrition of potato crop without significant changes in yield and its nitrate content. They also recorded that lowering of N-rate applied into the soil and an increase of N-rate applied into leaves caused a decrease of mineral nitrogen in the soil.

Love *et al*. (2005) used four cultivars, Bannock Russet, Gem Russet Summit Russet and Russet Burbank treated with four N doses (0, 100, 200, and 300 kg N ha^{-1}) using two different application timing procedures (“early,” with two-thirds N applied preplant, and “late,” with one-third applied preplant). They observed that cultivar Summit

Russet showed a strong trend for improved N use-efficiency when most of the N was applied early. However the other varieties were not showing any response to application timing.

To see the effect of split application of nitrogen fertilizer on N_2O emissions and denitrification rate in potato production over two year an experiment was conducted by Burton *et al.* (2008). They found that timing of nitrogen fertilizer application influences the availability of nitrate as substrate for denitrification. They used three treatments of nitrogen 0, 200 kg ha^{-1} at planting and 200 kg ha^{-1} (120 kg ha^{-1} at planting + 80 kg ha^{-1} at final hilling). Cumulative N_2O emission was increased with nitrogen fertilizer application. Split nitrogen application decreased cumulative N_2O emissions in 2003, but not in 2002, compared with basal nitrogen fertilization. A greater proportion of N_2O emissions was observed in 2003 (67%) compared with 2002 (17%). Nitrogen fertilization resulted ina significant increase in cumulative N_2O emissions relative to the treatment with no fertilizer nitrogen application. In 2003, split nitrogen application resulted in lower cumulative N_2O emissions compared with all basal applied fertilizer. However, scheduling of fertilizer nitrogen application had no significant effect in cumulative N_2O emissions in 2002.

In an experiment Ciecko *et al*. (2010) was found that increasing share of foliar nitrogen fertilization led to a decreased content of nitrates in potato tubers tested after harvest.

Similarly the interactive effects of different hill shapes and distribution of in-season N fertilizer applications at various timings were evaluated by Kelling *et al.* (2015) in a 3-year potato (*Solanum tuberosum* L. cv. Russet Burbank) experiment in central Wisconsin. Splitting the in-season N into three applications (33% emergence, 50% early tuberization, 17% early tuberization + 20 days) improved yield and quality especially in years with significant leaching of N. However, further dividing the N fertilizer into four applications may not have supplied enough early N as this treatment resulted in more small tubers in one of the years where leaching of N was greatest. In this study, N timing had no effect on tuber N concentration or uptake.

Kumar (2015) observed that increment in nitrogen dose along with split application enhance nitrogen uptake by plant and tubers however split application also increased nitrogen use efficiency of the plant. In his study he observed that application of 160 kg N as 50% basal + 25% topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP provide good nitrogen uptake and NUE.

Foliar application of urea also reduces nitrogen losses and increases plant nitrogen use efficiency. Results of experiment conducted by Qadri *et al.* (2015) revealed that DAP 120 + Urea 8 kg acre^{-1} as foliar remained well regarding productivity and quality of potato. The overall fertilizer efficacy regarding yield and quality observed maximum in this treatment.

The effect of the N fertilizer rate and timing of application on N use efficiency (NUE) of chipping potato 'FL1867' a research was done by Zotarelli *et al.* (2015). The trial was conducted with grower collaboration for two years (2011 and 2012) on three commercial farms using subirrigation on coarse textured soils in Florida. They examined that maximum daily N uptake by the potato crop found between 55 and 65 days after planting, coinciding with the onset of tuber bulking stage. They also noticed that tuber yield was either not influenced by N application or responded quadratically peaking at Nemerg levels between 95 and 125 kg ha^{-1}. Above this range N application rates decreased yield and NUE. They also observed that plant N uptake and tuber yield did not increase with Ntuber initiation rate above 56 kg ha^{-1} and was associated with lower NUE.

Rens *et al.* (2016) assessed that FNUE (N-fertilizer uptake efficiency) of fertilizer applications at different growth stages of crop is critical to develop management recommendations which enhance fertilizer use by minimizing N losses. They investigated N-fertilizer uptake efficiency of two chipping potato (*Solanum tuberosum* L.) varieties ('Atlantic' and 'FL1867') under three typical fertilizer application timings at the Hastings Agricultural Extension Center located in Hastings, FL, USA. All varieties received a total of 225 kg ha^{-1} of N throughout the season split into three applications of 75 kg ha^{-1} as ammonium nitrate (NH4NO3) given at pre-plant, plant emergence and tuber initiation. At each application timing FNUE was evaluated by the substitution of conventional N-fertilizer by isotope labelled ammonium nitrate (15 NH4 15 NO3). The overall FNUE was also similar at 45% across both varieties and years. FNUE was 11% for the pre-plant application, while 62% for the applications at emergence and tuber initiation stages. They also noticed that since a small fraction of the N applied at preplant was recovered in the plant, N fertilizer application closer to the potato planting may increase the FNUE.

2.5 Effect of nitrogen on economics

Chowdhury *et al*. (2002a) calculated significant differences in economics of all the treatments of urea given to the potato crop and concluded that among the doses and methods, 180 kg ha^{-1} urea dose split as 50% basal and 50% topdressing at 30 and 50 DAP gave highest benefit cost ratio (1.99).

Love *et al*. (2005) used four cultivars, Bannock Russet, Gem Russet Summit Russet and Russet Burbank treated with four N doses (0, 100, 200, and 300 kg N ha^{-1}) using two different application timing procedures (“early,” with two-thirds N applied preplant, and “late,” with one-third applied preplant). They recorded a trend for greater profitability for Summit Russet when the majority of N was applied during tuber bulking. Summit Russet showed a strong trend for improved N use-efficiency when most of the N was applied early.

Chadha *et al.* (2006) evaluated effect of split doses of N, K and FYM on the productivity of seed potato (Kufri Jyoti) in cold desert of Himachal Pradesh. The treatments were consisted of 60 kg ha^{-1} N each at planting and earthing up (45 DAP), 40 kg ha^{-1}N each at planting, earthing up and 60 DAP and 30 kg ha^{-1}N each at planting, earthing up, 60 DAP and 75 DAP. They observed maximum B-C ratio (1.98) in four splits with highest net return of Rs. 72,060.

Regarding spacing, crop duration and N rates on potato economic analysis a trial was done by Kumar *et al.* (2011) indicated that application of 270 kg N ha^{-1} in two equal splits at planting and earthing-up gave 7.5% more returns over 3 splits + 1 foliar spray of urea.

Economic analysis of some nitrogen application treatments effect on potato was done by Kumar (2015) revealed that more tuber yield gives more net profit and B-C ratio. In their experiment they calculated highest net return of Rs. 73090.75 and B-C ratio of 1.81 in the treatment 50% N of RDF basal + 25% N of RDF as topdressing at 25 DAP with one foliar spray of 2% urea at 40 DAP.

Materials and Methods

A research entitled **“Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)”** was conducted during *rabi* season 2014-15 and 2015-16. During the course of investigation, the details of the materials used and procedures followed for treatment evaluation are described below:

3.1. Site of experiment

The present field experiment was undertaken during *rabi* season of the year 2014-15 and 2015-16 at Vegetable Research Center (VRC) of the G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand). Geographically, Pantnagar lies in *tarai* plains of foot hills of Shivalik range of Himalayas at 29.5° N latitude, 79.3° E longitude and at an altitude of 243.84 meters above the mean sea level. The estimation of quality and post harvest analytical parameters was carried out in the laboratory of Vegetable Science and Agronomy Department, College of Agriculture.

3.2. Climate and weather

The climate of Pantnagar is humid subtropical with the maximum temperature ranging from 32ºC to 44ºC in summer and minimum 4.4ºC in winter. The summer is dry and hot, winter is too cold and frost can be expected from the last week of December to end of the January. The onset of monsoon usually occurs from the last week of June and continues in appreciable amount up to the middle of September. High rainfall (135 cm) and wide temperature fluctuations are salient features of Pantnagar *tarai*. Occasional shower also occur due to western disturbance during the winter and summer months, however splashing rainfall occur in the spring season. The weather conditions prevailing during the course of experimental period (November to February) given in Appendix-IA & IB.

3.3. Soil analysis

Before basal placement of fertilizer and planting of the tubers, a composite soil sample upto 0-15 cm depth was taken from the experimental field for assessing the fertility level of soil. The physical and chemical properties of the soil were analyzed in the Soil Testing Laboratory have been given in Table 3.1.

Table 3.1. Physico-chemical composition of soil of the experimental plot:

S. No.	Components	Values obtained		Methods used
		2014-15	**2015-16**	
1.	Texture	Sand: 61.6 % Silt: 26 % Clay: 12.4 % Sandy - loam	Sand: 65.1 % Silt: 24.3 % Clay: 10.6 % Sandy – loam	Bouyoucos hydrometer method **(Bouyoucos, 1962)**
2.	Ph	7.7	7.3	Glass electrode method **(Jackson, 1967)**
3.	Available nitrogen (kg N/ha)	188.76	191.37	Alkaline permanganate method **(Subbaiah and Asija, 1956)**
4.	Available phosphorus (kg P/ha)	19.65	18.10	Olsen's method **(Olsen *et al.*, 1954)**
5.	Available potash (kg K/ha)	151.22	147.43	Flame photometer **(Jackson, 1967)**
6.	Organic carbon (%)	0.90	0.83	Walkely-Black titeration method **(Walkley and Black, 1934)**

3.4. Experimental procedures

The experiment was consisted of ten treatments replicated thrice in Randomized Block Design and each treatment was allocated randomly in each block. During experimentation, the layout of the field in both the seasons is depicted in Fig. 3.1 and 3.2. Experiment and treatments detail are has given in Table 3.2 and Table 3.3. Schedule of pre and post-planting operations during the crop growth is presented in Table 3.4.

Table 3.2. Experiment detail

Design	Randomized Block
Replications	03
Treatments	10
Number of Plots	10 x 3 = 30
Gross Plot size	4.2×4 m^2
Net Plot size	3.6×3.6 m^2
Distance between Rows	60 cm
Distance within Rows	20 cm
Variety	Kufri Sadabahar
Number of rows per plot	6
Number of tubers planted per row	20
Total number of tubers per plot	120
Main irrigation channel width	1.2 m
Sub irrigation channel width	1 m

3.5 Kufri Sadabahar

Kufri Sadabahar is a medium maturing, main season and high yielding potato variety. It is a clonal selection from a cross between MS/81-145 and PH/F-1545. The plants are tall and vigorous with moderately resistant to late blight. Tubers are white, oblong with shallow eyes and white flesh. It posses good keeping quality and high tuber dry matter (20%). Tubers are easy to cook and free from discolouration after cooking with waxy texture and mild flavor. It is suitable for cultivation in Uttar Pradesh and adjoining areas. It was released as a replacement of Kufri Bahar. The yield potential of this variety is 350-400 q/ha under optimum agronomical practices.

Table 3.3. Treatments_detail

T_1	50% N of RDF as basal + 50% top dressing at 25 DAP
T_2	50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP
T_3	25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP
T_4	50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP
T_5	50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP
T_6	50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP
T_7	50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP
T_8	25% N of RDF as basal + 75% top dressing at 25 DAP
T_9	25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP
T_{10}	(No application of nitrogen)

- Recommended dose of P & K applied as basal in all treatments.
- Source of nitrogen used: Urea (46% N)
- Recommended dose of fertilizer: 160:100:120 Kg $N:P_2O_5:K_2O$ per ha

3.6. Cultural operations

3.6.1. Field preparation

One deep ploughing, followed by 3-4 cross harrowing and leveling was done by tractor driven implements. The plots were demarcated and soil samples were taken randomly from each plot. These samples were mixed properly to prepare a composite and uniform soil sample for physico-chemical analysis.

Fig. 3.1 Experimental layout in 2014-15

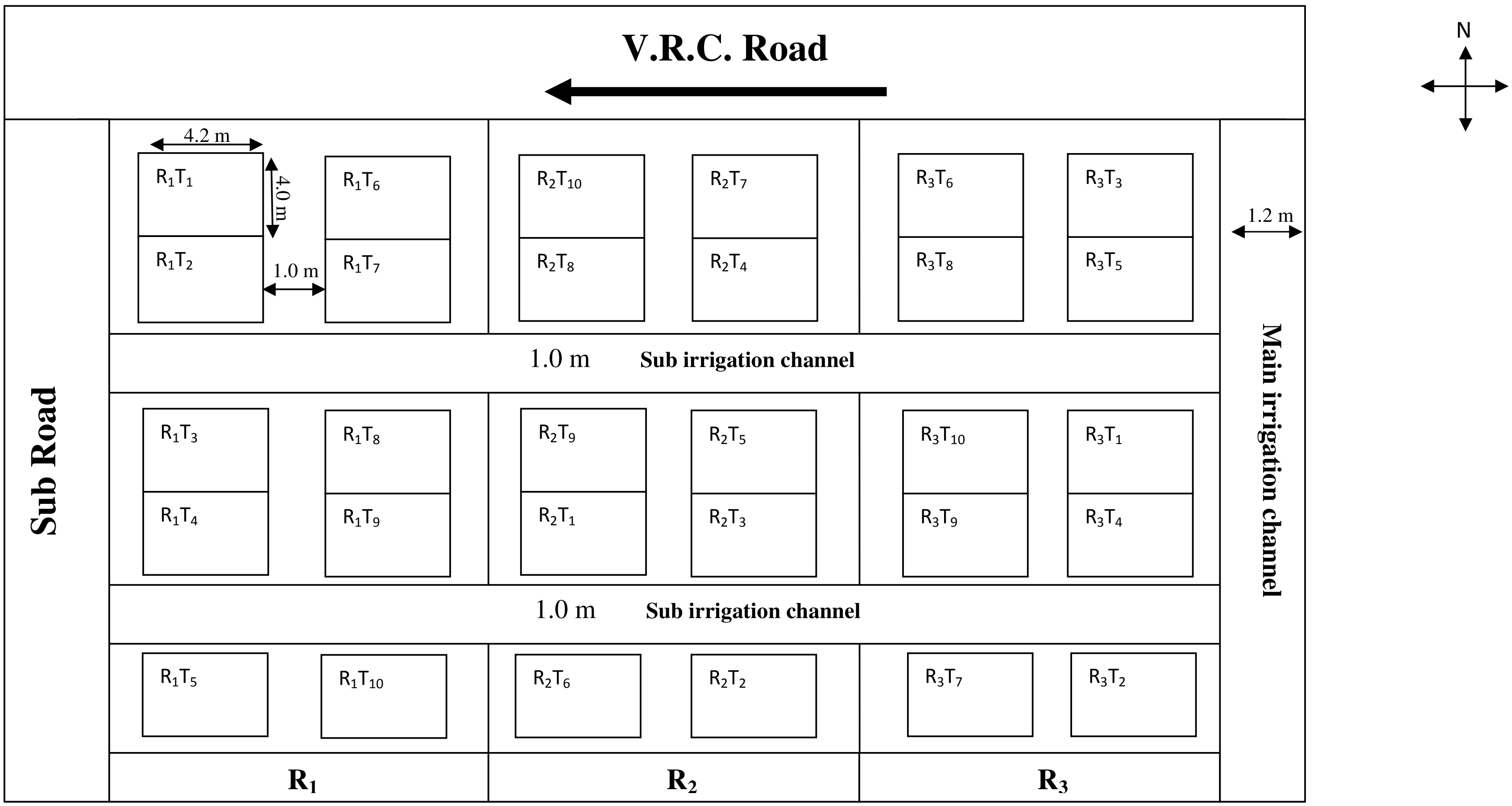

Fig.3.2. Experimental layout in 2015-16

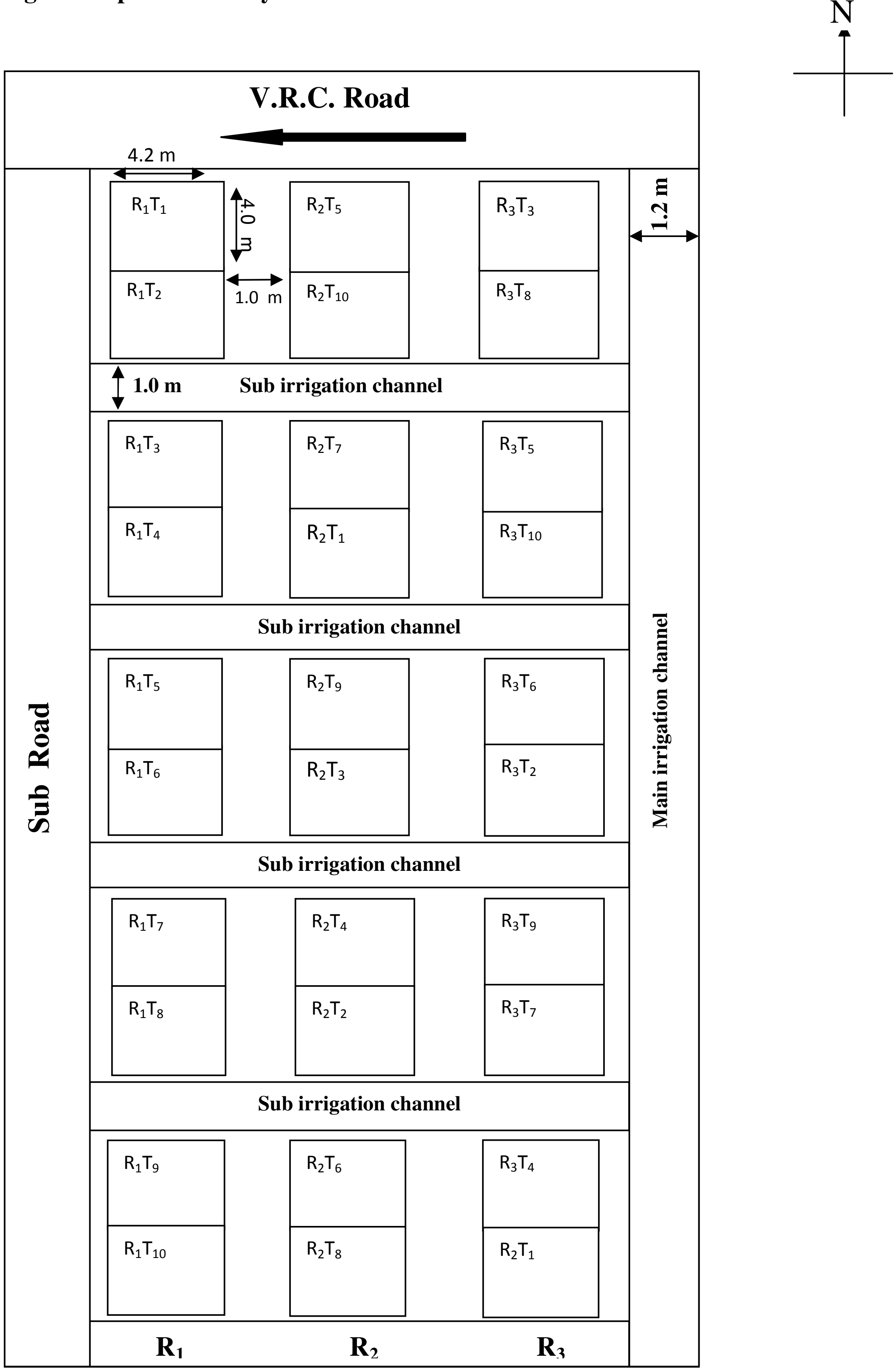

Table 3.4 Schedule of pre and post-planting operations during the crop growth

Sr. No.	Operation	2014-15	2015-16	Remarks
1.	Ploughing and harrowing	26-10-2014	23-10-2015	By tractor
2.	Lay out	28-10-2014	25-10-2015	Demarcation of lines and making of plots.
3.	Soil sampling	29-10-2014	26-10-2015	Samples at different spots from each plot were taken from a depth of 0-15 cm
4.	Fertilizer application (basal)	30-10-2014	27-10-2015	Manually
5.	Planting of tubers	01-11-2014	30-10-2015	Manually
6.	Irrigation I	19-11-2014	17-11-2015	Manually
7.	Weeding	25-11-2014	22-11-2013	Manually
8.	Top dressing/ Spraying of Urea (as per treatment)	26-11-2014	23-11-2015	Manually
9.	Earthing up	27-11-2014	25-11-2015	Manually
10.	Spray of insecticide and fungicide (I)	29-11-2014	04-12-2015	Manually
11.	Irrigation II	06-12-2014	7-12-2015	Manually
12.	Top dressing/ Spraying of urea (as per Treatment	10-12-2014	09-12-2015	Manually
13.	Spray of fungicide (II)	22-12-2014	21-12-2015	Manually
14.	Top dressing/ Spraying of Urea (as per treatment)	26-12-2014	23-12-2015	Manually
15.	Spray of insecticide (II)	29-12-2014	28/12/2015	Manually
16.	Dehaulming	21-01-2015	20-01-2016	Manually
17.	Harvesting	03-02-2015	02-02-2016	Manually

3.6.2. Fertilizer application

After proper demarcation of the plots a basal application of full amount of P_2O_5 @ of 100kg/ha and K_2O @ 120 kg/ha in the form of SSP and MOP, respectively, was carried out in the experimental field. The different doses of nitrogen as per treatment were applied to each plot in the form of urea through basal, top dressing and foliar spray.

3.6.3. Selection of seed and planting

Well sprouted, disease free, medium sized (2.5-5.0 cm diameter) tubers having 50-75 g weight were selected. The tubers then planted manually on ridges at 20 cm spacing and covered by soil immediately with the help of *khurpa*.

3.7. Observations

3.7.1. Growth parameters

Five plants in each plot (leaving the border rows and border plants in each plot), were selected randomly and tagged to record various parameters under the observation.

3.7.1.1 Plant emergence

The number of plants emerged out in each plot was counted at 20 and 30 days after planting and per cent emergence was calculated by following formula:

$$\text{Emergence (\%)} = \frac{\text{Number of tubers emerged per plot}}{\text{Number of tubers planted per plot}} \times 100$$

3.7.1.2 Plant height

Plant height comprises the length of the longest shoot from the base of the sprout to the growing point. It is measured with the help of meter scale and the data were recorded in centimeter (cm) at 30, 45, 60 DAP and at de-haulming. The mean plant height was obtained by average of the length of five plants.

3.7.1.3 Number of haulms

The total number of haulms per hill from tagged plants were counted at 30, 45, 60 DAP and at de-haulming and averaged.

3.7.1.4 Number of leaves

The number of compound leaves in five-tagged plants in each experimental plot was counted at 30, 45, 60 DAP and at de-haulming and divided by five.

3.7.1.5 Diameter of haulm

The diameter of haulm per hill from tagged plants was measured at 30, 45, 60 DAP and at de-haulming with the help of 'Vernier Callipers', recorded in millimeter (mm) and averaged at all the four stages and expressed as plant^{-1}.

3.7.1.6 Dry weight

The plant samples taken at 30, 45, 60 DAP and at de-haulming for fresh weight were dried in sun for 7-8 hours/day for 2-3 days and then dried in oven at about 60^0C temperature, till the samples attained a constant weight. After drying, the samples weighed and dry weight was recorded in g, averaged and expressed as plant^{-1}.

3.7.1.7 Leaf area index

Five leaves from each tagged plants were randomly taken before de-haulming and their leaf area was measured with the help of leaf area meter. The leaf area of all leaves were calculated and summed up to get whole plant area and leaf area index was calculated, using formula

$$\text{Leaf area index} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf area(area covered in cm}^2\text{ per plant)}}$$

3.7.1.8 Leaf chlorophyll content

Chlorophyll content before de-haulming was calculated by the method of **Bruinsma, 1963**. The method was as follows-

Spectrophotometer determination of chlorophyll:

I. The leaves were cut into small pieces and major veins and any tough, fibrous tissue were disarded.

II. 0.10 g (100mg) of material was taken (record total fresh weight of each sample) for grinding

III. The tissue was put into a mortar and 10 ml of 80 % acetone (acetone:water-80:20 v/v) was added. The tissue was ground with the help of pestle and pulverized completely to prepare a homogenate.

IV. The homogenate was filtered through the filter paper. The retentate was removed by the filter paper and the extract was collected in a test-tube.

Determination of chlorophyll concentration:

I. A clear cuvette was taken for the spectrophotometer and filled two-thirds full with 80 % acetone; this is the blank. The cuvette was wiped by a tissue and was put into the spectrophotometer. The wavelength was set at 663 nanometer and absorbance was adjusted to 0 with the blank. Then the blank was removed and saved for the next measurement.

II. A second cuvette was filled two-thirds full with sample extract after gentle swirl. The absorbance was recorded at same wavelength. 2nd step was repeated with the other samples.

III. The wavelength was adjusted at 645 nm. The blank was reinserted in cuvette and rezeroed the absorbance. The blank was removed and reinserted the sample extracts one by one. The readings for all sample extracts were recorded.

Calculation of chlorophyll 'a' and 'b' (mg/ g) was done by following formula-

$$\text{Chlorophyll 'a'} = \frac{(12.7 \text{ x A663}) - (2.63 \text{ x A645})\text{V}}{\text{W(mg)}}$$

$$\text{Chlorophyll 'b'} = \frac{(22.9 \text{ x A645}) - (4.48 \text{ x A663})\text{V}}{\text{W(mg)}}$$

Where, A is Optical density, V is volume of acetone and W is weight of sample.

3.7.2 Yield parameters

3.7.2.1 Number of tubers

Five plants at 30, 45, 60 DAP and at de-haulming stages were dug from each plot at random leaving the border plants. Number of tubers were counted and averaged for each of these plants and expressed as plant^{-1}.

3.7.2.2 Fresh weight of tubers

Five plants at four stages were dug randomly from each plot leaving the border plants. Tuber weight per plant was, recorded and averaged for each of these plants and expressed as plant^{-1}.

3.7.2.3 Grade wise number of tubers

The grade wise number of harvested tubers from each plot was counted and converted into tonnes per hectare.

3.7.2.4 Total number of tubers

First the number of tubers per plot was calculated by adding number of tubers of all four grade and then converted into per hectare by using following formula-

$$\text{Total tubers per hectare} = \frac{\text{Tubers per Plot}}{\text{Net plot area}} \text{ x } 10000$$

3.7.2.5 Grade wise tuber yield

The total yield harvested from each plot was sorted out into four grades based on their size *viz.* <25g, 25-50g, 51-75g, >75g and weighed and convert into tonnes per hectare.

3.7.2.6 Tuber yield

The total yield of harvested tubers per hectare (t ha^{-1}) was calculated on the basis of tuber yield per plot and converted into tonnes per hectare by using following formula-

$$\text{Tuber yield per hectare} = \frac{\text{Tuber yield per plot}}{\text{Net plot area}} \text{ x } 10000$$

3.7.2.7 Marketable tuber yield

The diseased and damaged tubers were sorted out and the marketable yield of harvested tubers per hectare was calculated based on marketable yield of tubers per plot and converted into tonnes per hectare.

3.7.2.8 Harvest index

The harvest index per plot from different treatments was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

where,

Economic yield = Total tuber yield

Biological yield = Total tuber yield + Total haulm yield

3.7.3 Quality parameters

3.7.3.1 Dry matter content

The dry matter content of tuber was determined by oven drying method. 100 g fresh tuber weight from each treatment was taken and dried in oven at 80°C till constant weight then dry weight of tuber was recorded in per cent and calculated by using following formula -

$$\text{Dry matter content (\%)} = \frac{\text{Oven dried weight of tuber (g)}}{\text{Fresh weight of tuber (g)}} \times 100$$

3.7.3.2 Protein content

It was determined by procedure given by Ranganna, 1986. After determination of N content in tuber (%), the protein content was calculated by following conversion formula given by AOAC, 2000:

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

3.7.3.3 Total soluble solids (T.S.S.)

Potato tuber juice was extracted from each representative sample and used for T.S.S. estimation by hand held refractrometer at room temperature. The results were expressed in terms of %.

3.7.3.4 Specific gravity

A representative sample of tubers was taken from each plot after harvesting. The volume of tubers was determined by water displacement method. The specific gravity was determined by following formula:

$$\text{Specific gravity of tuber (g/cm}^3\text{)} = \frac{\text{Weight of tuber (g)}}{\text{Volume of water displaced (cm}^3\text{)}}$$

3.7.4 Soil analytical parameters

3.7.4.1 Estimation of soil pH before planting

Soil pH was determined using Digital pH meter. As per the procedure given below:

Method

I. 20 g soil was taken in a 100 ml beaker.

II. 50 ml distilled water was added in the soil, the mixture was shaken with the help of glass rod and was kept for 30 minutes.

III. The pH meter was put 'on' before 30 minutes of taking reading.

IV. The temperature of the suspension was recorded. The temperature of the pH meter was adjusted.

V. The pH meter was standardized with the help of Standard Buffer solutions. For this the electrode was dipped in a 7.0 buffer and calibrated it then dipped in a 4.0/9.2 buffer after washing with distilled water and drying it with tissue paper and calibrated.

VI. The electrode then dipped in beaker containing soil water suspension to record the pH.

VII. The pH value of the soil sample was noted down.

3.7.4.2 Available nitrogen content in soil at harvest

The procedure to determine the available nitrogen given by **Subbiah and Asija (1956)** was employed. The procedure was as follows-

I. 20 g soil was placed in 800 ml dry Kjeldahl flask.

II. 20 ml distilled water was added to it and swirled then 1 ml of liquid paraffin and a few glass beads were added to prevent frothing and bumping respectively during distillation. Then each of 32 % $KMnO_4$ (320 g l^{-1}) and 2.5 % NaOH (25 g l^{-1}) solutions was poured in it.

III. The contents in a Kjeldahl assembly was distilled at a steady rate & the liberated ammonia was collected in an Erlenmeyer flask (250 ml) containing 20 ml of boric acid solution with mixed indicator. With the absorption of ammonia, pink colour of boric acid solution turned green. Nearly 100 ml of distillate was collected in about 30 minutes.

IV. The content then was titrated with 0.02 N H_2SO_4 to the original shade (pink).

V. Similar procedure was followed with the blank (without soil). Blank correction was also made during final calculations.

Calculation

Available N (kg ha^{-1}) = (S-B) x N H_2SO_4 x 0.014 x 100 x 10^4 x 2.24/ weight of soil sample = (S-B) x 31.36

Where, S = burette reading of treated sample

B = reading of blank sample

3.7.4.3 Available phosphorus in soil:

Available phosphorus in soil was estimated employing Olsen's method **(Olsen *et al*., 1954).**

I. 2.5 g of soil sample was weighed in 100 ml conical flask.

II. 20 ml of Olsen's reagent (0.5M $NaHCO_3$) Sodium bicarbonate was added.

III. The mixture was shaken for 30 minute on a mechanical shaker.

IV. Content was filtered through Whatman No.1 filter paper in 100 ml volumetric flask.

V. 10 ml of clear and colourless filtrate was transfered into a 25ml volumetric flask.

VI. Then 5 ml of ammonium molybdate solution containing 400 ml of 10*N* HCl per liter was gradually added.

VII. The solution was shaken slowly and carefully to drive out the CO_2 evolved.

VIII. 1 ml of freshly diluted $SnCl_2$ solution was added. After a mild mixing, the volume was made to 25 ml.

IX. The blue colour intensity was read at 630 nm (red filter).

X. A blank without soil was also run under same manner.

XI. Standards: 0.219 g KH_2PO_4 was dissolved in water and 2.5ml 7N H2SO4 was added in it. The volume was made up to 1 litre with distilled water. It was the stock solution of 50 ppm. The working standard of 2 ppm was made from it by taking 1ml in 25 ml flask and dilute up to mark. Further 0, 0.5, 1, 2, 3 and 5 ml of 2 ppm P solution were taken in separate 25 ml volumetric flask. 5 ml of chloromolybdic acid and 1 ml of diluted SnCl2 was added and the volume was made up to mark by distilled water.

XII. Standard curve: The standard curve for absorbance v/s concentration of P was plotted on simple graph paper and corresponding concentration of P in samples was found out by curve.

Calculation:

Available P (kg ha^{-1}) = (P_S × 25 × 20 × 2.24 × 2.29) = P_S × 512.96

3.7.4.4 Available potassium in soil

Available potassium in soil was determined by flame photometer (**Jackson, 1967**).

I. 5 g soil sample was weighed in 100 ml conical flask.

II. 25 ml of the neutral 1 *N* ammonium acetate solution was added and was shaken for 5 minutes.

III. The solution was then filtered through Whatman No.1 filter paper.

IV. The K concentration was measured in the filtrate using flame photometer.

V. Standards (1000 ppm): 1.908 g of AR grade KCL dissolved in 1 liter of distilled water. 100 ppm solution was prepared from it by taking 100 ml and diluted upto 1 liter. From it 0, 10, 20, 30, 40 and 50 ml was taken in separate 25 ml flask and filled up to mark by distilled water.

VI. Standard curve: The standard curve for absorbance v/s concentration of K was plotted on simple graph paper and corresponding concentration of K in samples was found out by curve.

Calculation: Available K (kg ha^{-1}) = R ×{Volume of extract (ml) × 2.24}/ weight of soil taken in g = Ks × 11.2

3.7.5 Plant analytical parameters

3.7.5.1 Nitrogen content in potato plant and tuber

Principle-

Total nitrogen content in plant samples is commonly determined by the Kjeldahl's method (**Singh *et al.* 2007).** This essentially involved

I. digestion of sample to convert the various nitrogen compounds in the sample to the NH_4 form and

II. Determination of NH_4-N in the digest.

It also include NO_3-N in estimation, so procedure with salicylic acid thiosulphate modification is used. Nitro compounds formed by the reaction of salicylic acid with nitrate in acid medium are reduced to corresponding amino compound by heating the mixture with sodium thiosulphate and zinc dust. The main product of nitrogen is 5-nitrosalicyclic acid and small amount of 3-nitrosalicylic acid.

Procedure-

(a) Digestion-

I. 0.2g dried plant sample was taken to a Kjaldahl flask.

II. 10 ml sulphuric acid- salicylic acid mixture was added and gently swirled to bring the dry sample in contact with the reagent. Allowed it to stand overnight.

III. Next day 5 g sodium thiosulphate was added and gently heated for about 5 minutes (to avoid forthing).

IV. Cooled the contents and 10 g sulphate mixture (K_2SO_4 + $CuSO_4$ + Se powder) was added. Digested on Kjeldahl apparatus at full heat (150^0C for 45 minutes and then at 350^0C for another 45 minutes). Glass beads were added to avoid bumping. The digestion was continued for about 1 hour untill the solution got clear. Upon completion of digestion the digest was cooled and diluted with some water. Distillation was carried out as described below.

(b) Distillation-

I. The digested sample was transferred in the micro Kjeldahl distillation apparatus. The flask was rinsed thrice with 50 ml of deionized water and added 10 ml of 40 % NaOH solution to it.

II. In a 150 ml conical flask, 10 ml of 4 % boric acid solution containing bromocresol green and methyl red indicators was taken. The condenser outlet was dipped into the solution of this flask.

III. Distilled it for about 20-30 minutes and removed the flask from heater.

IV. Then the boric acid, containing distilled ammonia was titrated against 0.005 N H_2SO_4. The blank titration was also run to same end point.

Observation and calculation-

Weight of sample = 0.5g

Normality of H_2SO_4 = 0.005 (*N*/200)

Volume of aliquot = 100 ml

Volume of aliquot taken = 5 ml

Titration value (TV) = Sample titration (ml) – blank titration (ml)

N % in plant = TV x 0.00007 x 100 x 100 / (0.5 x 5)

= 0.28 x TV

(Since, 1 ml 0.01 NH_2SO_4 = 0.00014 g N; 1 ml 0.005 NH_2SO_4= 0.00007 g *N*).

3.7.5.2 Nitrogen uptake in plant and tuber

Nitrogen uptake in plant and tuber was calculated by the formula-

$$\text{Nitrogen uptake (kg/ha)} = \frac{\text{Nitrogen Content \%}}{100} \text{ x Dry weight (kg/ha)}$$

3.7.5.3 Total nitrogen uptake in plant

Total nitrogen uptake in plant was calculated through adding nitrogen uptake by plant and nitrogen uptake by tuber.

3.7.5.4 Nitrogen use efficiency

The maximum requirement of nitrogen was determined by fitting a quadratic equation computed between nitrogen application rates and aggregate tuber yield. Nitrogen use efficiency (NUE, Kg of tuber produced per kg of nitrogen applied) for each treatment was determined by subtracting the control yield (Y_C) from the yield obtained at a particular N level (Y_N) and then dividing the outcome value by the quantity of the N fertilizer applied at that level (Janssen, 1998):

$$\text{Nitrogen Use Efficiency \% (NUE)} = \frac{(Y_N - Y_C)}{N_R} \times 100$$

Where,

Y_N is yield at the particular N level, Y_C is yield at N_C level (control) and N_R is the particular N rate.

3.7.5.5 Nitrogen apparent recovery

Nitrogen apparent recovery (in per cent) for each treatment was determined by subtracting the nitrogen uptake by plant in control (NU_C) from the N uptake in plant at a particular N level (NU_N) and then dividing the outcome value by the quantity of the N fertilizer applied at that level (Niu *et al.,* 2011):

$$\text{Nitrogen Apparent Recovery (\%)} = \frac{NU_N - NU_C}{N_R} \times 100$$

Where,

NU_N is N uptake by plant at the particular N level, NU_C is N uptake by plant at N_C level (control) and N_R is the particular N rate.

3.7.6 Economics of the treatments

Economic components of different treatments were worked out under as follows:

3.7.6.1 Cost of cultivation (`ha^{-1})

The cost of cultivation was worked out by taking all considerations of expenditure incurred on the basis of existing market rate of inputs.

3.7.6.2 Total output (`ha^{-1})

Total output was calculated by multiplying per hectare yield of tubers under various treatments with prevailing selling rates of tubers in the local market.

3.7.6.3 Net Return

Net return in each treatment was worked out by subtraction of cost of cultivation from the gross return.

3.7.6.4 Benefit-Cost ratio

The benefit: cost ratio was computed by adopting following formula:

$$\text{Benefit: Cost ratio} = \frac{\text{Gross income (`/ha)}}{\text{Total expenditure (`/ha)}}$$

3.7.7 Statistical analysis

The data recorded during the course of experiment were subjected to analysis through computer by using STPR3 programme, designed and developed by department of Mathematics and Statistics, College of Basic Sciences and Humanities, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand.

Results and Discussion

The results obtained in the study entitled "**Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)**" is presented and discussed with relevant literature under the following headings:

4.1 Plant growth parameters

4.2 Yield parameters

4.3 Quality parameters

4.4 Soil analytical parameters

4.5 Plant analytical parameters

4.6 Economics

4.1 Plant growth parameters

4.1.1 Plant emergence

Emergence is a developmental stage when the first leaf of plant emerges from the soil. At 10 days after planting, plants started emerging out from most of the tubers in each plot. The emergence was almost completed within a month. Plant emergence was counted at 20 and 30 days after planting during both the years. The data has been presented in Table 4.1, and analysis of variance in Appendix II.A, II.B, II.C, II.D, II.E and II.F. The data indicated that different nitrogen treatments did not show any significant variation for plant emergence in both the years as well as in pooled data.

During first year (2014-15) at 20 DAP, the maximum emergence (87%) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_{10} (No application of nitrogen), whereas it was recorded minimum (69%) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). In second year (2015-16), maximum emergence was recorded (86%) with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) and minimum (74%) with T_4 (50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP). Pooled analysis over the years, revealed maximum emergence (88%) with treatment T_{10} (No application of nitrogen) and minimum (72%) with treatment T_4 (50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP).

Table 4.1: Effect of nitrogen scheduling on plant emergence

Treatments	Emergence (%)					
	20 DAP			30 DAP		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	72	85	78	88	89	88
T_2	77	79	78	90	87	89
T_3	71	86	79	86	91	88
T_4	70	74	72	83	89	86
T_5	69	84	76	80	88	84
T_6	75	85	80	89	89	89
T_7	72	78	75	91	92	91
T_8	74	84	79	88	91	90
T_9	87	84	85	90	96	93
T_{10}	87	85	88	89	89	89
SEm.±	7	4	4	3	3	2
CD at 5%	NS	NS	NS	NS	NS	NS

At 30 days after planting during first year, maximum emergence (91%) was recorded with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) and minimum (80%) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) while in second year, it was recorded maximum (96%) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum (87%) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). The mean data over the years showed maximum emergence (93%) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum (84%) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP).

It is evident from the data (Table 4.1) that nitrogen treatments did not play any role in tuber emergence as all the treatments showed more than 80% emergence at 30 days including control (without nitrogen). It depends on the physiological stage and sprouts present on the tuber. Sahu *et al.* (2016) and Hosseini *et al.* (2017) also found the similar effect of nitrogen treatments on potato emergence. Sharma *et al.* (2015) reported highest tuber germination due to good quality seed tubers. According to Ayyub *et al*. (2006), tuber emergence depends upon genetic makeup of the plant and effect of microclimate. In contrary to this, Chowdhaury *et al*. (2002a) observed significant variation in nitrogen application methods with respect to plant emergence. They recorded maximum plant emergence in the split application of urea.

4.2.2 Plant height

Plant height was taken at 30, 45, 60 DAP and at de-haulming stage in both the years and pooled data. The effect of nitrogen treatments on plant height at various stages (30, 45, 60 DAP and de-haulming) has shown in Table 4.2 and analysis of variance in Appendix III.A, III.B, III.C, III.D, III.E, III.F, III.G, III.H, III.I, III.J, III.K and III.L. Statistically significant effect of different nitrogen treatments was observed at all the stages of crop except at 30 days after planting during both the years and pooled data.

At 30 days after planting in 2014-15, the maximum plant height (29.3 cm) was measured with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3%

at 25 & 40 DAP) and minimum (25.3 cm) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP), whereas in 2015-16, it was measured maximum (28.8 cm) with T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) and minimum (23.7 cm) with T_{10} (No application of nitrogen). Pooled data over the years showed maximum plant height (27.9 cm) with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) and minimum (25.3 cm) with T_{10} (No application of nitrogen).

At 45 DAP during 2014-15, maximum plant height (53.1 cm) was measured with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) which was at par to treatments T_2 (52.1 cm), T_8 (51.6 cm), T_9 (51.5 cm) and T_1 (50.5 cm), respectively. In 2015-16 the maximum was measured (50.9 cm) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatment T_8 (49.4 cm). Mean data over the years showed maximum plant height (51.2 cm) with T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatments T_8 (50.5 cm), T_7 (49.7 cm) and T_2 (48.8 cm). The minimum plant height (38.4, 41 and 39.7 cm in both the years and pooled data, respectively) at this stage was measured with treatment T_{10} (No application of nitrogen).

At 60 days after planting during 2014-15, the maximum plant height (60.2 cm) was measured with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to all other treatments except T_7, T_4, T_5 and T_{10}. In 2015-16 it was recorded maximum (54.9 cm) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was at par to treatments T_9 (53.7 cm), T_2 (51.2 cm), T_7 (50.6 cm) and T_5 (50.5 cm), respectively. Pooled data showed maximum plant height (55.7 cm) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was statistically similar to treatments T_8 and T_9 (55.4 cm) respectively. The minimum plant height (47.3, 42 and 44.7 cm, both the years and pooled data, respectively) was measured with treatment T_{10} (No application of nitrogen).

Table 4.2: Effect of nitrogen scheduling on plant height

Treatments	Plant height (cm)											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	27.7	26.0	26.9	50.5	43.2	46.9	57.1	44.4	50.8	59.8	58.4	59.1
T_2	28.3	26.3	27.3	52.1	45.4	48.8	60.2	51.2	55.7	61.9	57.0	59.5
T_3	25.4	27.6	26.5	44.5	44.2	44.3	55.7	47.6	51.7	56.4	56.4	56.4
T_4	25.8	26.2	26.0	48.4	42.8	45.6	53.7	45.2	49.5	56.7	56.8	56.7
T_5	25.3	28.0	26.6	46.1	43.6	44.8	52.9	50.5	51.7	56.0	56.5	56.3
T_6	27.0	28.8	27.9	48.1	43.4	45.8	55.7	47.2	51.4	56.7	56.8	56.7
T_7	29.3	25.2	27.2	53.1	46.2	49.7	54.0	50.6	52.3	55.4	53.4	54.4
T_8	27.0	24.1	25.5	51.6	49.4	50.5	55.8	54.9	55.4	56.9	59.8	58.4
T_9	26.5	28.8	27.7	51.5	50.9	51.2	57.1	53.7	55.4	61.6	60.8	61.2
T_{10}	26.8	23.7	25.3	38.4	41.0	39.7	47.3	42.0	44.7	51.7	45.8	48.8
SEm.±	1.7	3.0	1.6	1.2	1.0	0.9	1.5	1.6	1.0	1.0	0.9	0.7
CD at 5%	NS	NS	NS	3.7	3.0	2.7	4.6	4.7	2.9	3.1	2.6	2.0

At de-haulming stage during 2014-15, the longest plants (61.9 cm) were measured with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to treatment T_9 (61.6 cm) and T_1 (59.8 cm). In 2015-16 it was measured maximum (60.8 cm) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was statistically similar to treatment T_8 (59.8 cm) and T_1 (58.4 cm). Pooled data over the years showed longest plants (61.2 cm) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_2 (59.5 cm). The shortest plants (51.7, 45.8 and 48.8 cm in both the year and pooled data, respectively) were measured with treatment T_{10} (No application of nitrogen).

It was observed from the data (Table 4.2) that nitrogen treatment significantly affected plant height at later stages. However, at all the stages longest plants were measured in split nitrogen application as basal + topdressing + foliar. This might be due to better availability of nitrogen and the enhancing effect of nitrogen on vegetative growth by cell division and cell elongation which indirectly affect tissue formation and consequently vegetative growth of the plant. Rizk *et al.* (2013) in their study obtained taller potato plants with foliar spray of urea. They concluded that it might be due to speed absorption by leaf tissues, consequently more plant vigour. In a study, Ayyub *et al*. (2006) recorded that initially broadcasted plus broadcasted or side dressing, later on, behaved significantly better, produced taller plants as compared to initial full doses or foliar application.

4.1.3 Number of haulms

Effect of different nitrogen treatments on number of haulms per plant has been presented in Table 4.3 and analysis of variance in Appendix IV.A, IV.B, IV.C, IV.D, IV.E, IV.F, IV.G, IV.H, IV.I, IV.J, IV.K, IV.L. Nonsignificant effect of different nitrogen treatments on number of haulm per plant was recorded at all the stages in both the years and pooled data.

The mean data over the years (Table 4.3) showed that highest number of haulms (5 per plant) at 30 days after planting was counted with Treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP). The minimum haulms

Table 4.3: Effect of nitrogen scheduling on number of haulms

Treatments	Number of haulms (plant^{-1})											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	4	4	4	4	4	4	5	5	5	5	5	5
T_2	4	4	4	5	5	5	5	5	5	5	6	5
T_3	4	5	4	4	5	5	5	5	5	5	6	5
T_4	4	4	4	5	4	4	5	4	5	5	4	5
T_5	4	3	4	5	4	4	5	4	5	5	5	5
T_6	5	4	4	5	5	5	5	5	5	5	5	5
T_7	4	4	4	4	4	4	5	4	5	5	5	5
T_8	5	5	5	5	5	5	5	6	5	5	6	6
T_9	5	4	5	5	5	5	6	6	6	6	6	6
T_{10}	4	4	4	4	4	4	5	4	4	5	4	5
SEm.±	0.5	0.3	0.3	0.5	0.4	0.3	0.3	0.5	0.2	0.4	0.4	0.3
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	0.73	NS	NS	NS

(4 per plant) were counted in rest of the treatments. At 45 days after planting, treatments $T_{2,}$ $T_{3,}$ $T_{6,}$ T_8 and T_9were showing 5 haulms per plant whereas, rest were showing 4 haulms per plant.

At 60 days after planting all the treatments were showing 5 haulms per plant except treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which showed maximum haulms (6 per plant) and minimum haulms (4 per plant) was recorded with treatment T_{10} (No application of nitrogen).

Finally at de-haulming stage, maximum haulms (6 per plant) was recorded with treatments T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP), while 5 haulms per plant were recorded in rest of the treatments.

The data depicted in Table 4.3 clearly revealed that different nitrogen application methods and timing did not affect number of haulms per plant and it increased with the age of the plant. This character mainly depends on the variety, physiological state and number of sprouts present on the seed tuber rather than fertility of the soil. According to Jasim (2013) number of haulms could not be affected by foliar spray of nitrogen. In fact, haulms are formed after planting and before adding foliar nitrogen. In contrast, Sahu *et al*. (2016) observed the highest number of shoots per plant may due to adequate supply of nitrogen which is associated with higher photosynthetic activity leading to more number of shoots per plant.

4.1.4 Number of leaves

The data regarding effect of different nitrogen treatment on number of leaves per plant has presented in Table 4.4 and analysis of variance has shown in Appendix V.A, V.B, V.C, V.D, V.E, V.F, V.G, V.H, V.I, V.J, V.K, V.L. Significant difference was observed among nitrogen scheduling with respect to leaves per plant at all the stages except 30 DAP in first year.

At 30 days after planting, in both the years, the maximum number of leaves (24 and 25 per plant) was counted with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP), which was at par to treatment T_9 (24 per plant) and T_7 (22 per plant) in second year. Minimum number of leaves (17 per plant per plant) was counted

Table 4.4: Effect of nitrogen scheduling on number of leaves

Treatments	Number of leaves ($plant^{-1}$)											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	20	17	19	35	33	33	40	37	38	38	37	37
T_2	22	18	20	32	32	32	37	35	36	36	34	35
T_3	21	20	20	31	29	30	35	34	34	36	33	35
T_4	21	19	20	29	30	30	34	31	33	35	31	33
T_5	20	17	18	31	28	29	36	35	35	35	36	36
T_6	19	17	18	32	31	31	37	34	35	34	33	34
T_7	20	22	21	30	29	29	35	33	34	37	34	35
T_8	24	25	24	35	32	34	42	39	41	42	38	40
T_9	23	24	23	38	35	36	45	42	44	44	42	43
T_{10}	17	18	18	22	21	22	25	22	23	23	20	22
SEm.±	2	1	1	2	2	2	3	2	2	2	3	2
CD at 5%	NS	3	4	7	6	5	8	7	6	5	8	5

with treatment T_{10} (no application of nitrogen) in first year and in second year with T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP), T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP), respectively. Pooled data over the years showed maximum number of leaves (24 per plant) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP), which was at par to treatments T_9 (23 per plant), T_2, T_3 and T_4 (20 per plant). It was recorded minimum (18 per plant) with T_5 (50% N of RDF as basal + 50% top dressing at 25 dap + one foliar spray of urea @ 3% at 40 DAP), T_6 (50% N T_4 of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) and T_{10} (no application of nitrogen).

At 45 DAP, the maximum number of leaves in first year (38 per plant) and in second year (35 per plant) was counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which, was statistically at par to all other treatments except T_7, T_4 and T_{10} (30, 29 and 22 per plant, respectively) in first year and with treatments T_5 (28 per plant) and T_{10} (21) in second year. Pooled data over the years showed maximum number of leaves (36) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatments T_8 (34 per plant), T_1 (33 per plant), T_2 (32 per plant) and T_6 (31 per plant), respectively. It was recorded minimum (22, 21 and 22 per plant in both the years and pooled data, respectively) with treatment T_{10} (no application of nitrogen).

At 60 DAP, the maximum leaves per plant in first year (45 per plant) and in second year (42 per plant) were counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). This was significantly at par to treatments T_8 (42 per plant), T_1 (40 per plant), T_2 and T_6 (37 per plant) in first year and with treatments T_8 (39 per plant), T_1 (37 per plant), T_2 and T_5 (35 per plant) in second year. Pooled data over the years showed maximum number of leaves (44 per plant) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatment T_8 (41 per plant) and T_1 (38 per plant). The minimum number of leaves per plant (25, 22 and 23 per plant in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

At de-haulming stage, maximum leaves per plant in first year (44 per plant) and in second year (42 per plant) was counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which, was at par to T_8 (42 per plant) in first year and in second year with T_8 (38 per plant), T_1 (37 per plant), T_5 (36 per plant), T_2 and T_7 (34 per plant). Pooled data over the years showed maximum leaves (43 per plant) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_8 (40 per plant). In both the years and pooled data minimum leaves (23, 20 and 22 per plant, respectively) was counted with treatment T_{10} (No application of nitrogen).

The results indicated that split application of nitrogen in suitable amount significantly influenced number of leaves per plant at all growth stages. More leaves per plant were observed with the treatments having more plant height as it had more number of nodes consequently more leaf formation. This might be due to the fact that the split application of nitrogen improved soil as well as plant nutrient status which helped in better growth of the plant in comparison to without application of nitrogen and recommended dose. Peter *et al.* (2015) also reported that both nitrogen fertilizer rate and split frequency increased number of leaves per hill. At de-haulming, the number of leaves per plant in some treatments was decreased due to maturation or senescence. A similar reduction in number of leaves at later stage was also recorded by Jatav *et al*. (2017). They were of the view that more dose of nitrogen promoted and retained more number of leaves at later stage of growth of potato.

4.1.5 Diameter of haulm

Effect of nitrogen treatment on diameter of haulm has shown in Table 4.5 and analysis of variance in Appendix VI.A, VI.B, VI.C, VI.D, VI.E, VI.F, VI.G, VI.H, VI.I, VI.J, VI.K, VI.L. During both the year and pooled data, diameter of haulm significantly varied with different nitrogen application methods at all the stages except 30 DAP in 2014-15 and 45 DAP in both years and pooled data.

At 30 days after planting, maximum diameter of haulm in first year (8.4 mm) and in second year (7.9 mm) was recorded with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP). It was at par to all other treatments except T_7 and T_{10} (7.2 and 6.8 mm) in second year. Pooled analysis over the years showed maximum diameter of haulm (8.2 mm) with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) which was at par to T_9 (7.7 mm).

Table 4.5: Effect of nitrogen scheduling on diameter of haulm

Treatments	Diameter of haulm (mm)											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	7.5	7.5	7.5	8.6	8.2	8.4	9.1	8.8	8.9	8.3	8.2	8.3
T_2	7.6	7.3	7.5	9.3	8.8	9.1	9.5	9.0	9.2	8.5	7.5	8.0
T_3	7.7	7.4	7.6	8.4	8.1	8.3	8.7	8.5	8.6	7.9	8.1	8.0
T_4	7.2	7.6	7.4	7.6	7.8	7.7	8.6	7.9	8.3	7.9	7.1	7.5
T_5	7.8	7.4	7.6	8.7	8.1	8.4	9.8	8.2	9.0	8.3	8.0	8.1
T_6	8.4	7.9	8.2	8.6	8.3	8.5	9.3	7.8	8.6	7.9	8.1	8.0
T_7	8.0	7.2	7.6	8.5	8.2	8.3	9.4	7.5	8.4	8.9	9.0	8.9
T_8	7.6	7.4	7.5	8.3	8.2	8.2	8.5	8.7	8.6	7.7	9.2	8.4
T_9	7.6	7.7	7.7	8.3	8.0	8.1	8.5	8.2	8.4	8.1	8.9	8.5
T_{10}	6.6	6.8	6.7	7.0	7.1	7.1	7.7	7.2	7.4	7.5	6.5	7.0
SEm.±	0.34	0.18	0.18	0.50	0.68	0.47	0.36	0.37	0.31	0.25	0.38	0.20
CD at 5%	NS	0.6	0.5	NS	NS	NS	1.1	1.1	0.9	0.8	1.1	1

However minimum haulm diameter was observed in treatment T_{10} (6.6, 6.8 and 6.7 mm during both the years and pooled data, respectively).

At 45 days after planting, maximum diameter of haulm in first year (9.3 mm) and in second year (8.8 mm) was recorded with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). Pooled analysis over the years showed maximum diameter of haulm (9.1 mm) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). However minimum was recorded in T_{10} (7, 7.1 and 7.1 mm, both the years and pooled data, respectively).

At 60 days after planting, the maximum diameter of haulm in first year (9.8 mm) was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 dap + one foliar spray of urea @ 3% at 40 DAP) which was at par to all other treatments except T_4, T_8, T_9 and T_{10} in the first year. In second year, it was recorded maximum (9 mm) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to all other treatments except T_6, T_7 and T_{10}. Pooled data over the years showed maximum diameter of haulm (9.2 mm) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to all other treatments except treatment T_{10}. However minimum was recorded in T_{10} (7.7, 7.2 and 7.4 mm, both the years and pooled data, respectively).

At de-haulming stage, in the first year, maximum haulm diameter (8.9 mm) was recorded with T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) which, was statistically similar with treatments T_2 (8.5 mm), T_1 (8.3 mm), T5 (8.3 mm) and T_9 (8.1 mm). In second year, it was recorded maximum (9.2 mm) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was at par to all other treatments except T_2, T_4 and T_{10}. Pooled analysis showed maximum haulm diameter with treatment T_7 having 8.9 cm diameter and was at par to all other treatments except T_4 and T_{10}. However minimum haul diameter was recorded in treatment T_{10} (7.5, 6.5 and 7.0 mm, respectively)

It is evident from the data (Table 4.5) that application of nitrogen increased haulm thickness. Moreover, it was increased with split application including foliar spray. It might be due to more production of photosynthates in plants leads to more haulm thickness. Similar to this Al-Moshileh *et al.* (2005) reported that splitting nitrogen rates into three doses applied equally at 0, 45 and 60 days after planting improved stem thickness. Our results also supported by results obtained by Rizk *et al.* (2013) who found more haulm thickness with 3% foliar spray of nitrogen.

4.1.6 Dry weight

The data regarding effect of nitrogen treatments on dry weight of potato plant is depicted in Table 4.6 and analysis of variance has shown in Appendix VII.A, VII.B, VII.C, VII.D, VII.E, VII.F, VII.G, VII.H, VII.I, VII.J, VII.K, VII.L. A significant effect was recorded of all the nitrogen treatments on dry weight of the plant at all the stages during both the years and pooled data except 30 days after planting in both the years.

At 30 days after planting, maximum dry weight (16 g and 14 g per plant in first and second year, respectively) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). Pooled data over the years showed maximum dry weight of the plant (15 g per plant) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was statistically similar with treatment T_6 (14 g per plant) and T_2, T_3, T_7 and T_8 (12 g per plant). The minimum dry weight (9 g per plant in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen) and also with T_5 (50% N of RDF as basal + 50% top dressing at 25 dap + one foliar spray of urea @ 3% at 40 DAP) in second year.

At 45 days after planting, maximum dry weight (26 g per plant) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) in first year which was at par to all other treatments except T_1, T_2, T_3, and T_{10}. In second year, maximum dry weight of the plant (24 g per plant) was recorded with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to T_1 (20 g per plant). In pooled data over the years, it was maximum (22 g per plant) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to all other treatments except T_5. It was recorded minimum with T_{10} (No application of nitrogen) in first year (17 per plant) and pooled data (16 g per plant)

Table 4.6: Effect of nitrogen scheduling on dry weight

Treatments	Dry weight (g plant^{-1})											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	12	11	11	19	20	20	27	24	26	44	41	42
T_2	12	11	12	19	24	21	25	25	25	40	40	40
T_3	13	12	12	20	18	19	26	21	23	39	38	39
T_4	11	10	10	24	17	20	28	26	27	41	37	39
T_5	10	9	10	21	14	18	30	27	29	40	38	39
T_6	16	13	14	24	17	20	27	24	26	43	41	42
T_7	12	12	12	26	16	21	29	28	29	42	40	41
T_8	13	11	12	23	18	21	29	29	29	42	42	42
T_9	16	14	15	26	17	22	33	30	32	44	43	43
T_{10}	9	9	9	17	14	16	20	19	20	30	30	32
SEm.±	2	1	1	2	1	1	2	2	1	2	1	1
CD at 5%	NS	NS	3	5	4	3	6	5	4	5	4	3

while in the second year (14 per plant) with T_5 (50% N of RDF as basal + 50% top dressing at 25 dap + one foliar spray of urea @ 3% at 40 DAP) and T_{10} (No application of nitrogen).

At 60 days after planting, maximum dry weight (33 g per plant) in first year and (30 g per plant) in second year was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was statistically at par to all other treatments except T_3, T_2 and T_{10} in the first year while in second year, it was at par to others except treatments T_1, T_6, T_3 and T_{10}. Pooled data over the years showed maximum dry weight (32 g per plant) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatments T_7 and T_8 (29 g per plant). The minimum dry weight of the plant (20, 19 and 20 g per plant in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

At de-haulming stage, maximum dry weight of the plant (44 g per plant) in first year was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and with T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was at par to all other treatments except T_{10}. In second year and pooled data it was recorded maximum (43 g per plant) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to all other treatments except T_3, T_4, T_5 and T_{10}. The minimum dry weight of the plant (30, 30 and 32 g per plant in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

Adequate nitrogen supply at vegetative growth stage and additional foliar application leads to more dry matter accumulation in the plants (Table 4.6). Foliar application facilitates speed absorption of nitrogen by leaf tissues which enhanced photosynthesis process resulted in more dry matter assimilation in shoot. The increase in dry weight was also due to more plant height, number of leaves and thickness of haulm. Our results were in close conformity with the results obtained by Kumar (2015). They recorded maximum dry weight of the plant in 50% basal N + 25% topdressing at 25 DAP + 2% spray of urea at 40 DAP. Nasir *et al.* (2006) also reported that more splitting of nitrogen produce more dry matter in shoots.

4.1.7 Leaf area index

Data regarding leaf area index at de-haulming stage is depicted in Table 4.7 and analysis of variance is presented in Appendix VIII.A, VIII.B, VIII.C. LAI is the ratio of leaf surface to the area covered by the plant canopy. It is clearly evident from the data that nitrogen treatments significantly affected the leaf area index.

In first year, the leaf area index was recorded maximum 5.2 with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was statistically similar with T_9 (4.7) while in the second year, it was recorded maximum (5.4) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was at par to treatments T_9 (5.2), T_4 (5), T_1 (4.9) and T_3 (4.8). Pooled data over the years showed maximum leaf area index (5.0) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was at par to T_8 (4.9) and T_4 (4.7). The minimum LAI (2.7, 2.3 and 2.5 in both the year and pooled data) was recorded with treatment T_{10} (No application of nitrogen).

The perusal data in Table 4.7 indicated that LAI was increased with adequate nitrogen application during vegetative stage moreover, an additional foliar spray further enhanced it. It might be due to the rapid leaf expansion caused by adequate nitrogen supply resulted in high LAI. However, excess nitrogen supply damaged the plant tissue which reduce leaf expand consequently less leaf area index as recorded with treatment T_5. On the other hand, untreated plants showed less LAI as compared to treated one. Similar to this Martin *et al*. (2001) recorded a quick decline in leaf area index in case of no nitrogen. Agu (2004) reported that leaf area index increased when nitrogen was applied at sowing and decreased with delay in the application. In contrary to this Kumar *et al.* (2011) reported that nitrogen application time did not affect LAI of potato.

4.1.8 Leaf chlorophyll content

Chlorophyll content of the leaves was estimated before de-haulming stage in both the years and pooled data is presented in Table 4.7 and analysis of variance is given in Appendix IX.A, IX.B, IX.C, IX.D, IX.E, IX.F. All the nitrogen treatments significantly influenced leaf chlorophyll content.

Table 4.7: Effect of nitrogen scheduling on leaf area index and leaf chlorophyll content

Treatments	Leaf area index			Leaf chlorophyll content (mg g^{-1})					
				Chlorophyll 'a'			Chlorophyll 'b'		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	5.2	4.9	5.0	0.76	0.74	0.75	0.83	0.80	0.81
T_2	3.9	4.2	4.0	0.78	0.71	0.74	0.86	0.78	0.82
T_3	4.0	4.8	4.4	0.66	0.67	0.66	0.78	0.79	0.78
T_4	4.4	5.0	4.7	0.69	0.69	0.69	0.77	0.79	0.78
T_5	3.0	3.1	3.1	0.71	0.71	0.71	0.78	0.78	0.78
T_6	3.2	3.4	3.3	0.64	0.67	0.66	0.79	0.78	0.78
T_7	3.6	3.7	3.6	0.74	0.74	0.74	0.82	0.85	0.83
T_8	4.5	5.4	4.9	0.79	0.79	0.79	0.86	0.86	0.86
T_9	4.7	5.2	5.0	0.71	0.77	0.74	0.78	0.89	0.83
T_{10}	2.7	2.3	2.5	0.63	0.59	0.61	0.76	0.73	0.75
SEm.±	0.2	0.3	0.1	0.01	0.02	0.01	0.02	0.01	0.01
CD at 5%	0.5	0.8	0.4	0.02	0.05	0.03	0.05	0.04	0.03

Maximum chlorophyll ‘a' content (0.79 mg g^{-1}) was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) in both the years which was at par to treatment T_2 (0.78 mg g^{-1}) in first year and in second year with treatments T_9 (0.77 mg g^{-1}), T_1 and T_7 (0.74 mg g^{-1}). Pooled data over the years also showed maximum chlorophyll ‘a' content (0.79 mg/g) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was superior to other treatments. The minimum chlorophyll ‘a' content (0.63, 0.59 and 0.61 mg g^{-1} in both the years and pooled data) was recorded under treatment T_{10} (No application of nitrogen).

Similarly, chlorophyll ‘b' content was recorded maximum (0.86 mg g^{-1}) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to treatment T_1 (0.83 mg g^{-1}) and T_7 (0.82 mg g^{-1}). In second year, it was recorded maximum (0.89 mg/g) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and was at par to treatment T_8 (0.86 mg/g) and T_7 (0.85 mg g^{-1}). On the basis of pooled data over the years it was maximum with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and was at par to treatments T_7 and T_9 (0.83 mg g^{-1}). Minimum chlorophyll ‘b' content (0.76, 0.73 and 0.75 mg/g, both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

Chlorophyll is a plant pigment, whose content in a plant depends on several factors ranged from agronomic treatments, *e.g.* applied fertilization to environmental conditions. The results revealed that chlorophyll content was increased with increase in nitrogen application. It might be because nitrogen is a structural element of chlorophyll and protein molecules, and thereby affects formation of chloroplasts and accumulation of chlorophyll in leaves (Tucker, 2004). Though, nitrogen application in excess also reduced chlorophyll content as in case of T_5 might be due to toxic effect of nitrogen. Ciecko *et al.* (2012) reported a linear increase in the content of Chl ‘a' and Chl ‘b' in potato leaves by increasing share of N applied to leaves in the total nitrogen rate of 80 kg N ha^{-1}, within the range of 8 to 40 kg N ha^{-1}. Guler (2009) did not find any significant effect of nitrogen on chlorophyll content of potato.

4.2 Yield parameters

4.2.1 Number of tubers

The effect of nitrogen treatments with respect to number of tubers per plant has been depicted in Table 4.8 and analysis of variance has given in Appendix X.A, X.B, X.C, X.D, X.E, X.F, X.G, X.H, X.I, X.J, X.K, X.L. It is evident from the Table 4.8 that number of tubers per plant was significantly affected by different nitrogen treatments except 30 days after planting in both years and 45 days after planting in both the years and pooled data.

At 30 days after planting, the maximum number of tubers (5, 6 and 6 per plant in both the years and pooled data, respectively) was counted with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP).

At 45 days after planting, maximum number of tubers (7 per plant) was counted with all the treatments except treatments $T_{4,}$ T_6, T_7 and $T_{10.}$ Minimum number of tubers (5 per plant) with treatment T_{10} (No application of nitrogen), T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) and T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP), whereas in second year, it was recorded maximum (6 per plant) with all the treatments except $T_{4,}$ T_3, T_7 and T_{10} and minimum (4 per plant) were recorded with treatments T_{10} (No application of nitrogen) and T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP). Pooled analysis showed maximum tubers (7 per plant) with treatments T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP), T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) while, minimum tubers per plant (5 per plant) with treatment T_{10} (No application of nitrogen), T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) and T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP).

At 60 days after planting, in the first year, the maximum number of tubers (11 per plant) was counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP), whereas in second year, maximum tubers (9 per plant) was recorded with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP), T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP), T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray

Table 4.8: Effect of nitrogen scheduling on number of tubers

Treatments	Number of tubers ($plant^{-1}$)											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	3	4	3	7	6	7	9	9	9	12	10	11
T_2	4	3	3	7	6	6	10	8	9	12	10	11
T_3	3	4	3	7	4	6	9	6	8	11	9	10
T_4	3	3	3	6	5	6	8	9	8	10	10	10
T_5	3	3	3	7	6	6	7	7	7	11	8	10
T_6	3	5	4	5	6	5	8	6	7	11	8	9
T_7	3	3	3	5	5	5	10	8	9	10	9	10
T_8	5	6	6	7	6	7	10	9	9	12	10	11
T_9	4	4	4	7	6	7	11	9	10	12	11	12
T_{10}	4	4	4	5	4	5	6	5	6	9	7	8
SEm.±	0.62	1.17	0.54	0.72	0.73	0.49	0.18	0.47	0.25	0.21	0.40	0.22
CD at 5%	NS	NS	1.6	NS	NS	NS	0.5	1.4	0.7	0.6	1.2	0.7

of urea @ 3% at 40 DAP) and T_4 (50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP) which was at par to T_2 and T_7 having 8 tubers per plant. Pooled data over the years showed maximum tubers (10 per plant) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). It was recorded minimum (6, 5 and 6 per plant in both the years and pooled data, respectively) with treatment T_{10} (No application of nitrogen).

At de-haulming stage, maximum tubers per plant in first year (12 per plant) and in second year (11 per plant) were counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). It was at par to T_1, T_2, T_8 and T_4 (10 per plant) in the second year. Pooled data over the years showed maximum tubers (12 per plant) with treatment T_9 (25% N of RDF as basal + 50% T_9 top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). Minimum (9, 7 and 8 per plant in both the years and pooled data, respectively) was recorded under treatment T_{10} (No application of nitrogen).

Nitrogen had a positive effect on tuber initiation and its number per plant. More tubers were produced with treated plants particularly with split (basal + top dressed + foliar) application of nitrogen. It might be due to more absorption of nutrients which increased photosynthetic activity as well as translocation of photosynthates consequently more plant vigour responsible for formation of more tubers. In a study Tekalign and Hammes, (2005) were of the view that N may increase the number of tubers by enhancing individual stem vigour, although effects are not always consistent. Contrary to it, Peter *et al.* (2015) reported that split application levels increased from 1 to 3 decreased the potato tuber count per plant. Vaezzadeh and Naderidarbaghshahi (2012) reported that number of tubers depends upon number of haulms per plant.

4.2.2 Fresh weight of tubers

The response of nitrogen scheduling on fresh weight of tubers per plant is shown in Table 4.9 and analysis of variance is given in Appendix XI.A, XI.B, XI.C, XI.D, XI.E, XI.F, XI.G, XI.H, XI.I, XI.J, XI.K, XI.L. All the treatments significantly affected the fresh weight of tubers per plant at all the stages except at 45 days after planting.

Table 4.9: Effect of nitrogen scheduling on fresh weight of tubers

Treatments	Fresh weight of tubers (g plant^{-1})											
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	30 DAP			45 DAP			60 DAP			At de-haulming		
T_1	5	6	6	88	92	90	226	212	219	480	457	469
T_2	10	11	10	119	114	117	224	239	232	471	451	461
T_3	8	9	9	83	92	87	218	204	211	404	393	398
T_4	7	7	7	114	106	110	209	219	214	425	405	415
T_5	8	7	7	89	103	96	250	231	240	446	443	445
T_6	6	7	7	117	108	113	220	238	229	447	442	445
T_7	7	7	7	72	79	76	229	196	212	425	439	432
T_8	6	8	7	111	113	112	254	248	251	522	503	513
T_9	9	9	9	122	115	119	272	266	269	578	540	559
T_{10}	6	6	6	75	97	86	163	168	165	366	314	340
SEm.±	0.84	1.38	0.59	14.04	15.47	10.95	11.77	5	7.25	16.84	10.69	10.37
CD at 5%	3	NS	2	NS	NS	NS	35	15	22	50	32	31

At 30 days after planting, maximum fresh weight of tubers (10 g and 11 g per plant in first and second year, respectively) was recorded with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to all other treatments except T_6, T_8, T_{10} and T_1 in first year and was superior to other treatments in second year. Pooled data over the years showed maximum fresh weight of tubers (10 g per plant) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was at par to T_9 and T_3 (9 g per plant). The minimum (5 g per plant) was recorded with T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) in first year, whereas in second year and pooled data, it was (6 g per plant) with T_{10} (No application of nitrogen) and T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP), respectively.

At 45 days, highest tuber fresh weight *viz.*122, 115 and 119 g per plant (in both the years as well as in pooled data, respectively) was weighted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). However, it was minimum (72, 79 and 76 g per plant) with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) during both the years and pooled data, respectively.

At 60 days after planting, the maximum fresh weight of tubers (272 and 266 g per plant, respectively) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which, was at par to T_8 (254 g per plant) and T_5 (250 g per plant) in first year, while in second year, it was found superior over all other treatments. Pooled data over the years showed maximum fresh weight of the tubers (269 g per plant) at this stage with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and was at par to T_8 (251 g per plant). The minimum fresh tuber weight (163, 168 and 165 g per plant in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

At de-haulming stage, maximum fresh weight of tubers (578, 540 and 559 g per plant in both the years and pooled data, respectively) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was superior to other treatments. The minimum fresh tuber weight (366, 314 and 340 g per plant in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen)

It is evident from the data (Table 4.9) that adequate amount of nitrogen at tuberization leads to increase in fresh tuber weight per plant due to strong sink formation which increased tuber bulking period ultimately more weight of the tubers. Moreover, additional foliar spray enhanced tuber bulking due to speed absorption of nitrogen by leaves as recorded with treatment T_9. More number of tubers per plant was also increased fresh weight of tubers per plant. Similar to this Banjare *et al.* (2014) observed increase in fresh and dry weight of tuber per plant with increase in nitrogen fertility. Rizk *et al.* (2013) recorded high total fresh and dry weight of potato plant by using 3% foliar nitrogen.

4.2.3 Grade wise number of tubers per hectare

Data regarding grade wise number of tubers per hectare has presented in Table 4.10 Fig. 4.1 and analysis of variance in Appendix XII.A, XII.B, XII.C, XII.D, XII.E, XII.F, XII.G, XII.H, XII.I, XII.J, XII.K and XII.L. Data depicted in Table 4.10 clearly showed that in both the years and pooled data nitrogen scheduling significantly affected number of tubers in each grade.

Highest small grade (<25 g) tubers in first year (187 thousand tubers ha^{-1}) was counted with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) which was at par to all other treatments except T_5, T_7, T_8 and T_9, respectively. In second year, it was maximum (190 thousand tubers ha^{-1}) with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP) which was at par to T_3 (173 thousand tubers ha^{-1}) and T_2 (177 thousand tubers ha^{-1}). Pooled analysis over the years showed maximum (180 thousand tubers ha^{-1}) small grade tubers with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) which was at par to all other treatments except T_5, T_7, T_8 and T_9, respectively. The lowest number of small tuber (123, 109 and 116 thousand tubers ha^{-1}, in both the years and pooled data, respectively) was counted with treatment T_5.

Higher number of medium grade (25-50 g) tubers in first year (193 thousand tubers ha^{-1}) and in second year (187 thousand tubers ha^{-1}) was counted with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which, was at par to T_5, T_9 and T_8 (177, 175 and 175 thousand tubers ha^{-1}, respectively) in first year and with T_9,

Table 4.10: Effect of nitrogen scheduling on grade wise number of tubers

Treatments	Grade wise number of tubers ('000 ha^{-1})												Total Tubers ('000 ha^{-1})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	<25g			25-50g			51-75g			>75g					
T_1	169	149	159	193	187	190	168	151	160	152	131	142	682	619	651
T_2	180	170	175	142	132	137	148	137	143	133	119	126	604	557	580
T_3	187	173	180	131	116	124	164	145	154	114	97	105	597	530	564
T_4	168	156	162	161	150	155	136	119	128	123	110	117	588	535	562
T_5	123	109	116	177	157	167	145	131	138	138	127	133	584	524	554
T_6	167	190	178	153	139	146	166	152	159	145	132	138	631	613	622
T_7	138	134	136	158	139	148	165	151	158	140	129	135	601	553	577
T_8	144	138	141	175	154	164	193	209	201	187	145	166	699	646	672
T_9	146	128	137	175	157	166	215	184	200	207	228	218	743	697	720
T_{10}	175	146	161	125	116	120	90	72	81	72	64	68	462	398	430
SEm.±	11	10	8	8	14	8	12	19	12	12	7	7	19	25	18
CD at 5%	33	29	24	23	41	24	36	55	35	37	20	22	55	76	53

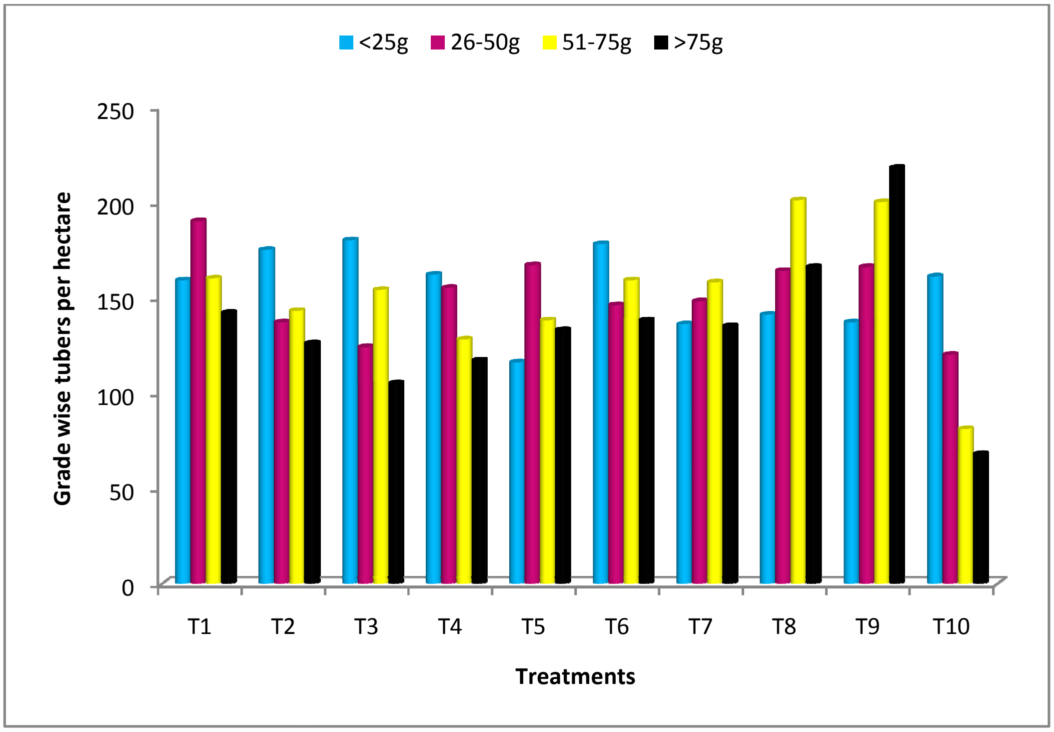

Fig. 4.1: Effect of nitrogen scheduling on grade wise number of tubers

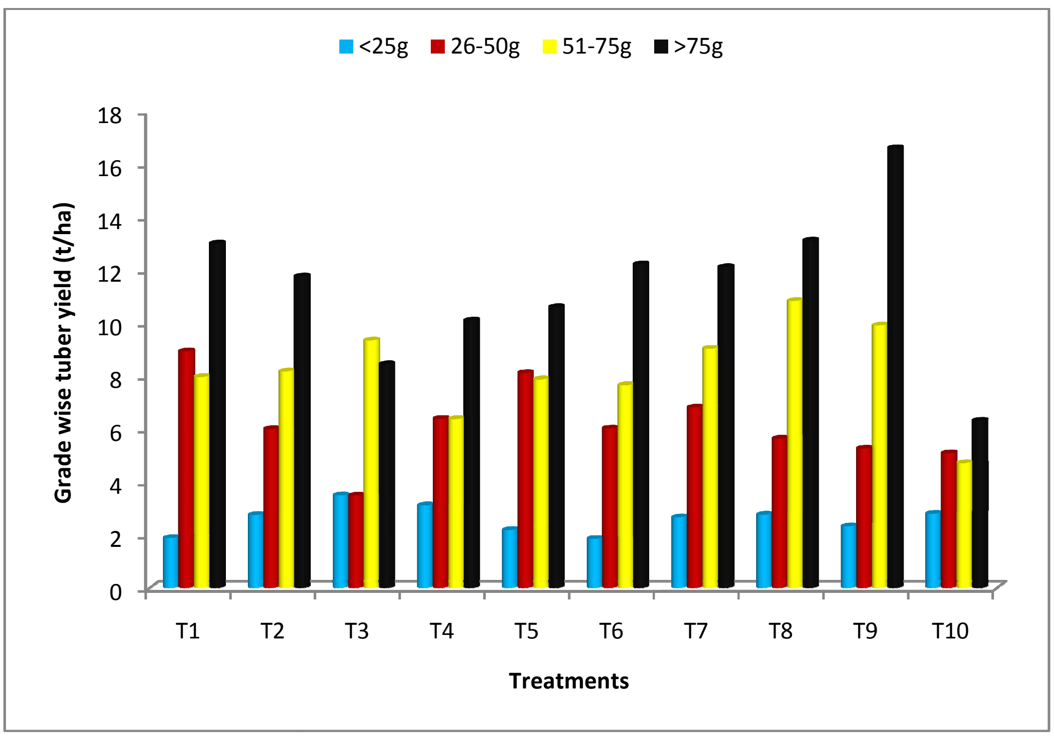

Fig. 4.2: Effect of nitrogen scheduling on grade wise tuber yield

T_5, T_8 and T_4 (157, 157, 154 and 150 thousand tubers ha^{-1}, respectively) in second year. Pooled analysis also showed maximum tubers (190 thousand tubers ha^{-1}) with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) and was at par to treatment T_5 and T_9 (167 and 166 thousand tubers ha^{-1}). The lowest (125, 116 and 120 thousand tubers ha^{-1}, in both the years and pooled data, respectively) was recorded with treatment T_{10} (no application of nitrogen).

Highest number of large grade (51-75 g) tubers in the first year (215 thousand tubers ha^{-1}) was counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). This was significantly at par to T_8 (193 thousand tubers ha^{-1}). However, in second year (209 thousand tubers ha^{-1}) highest was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was statistically similar to treatment T_9 (184 thousand tubers ha^{-1}). Pooled analysis showed maximum tubers (201 thousand tubers ha^{-1}) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was statistically similar with treatments T_9 (200 thousand tubers ha^{-1}). Lowest large grade tubers were recorded with treatment T_{10} (no application of nitrogen) having 90, 72 and 81 thousand tubers ha^{-1}, in both the years and pooled data, respectively. On the basis of pooled data, large grade tubers (51-75) with treatment T_8 were recorded 25.6% higher than recommended one.

The extra large grade tubers (> 75 g) were counted highest (207 and 228 thousand tubers ha^{-1} in first and second year, respectively) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatment T_8 (187 thousand tubers ha^{-1}) in first year and was significantly higher over other treatments in second year. Pooled data showed maximum tubers (218 thousand tubers ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was superior over other treatments. The lowest (72, 64 and 68 thousand tubers ha^{-1}, in both the years and pooled data, respectively) was counted with treatments T_{10} (no application of nitrogen). On the basis of pooled data, extra large grade tubers with treatment T_9 were 53.5% higher than recommended one.

A critical observation of the data (Table 4.10) regarding effect of nitrogen scheduling on grade wise number of tubers per hectare revealed that size of the tubers increased with increase in nitrogen application up to optimum. Nitrogen enhances photosynthetic activity of plants which facilitates more carbohydrate assimilation in tuber consequently bigger size was obtained. Moreover, its deficiency at tuber development stage produced smaller and less large size tubers. It was also observed that the deficiency was not fulfilled by foliar spray at tuber bulking stage. The adequate nitrogen at tuber initiation produced more number of large size tubers. Beside this a supplement foliar spray of urea at later stage increased tuber size which resulted in production of more extra large grade tubers. It might be due to the synchrony between demand and supply of nitrogen which leads to better growth of the plant producing bigger size tubers. Similar to this Kumar (2015) recorded maximum large grade tubers with application of 50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP. Fontes *et al.* (2010) and Casa *et al.* (2005) also reported that nitrogen deficiency at tuberization caused a decrease in size of the tuber.

4.2.4 Total number of tubers per hectare

Data pertaining to number of tubers per hectare with different nitrogen scheduling has shown in Table 4.10 and analysis of variance is given in Appendix XIII.A, XIII.B, XIII.C. A significant effect of all nitrogen scheduling was observed on total number of tubers per hectare.

The highest total number of tubers (743 thousand tubers ha^{-1} in first year and 697 thousand tubers ha^{-1} in second year) was counted with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was statistically at par to treatment T_8 (699 and 646 thousand tubers ha^{-1}) in both the years. Pooled data showed highest tubers (720 thousand tubers ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatment T_8 (672 thousand tubers ha^{-1}). Minimum tubers (462, 398 and 430 thousand tubers ha^{-1} in both the years and pooled data, respectively) were counted with treatment T_{10} (No application of nitrogen). On the basis of pooled data number of tubers per hectare with T_9 was increased by 10.59% over recommended practices.

The results (Table 4.10) indicated that split application (basal + topdress + foliar) of nitrogen gave better response than that of recommended. Nitrogen may increase the sink strength by increasing number of tubers. More number of tubers was might be due to more number of haulms and more nitrogen uptake as recorded with treatment T_9. Similar results were obtained by Sahu *et al.* (2014). Zabihi-e-Mahmoodabad *et al.* (2010) who reported that the number of tubers is increased with increase in number of stolons, number of haulms and nitrogen uptake. Etemad and Sarajuoghi (2012) observed a maximum number of tubers when small amount of nitrogen was applied as basal and rest after earthing up.

4.2.5 Grade wise tuber yield per hectare

Data pertaining to grade wise tuber yield per hectare as influenced by different nitrogen scheduling has shown in Table 4.11, Fig. 4.2 and analysis of variance is given in Appendix XIV.A, XIV.B, XIV.C, XIV.D, XIV.E, XIV.F, XIV.G, XIV.H, XIV.I, XIV.J, XIV.K and XIV.L. Data showed that small grade tuber yields initially not affected by nitrogen scheduling, whereas significant effect was observed on the yield of other grade tubers.

The small grade (<25 g) tuber yield was recorded highest (3.51 t ha^{-1}) with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) and T_4 (50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP) in first year and minimum (1.98 t ha^{-1}) with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP). In second year, it was recorded maximum (3.47 t ha^{-1}) with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) which was at par to all other treatments except T_1, T_5, T_6 and T_9. The minimum (1.62 t ha^{-1}) was recorded with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP). Pooled data showed the highest yield (3.49 t ha^{-1}) with treatment T_3 which was at par to all other treatments except T_1, T_5, T_6 and T_9, whereas the minimum (1.85 t ha^{-1}) was recorded with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP).

Similarly, medium grade (25-50 g) tuber yield per plot in first year (9.78 t ha^{-1}) was recorded maximum with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which, was statistically at par to treatment T_5 (8.04 t ha^{-1}). In the second year, maximum tuber yield (8.18 t ha^{-1}) was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) was at par to all other treatments except treatments T_9, T_{10} and T_3. Pooled data showed maximum medium grade tuber yield (8.93 t ha^{-1}) with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was statistically at par to treatment T_5 (8.11 t ha^{-1}).

Table 4.11: Effect of nitrogen scheduling on grade wise tuber yield

Treatments	Grade wise tuber yield (t ha^{-1})												Tuber yield (t ha^{-1})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
	<25g			25-50g			51-75g			>75g					
T_1	2.15	1.62	1.88	9.78	8.08	8.93	7.69	8.23	7.96	13.72	12.29	13.00	33.33	30.22	31.78
T_2	2.91	2.58	2.75	5.49	6.50	5.99	8.17	8.17	8.17	12.77	10.76	11.76	29.34	28.01	28.68
T_3	3.51	3.47	3.49	3.67	3.29	3.48	9.71	8.98	9.34	9.54	7.34	8.44	26.42	23.08	24.75
T_4	3.51	2.71	3.11	5.92	6.83	6.38	6.62	6.12	6.37	11.02	9.17	10.09	27.07	24.82	25.95
T_5	2.45	1.91	2.18	8.04	8.18	8.11	8.17	7.56	7.87	12.74	8.47	10.60	31.39	26.13	28.76
T_6	1.98	1.73	1.85	5.73	6.31	6.02	8.36	6.94	7.65	13.11	11.32	12.21	29.18	26.29	27.74
T_7	2.79	2.52	2.66	6.92	6.69	6.81	8.96	9.10	9.03	13.14	11.08	12.11	31.81	29.40	30.60
T_8	2.49	3.03	2.76	5.77	5.49	5.63	10.28	11.37	10.83	15.52	10.71	13.11	34.05	30.59	32.33
T_9	2.75	1.89	2.32	5.35	5.18	5.26	11.51	8.28	9.90	17.01	16.18	16.60	36.62	31.53	34.08
T_{10}	2.97	2.63	2.80	4.98	5.18	5.08	4.84	4.57	4.71	7.20	5.41	6.31	20.00	17.79	18.90
SEm.±	0.37	0.35	0.23	0.77	0.90	0.66	0.64	0.55	0.36	0.76	0.67	0.52	1.08	1.28	0.81
CD at 5%	NS	1.07	0.69	2.29	2.68	1.96	1.93	1.66	1.10	2.28	1.99	1.55	3.24	3.84	2.28

The minimum yield was recorded with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) having 3.67, 3.29 and 3.48 t ha^{-1} medium grade tuber yield, in both the years and pooled data, respectively.

The large grade (51-75 g) tuber yield was recorded maximum (11.51 t ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) in first year which was statistically similar with T_8 (10.28 t ha^{-1}) and T_3 (9.71 t ha^{-1}) However, in second year (11.37 t ha^{-1}), the maximum was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was superior over others. Pooled data showed maximum large grade tuber yield (10.83 t ha^{-1}) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP), which, was at par to T_9 (9.90 t ha^{-1}). It was recorded minimum (4.84, 4.57 and 4.71 t ha^{-1} in both the years and pooled data, respectively) with treatment T_{10} (No application of nitrogen). On the basis of pooled data, the yield of large grade tubers with treatment T_8 was 36% more than recommended one.

Extra large grade tuber yield was recorded maximum with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) having 17.01 t ha^{-1} in first years and 16.18 t ha^{-1} in second year, respectively. This was statistically similar with T_8 (15.52 t ha^{-1}) in first year and was significantly higher over all other treatments in second year. Pooled data showed maximum extra large grade tuber yield (16.60 t ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). It was recorded minimum (7.20, 5.41 and 6.31 t ha^{-1} in both the years and pooled data, respectively) with treatment T_{10} (No application of nitrogen). On the basis of pooled data, the yield of this grade tuber with treatment T_9 was 27.6% higher than recommended one.

Pooled analysis over the years revealed that nitrogen deficiency at tuberization produce more small tubers, whereas medium grade tuber yield was recorded maximum with treatments receiving more amount of nitrogen applied as basal. It might be due to the acid effect of urea. On the other hand, large and extra large size tuber yield was found maximum with treatment where adequate amount of nitrogen was applied at tuberization as well as basal. Further a supplementary foliar spray caused more food accumulation in tuber result in more extra large size tuber yield. However, consecutive foliar application could not completely substitute the topdressing due to insufficient N availability. It might be due to application of adequate amount of nitrogen increased carbon uptake and amino acid production resulted in more yield of large and extra large tubers. It may also because of better growth of the plant due to better and efficient use of nitrogen result increase in larger tuber formation. Our findings are in agreement with Kelling *et al*. (2015) who reported that nitrogen application in 3 splits produced more large size tubers than in 2 splits. In a study, Rizk *et al.* (2013) found that foliar application of urea at higher level *i.e.* 3% resulted in more number of average bigger tubers than using the lower urea level.

4.2.6 Total tuber yield per hectare

The effect of nitrogen scheduling with respect to tuber yield per hectare is shown in Table 4.11, Fig. 4.3 and analysis of variance has given in Appendix XV.A, XV.B and XV.C. Data indicated significant effect of nitrogen scheduling on tuber yield per hectare.

Highest tuber yield in first year (36.62 t ha^{-1}) and in second year (31.53 t ha^{-1}) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). This was statistically similar with treatment T_8 (34.05 t) in the first year and in second year with treatments T_8 (30.59 t ha^{-1}), T_1 (30.22 t ha^{-1}), T_7 (29.40 t ha^{-1}) and T_2 (28.01 t ha^{-1}). On the basis of pooled data highest tuber yield (34.08 t ha^{-1}) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was statistically similar with treatment T_8 (32.33 t ha^{-1}). Minimum tuber yield per hectare (20.03, 17.79 and 18.90 t ha^{-1} in both the years and pooled data, respectively) was recorded with treatment T_{10} (no application of nitrogen). On the basis of pooled data tuber yield per hectare with treatment T_9 was increased by 7.23% over recommended practices.

A critical analysis of the pooled data (Table 4.11) indicated that in comparison with other treatments, T_{10} have maximum contribution of small grade tubers (14.8%), and treatment T_5 have maximum contribution (28.2%) of medium grade tubers in total tuber yield per hectare while the contribution of large grade tubers was recorded maximum (37.7%) with treatment T_3 and of extra large grade tubers was with treatment T_9 (48.7%). Treatment T_9 had minimum contribution of small grade tubers (5.9%) and T_3 had minimum (14%) contribution of medium grade tubers. On the other hand, minimum contribution of large grade tubers (24.5%) was recorded with treatment T_4 and of extra large grade tubers with T_{10} (33.3%) in comparison to other treatments.

The data (Table 4.11) indicated that maximum tuber yield was recorded when adequate amount of nitrogen was applied in split form (basal + topdress + foliar) and it could not be replaced by consecutive foliar spray. The period from tuber initiation to mid-tuber bulking is critical for potato plants because of vegetative and storage growth advance together. During this stage, adequate N supplement is necessary to satisfy the demand of N and boost the development of tubers. Plants having more plant height, number of leaves, LAI produced more tuber yield because of more photosynthates formation and their translocation and accumulation to the tuber. It was also due to more number and weight of tubers per plant Badr *et al.* (2012). The result was supported by Getie *et al*. (2015) and Diengdoh *et al.* (2012) who reported that high yield is positively correlated with plant vigor and leaf area index. Al-Moshileh *et al.* (2005) obtained highest potato tuber yield at the rate of 300 kg N ha^{-1} with split into three equal doses applied at 0, 45 and 60 days after planting.

4.2.7 Marketable tuber yield

Data regarding marketable tuber yield as influenced by nitrogen scheduling is presented in Table 4.12, Fig 4.3 and analysis of variance is shown in Appendix XVI.A, XVI.B and XVI.C. The data indicated that nitrogen scheduling differed significantly from each other with respect to marketable tuber yield.

Highest marketable tuber yield (33.87 in first year and 29.64 t ha^{-1} in second year, respectively) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). This was statistically at par to T_8 having 31.57 t ha^{-1} in first year and T_1 (31.19 t ha^{-1}) in second year with T_8 (27.57 t ha^{-1}), T_1 (28.60 t ha^{-1}) and T_7 (26.88 t ha^{-1}). Pooled analysis showed highest marketable tuber yield (31.76 t ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatment T_8 (29.57 t ha^{-1}). The minimum marketable tuber yield (17.03, 15.16 and 16.10 t ha^{-1} in both the year and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen). It was evident from the pooled data that treatment T_9 gave 6.22% higher marketable yield than recommended one.

The results revealed that increase in marketable tuber was due to more yield of medium, large and extra large grade tubers which was produced in split application of nitrogen (basal + topdress or basal + topdress + foliar). However, consecutive foliar spray could not replaced topdressing. The split application of nitrogen dose also gave the highest percentage of soil coverage and marketable tuber yield as reported by Al-Moshileh *et al.* (2015). Our findings are supported by Kumar (2015) who recorded maximum marketable tuber yield per hectare with 50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP.

4.2.8 Harvest index

A perusal of data regarding effect of different nitrogen scheduling on harvest index of potato has given in Table 4.13 and Fig.4.4 and analysis of variance has shown in Appendix XVII.A, XVII.B and XVII.C. It is evident from the data revealed that nitrogen scheduling significantly affected to harvest index.

In the first year, the maximum harvest index (75.1%) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum (59.4%) with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP). In the second year, it was recorded maximum (71.2%) with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which, was statistically similar with treatments T_1 and T_8 (69.1 and 68.5%), respectively. In pooled data maximum (71.2%) HI was recorded with T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_8 (69.4%). It was minimum (60.0 and 60.4%) recorded with T_{10} (No application of nitrogen) in the second year and pooled data, respectively.

Critical observation of the data (Table 4.13) revealed that adequate amount of nitrogen application either through topdress or topdress + foliar spray at tuberization stage gave more harvest index due to the synchrony between N demand and supply rather than basal or later application. In order to get optimum yield, the plant should be kept green during tuber bulking stage to produce carbohydrates, but the plant should senesce near the harvest to promote retranslocation of carbohydrates to tubers from leaves. Sun *et al.* (2012) recorded maximum harvest index in potato with application of N at planting in conjunction with dressing at 20 days after emergence. Kumar (2015) also recorded maximum harvest index when nitrogen applied as basal + topdress+ foliar spray.

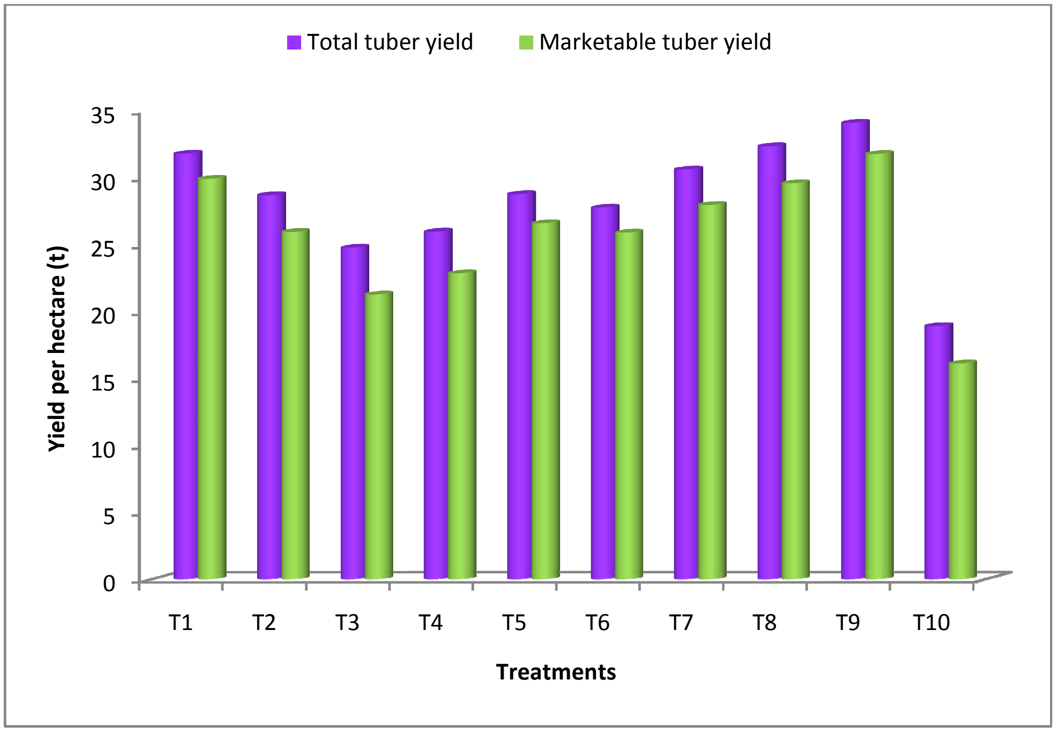

Fig. 4.3: Effect of nitrogen scheduling on total and marketable tuber yield

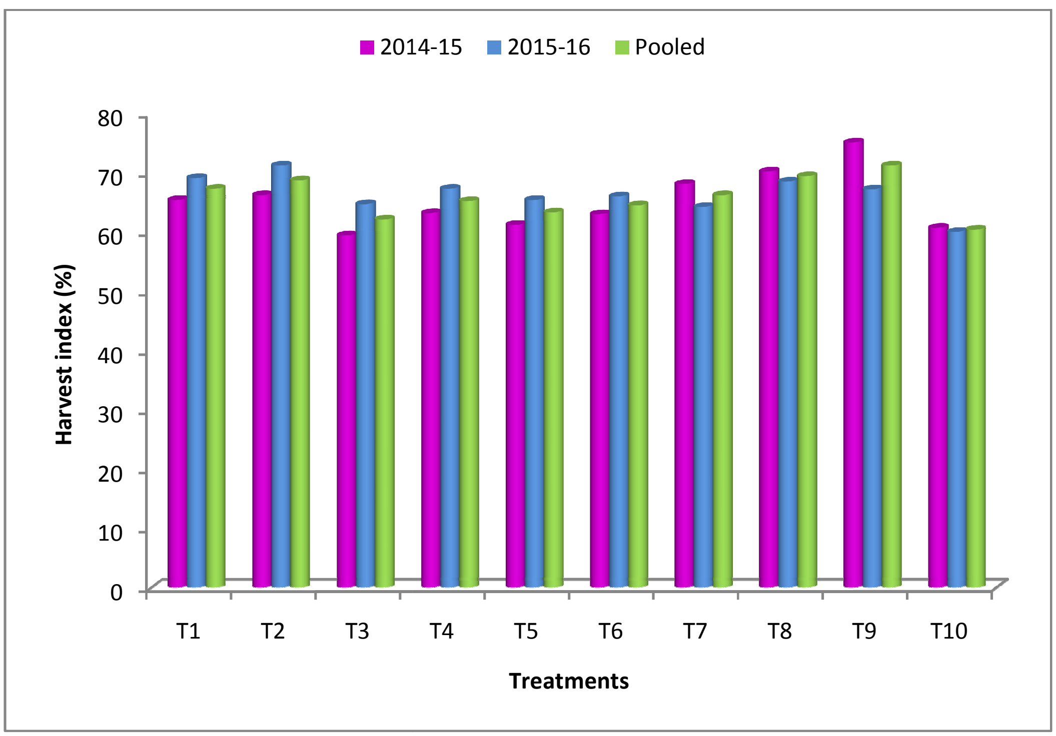

Fig. 4.4: Effect of nitrogen scheduling on harvest index

Table 4.12: Effect of nitrogen scheduling on marketable tuber yield

Treatments	Marketable tuber yield (t per hectare)		
	2014-15	**2015-16**	**Pooled**
T_1	31.19	28.60	29.90
T_2	26.43	25.43	25.93
T_3	22.91	19.61	21.26
T_4	23.56	22.12	22.84
T_5	28.94	24.22	26.58
T_6	27.20	24.57	25.88
T_7	29.02	26.88	27.95
T_8	31.57	27.57	29.57
T_9	33.87	29.64	31.76
T_{10}	17.03	15.16	16.10
SEm.±	1.01	1.26	0.77
CD at 5%	3.04	3.79	2.30

Table 4.13: Effect of nitrogen scheduling on harvest index

Treatments	Harvest index (%)		
	2014-15	**2015-16**	**Pooled**
T_1	65.4	69.1	67.3
T_2	66.2	71.2	68.7
T_3	59.4	64.7	62.1
T_4	63.2	67.3	65.2
T_5	61.2	65.4	63.3
T_6	63.0	66.0	64.5
T_7	68.1	64.2	66.2
T_8	70.2	68.5	69.4
T_9	75.1	67.2	71.2
T_{10}	60.7	60.0	60.4
SEm.±	0.9	1.0	0.7
CD at 5%	2.8	2.9	2.1

4.3 Quality parameters

4.3.1 Dry matter content

The data pertaining to dry matter content of the tuber is presented in Table 4.14, Fig. 4.5 and analysis of variance has shown in Appendix XVIII.A, XVIII.B and XVIII.C. In both the years and pooled data all the treatments significantly affected to dry matter content of the tuber.

Maximum dry matter content of the tuber in first year (19.4%) and in second year (19.3%) was recorded with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP). This was at par to all other treatments except T_5, T_8 and T_9 in first year, whereas in second year, this was at par to T_3 (18.2%), T_6 and T_9 (18%). Pooled analysis over the years also showed maximum dry matter content (19.3%) with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) which was at par to T_3 (18.6%). It was recorded minimum (16.2, 16.9 and 16.5% in both the years and pooled data, respectively) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP).

Critical analysis of data (Table 4.14) indicated that dry matter content was increased with decrease in nitrogen dose (basal + foliar). It might be due to the less concentration of nitrogen in foliar directly absorbed by leaf which promote photosynthesis consequently more dry matter formation. On the other hand, intensive application of nitrogen reduced dry matter content due to interference in carbohydrate assimilation in tuber as in case of T_5 and T_8. Application of optimum dose of nitrogen at appropriate time increased translocation of more photosynthates from source to sink has occurred up to maturity as a result of increased nutrient absorption by plant. Chen and Setter (2012) reported that strong leaf and stem sink capacity before tuber initiation compete with developing tubers for photosynthates which reduce dry matter accumulation in tuber. In contrast Hosseini *et al.* (2017) were observed that at tuberization excessive level of available N stimulates reformation of tubers. It may lead to lengthening of tuberization period and difference in tubers maturity which leads to the difference in dry matter content of tubers. Rizk *et al.* (2013) reported that urea foliar application at higher level, *i.e.* 3% resulted in better dry weight of tuber than using the lower level.

Table 4.14: Effect of nitrogen scheduling on quality parameters

Treatments	Quality parameters											
	Dry matter content (%)			Protein content (%)			Total soluble solids (%)			Specific gravity (g cm^{-3})		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	18.3	17.9	18.2	7.6	7.8	7.6	6.5	6.1	6.3	1.07	1.08	1.07
T_2	18.2	17.9	18	7.4	7.3	7.4	6.3	6.0	6.2	1.08	1.07	1.07
T_3	19.1	18.2	18.6	6.9	6.9	6.9	5.2	5.4	5.3	1.07	1.07	1.07
T_4	18.6	17.9	18.3	6.9	7.1	7.0	5.3	5.0	5.2	1.08	1.09	1.08
T_5	16.2	16.9	16.5	7.7	7.6	7.7	5.1	4.9	5.0	1.06	1.05	1.05
T_6	18.4	18	18.2	7.3	7.1	7.3	5.4	5.1	5.3	1.08	1.08	1.08
T_7	19.4	19.3	19.3	7.2	6.9	7.1	5.3	5.1	5.2	1.09	1.09	1.09
T_8	17.1	16.8	16.9	7.6	7.7	7.6	5.0	4.8	4.9	1.06	1.07	1.06
T_9	17.8	18	17.9	7.3	7.2	7.3	5.0	5.5	5.2	1.07	1.07	1.07
T_{10}	18.5	17.7	18.1	6.6	6.4	6.5	4.0	4.1	4.1	1.09	1.07	1.08
SEm.±	0.4	0.4	0.3	0.2	0.1	0.1	0.1	0.2	0.1	0.02	0.01	0.01
CD at 5%	1.2	1.3	0.9	0.6	0.4	0.4	0.3	0.5	0.3	NS	0.03	0.03

4.3.2 Protein content

The protein content of the tuber as affected by nitrogen treatments has been presented in Table 4.14, Fig. 4.5 and the analysis of variance is given in Appendix XIX.A, XIX.B and XIX.C. The analyzed data indicated that nitrogen treatments significantly influenced the protein content of the tuber.

In the first year, maximum protein content (7.7%) was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to all other treatments except T_4, T_3 and T_{10}. However, in second year, it was maximum (7.8%) with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was at par to T_8 (7.7%) and T_5 (7.6%), respectively. Pooled data showed the maximum protein content (7.7%) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to all other treatments except T_3, T_4, T_7 and T_{10}, respectively. The minimum protein content (6.6, 6.4 and 6.5%) was recorded with the treatment T_{10} (No application of nitrogen).

From the above results, it could be assessed that protein content was increased with increase in nitrogen application. Excess amount of nitrogen leads to increase nitrogen content in tuber consequently more protein formation takes place. The significant effect on protein content could be related to the vital role of nitrogen in the plant that associated directly or indirectly with protein synthesis in tuber as reported by Chandra *et al.* (2014). Trawczynski and Grzeskiewicz (2000) reported that partly application of urea to foliage had no influence on chemical composition of the tubers.

4.3.3 Total soluble solids

Data pertaining to total soluble solids has presented in Table 4.14, Fig. 4.5 and analysis of variance is given in Appendix XX.A, XX.B and XX.C. The data clearly indicates that T.S.S. of the potato tuber was significantly affected by nitrogen scheduling.

The maximum T.S.S. was recorded with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) having 6.5, 6.1 and 6.3% in both the years and pooled data, respectively which, was statistically similar with treatment T_2 (6.3, 6 and 6.2% in both the years ad pooled data, respectively). Minimum was recorded with treatment T_{10}

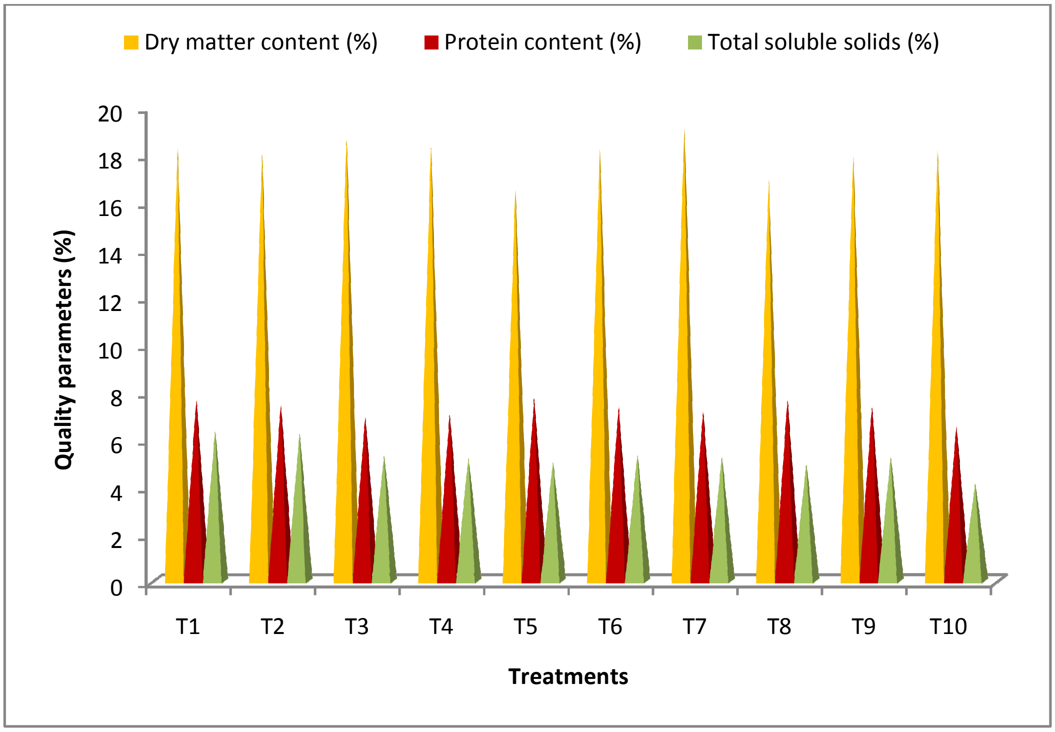

Fig. 4.5: Effect of nitrogen scheduling on dry matter, protein content and total soluble solids

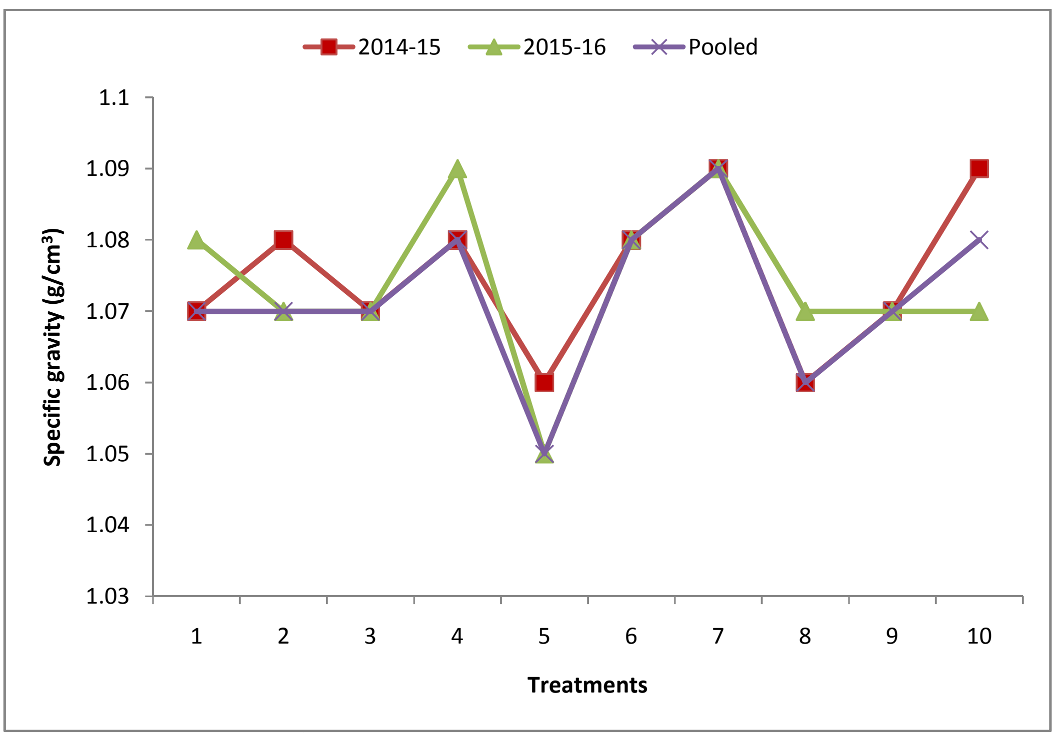

Fig. 4.6: Effect of nitrogen scheduling on specific gravity

(No application of nitrogen) *i.e.* 4, 4.1 and 4.1% in both the years and pooled data, respectively.

The results (Table 4.14) indicated that high total soluble solids in tuber was due to the application of nitrogen as basal + topdress and basal + topdress + spray. It was also increased with high basal dose of nitrogen. Later application of high nitrogen dose reduces T.S.S. content of the tuber. The probable reason of this reduction might be due to consistent increase in water content and turgidity of cells in tubers with increase in nitrogen at later stage (Banu *et al.* 2007). Ayyub *et al.* (2006) also recorded better T.S.S. content in case of initially broadcasted or later on side-dressed nitrogen as compared to full basal dose (broadcasted or side dressed) and foliar application of nitrogen. Jatav *et al.* (2017) recorded increase in T.S.S. content with nitrogen application upto150 kg ha^{-1} and further increase in nitrogen decrease it.

4.3.4 Specific gravity

Data related to effect of different nitrogen treatments on specific gravity has depicted in Table 4.14, Fig. 4.6 and analysis of variance is presented in Appendix XXI.A, XXI.B and XXI.C. It is evident from the Table 4.18 that specific gravity of the tuber did not affect significantly by nitrogen scheduling in the first year. However, in second year and pooled data, the effect was recorded significant.

Maximum specific gravity in first year (1.09 g/cm^3) was recorded with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) and with treatment T_{10} (No application of nitrogen), whereas in second year, it was maximum (1.09 g/cm^3) with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) and treatment T_4 (50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP) which was statistically similar with all other treatments except treatment $T_{5.}$. According to pooled analysis it was maximum (1.09 g/cm^3) with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) which was at par to all others except treatment T_5. The minimum (1.05, 1.06 and 1.05 g/cm^3 in both the years and pooled data) was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP.

Specific gravity is an important quality attribute of potato chips and French fries because it affects the thickness, colour, crispness, oiliness, taste and recovery rate of the product. Maximum specific gravity was recorded with basal + topdress + foliar application of nitrogen. From the results, it is cleared that in contrast to protein content specific gravity of potato is reduced by application of more nitrogen. It might be due to the increase in dry matter content of tuber with decreasing nitrogen dose which enhanced the carbohydrate accumulation in tuber and decreased protein formation resulted in more specific gravity. The findings are in agreement with the findings of Ozturk *et al.* (2010) and Chandra *et al.* (2017). In contrary to this Sharma *et al.* (2015) reported that nitrogen application to foliage reduced specific gravity of the tuber. Davis *et al.* (2014) also reported that high levels of N before or at tuberization can reduce specific gravity.

4.4 Soil analytical parameter

4.4.1 Available nitrogen content in soil at harvest

The data pertaining to available nitrogen content in soil after harvesting of potato crop has been shown in Table 4.15 and analysis of variance is given in Appendix XXII.A, XXII.B and XXII.C. It was significantly varied with different nitrogen scheduling.

In first year, the maximum available nitrogen content (190.95 kg ha^{-1}) in soil was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which, was at par to all other treatments except T_4 (148.46 kg ha^{-1}) and T_{10} (124.58 kg ha^{-1}). In the second year, it was maximum (178.22 kg ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which, was at par to all other treatments except T_3 (137.02 kg ha^{-1}), T_7 (142.25 kg ha^{-1}), T_6 (149.34 kg ha^{-1}) and T_{10} (110. 76 kg ha^{-1}). Pooled data showed maximum available nitrogen in soil (178.45 kg ha^{-1}) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) which was at par to treatments T_5 (172.62 kg ha^{-1}), T_1 (170.47 kg ha^{-1}), T_9 (170.03 kg ha^{-1}) and T_2 (162.01 kg ha^{-1}), respectively. Minimum (124.58, 110.76 and 117.67 kg ha^{-1}, in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

Critical observation of the data (4.15) revealed that soil retained maximum available nitrogen content, where more nitrogen was applied in soil. Our results are in close conformity with results of Mondal *et al.* (2007). Das *et al.* (2015) observed that net gain of soil nitrogen gradually decreased with the increased level of nitrogen application, which was mainly due to increased N-uptake by the crop.

Table 4.15: Effect of nitrogen scheduling on available nitrogen content in soil at harvest

Treatments	Available nitrogen content of soil after harvest (kg per hectare)		
	2014-15	2015-16	Pooled
T_1	182.47	158.47	170.47
T_2	159.26	164.75	162.01
T_3	164.97	137.02	150.99
T_4	148.46	158.16	153.31
T_5	185.08	160.16	172.62
T_6	167.47	149.34	158.41
T_7	171.76	142.25	157.00
T_8	190.95	165.96	178.45
T_9	161.84	178.22	170.03
T_{10}	124.58	110.76	117.67
SEm.±	10.79	9.29	6.05
CD at 5%	32.29	27.80	18.11

Table 4.16: Effect of nitrogen scheduling on nitrogen content in plant and tuber

Treatments	Nitrogen content in plant (%)			Nitrogen content in tuber (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	2.64	2.58	2.61	1.21	1.24	1.22
T_2	2.59	2.64	2.62	1.19	1.17	1.18
T_3	2.48	2.50	2.49	1.10	1.11	1.11
T_4	2.53	2.66	2.59	1.11	1.14	1.12
T_5	2.84	3.03	2.94	1.23	1.22	1.23
T_6	2.55	2.42	2.48	1.17	1.14	1.16
T_7	2.52	2.67	2.60	1.15	1.10	1.13
T_8	2.93	2.79	2.86	1.21	1.23	1.22
T_9	2.89	2.75	2.82	1.17	1.17	1.17
T_{10}	1.94	2.01	1.98	1.06	1.03	1.05
SEm.±	0.06	0.07	0.05	0.02	0.03	0.02
CD at 5%	0.18	0.22	0.14	0.07	0.09	0.06

4.5 Plant analytical parameters

4.5.1 Nitrogen content in plant

Table 4.16 represent the data regarding nitrogen content in plant and analysis of variance is shown by Appendix XXIII.A, XXIII.B and XXIII.C.

The data depicted in Table 4.16 showed that nitrogen content in plant was maximum (2.93%) with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) in the first year which was at par to treatment T_9 (2.89%) and T_5 (2.84%). In second year, it was maximum (3.03%) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was superior over other treatments. Pooled analysis over the years showed maximum nitrogen content in plant (2.94%) with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_8 (2.86%) and T_9 (2.82). Minimum was recorded with treatment T_{10} (No application of nitrogen) having 1.94, 2.01 and 1.98% in both the years and pooled data.

The above results indicated that more nitrogen application in split doses (basal + topdress or basal + topdress + spray) increased nitrogen content in plants especially when applied at later stages. N applied early in the season did not preferentially accumulate in the aboveground tissues or tubers as compared to N applied later in the season but before 60 DAP. An increased N content stimulates the photosynthetic capacity by the elevation of the content of stromal and thylakoid proteins in leaves (Mauromicale *et al.*, 2006). Our results are in accordance with the findings of Rens *et al.* (2016). Quadri *et al.* (2015) reported that foliar nitrogen increased leaf nitrogen content which strengthens source-sink relationship.

4.5.2 Nitrogen content in tuber

The data pertaining to nitrogen content in tuber has depicted in Table 4.16 and analysis of variance is given in Appendix XXIV.A, XXIV.B and XXIV.C. In both the year and pooled data nitrogen scheduling significantly affected the nitrogen content of tuber.

The maximum nitrogen content in tuber in first year (1.23%) was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to all other treatments except T_7, T_4, T_3, and

T_{10}. In second year, it was recorded maximum (1.24%) with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) and was at par to treatments T_8 (1.23%), T_5 (1.22%), T_2 and T_9 (1.17%), respectively. Pooled data showed maximum (1.23%) nitrogen content with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatments T_8, T_1 (1.22%), T_2 (1.18%) and T_9 (1.17%), respectively. The minimum nitrogen content in tuber (1.06, 1.03 and 1.05%, in both the years and pooled data, respectively) was recorded under treatment T_{10} (No application of nitrogen).

It is evident from Table 4.16 that nitrogen content of the tuber was increased with increase in nitrogen dose but up to optimum. Moreover soil applied nitrogen was more responsive rather than foliar spray. It might be due to the reason that N applied at adequate level was found beneficial, since hydrolysis of urea made more nitrogen easily available to the roots which in turned resulted in higher N content in tubers. Similar was reported by Chandra *et al.* (2016). Wadas *et al.* (2005) reported that, with increasing level of nitrogen fertilization, the nitrate content of tuber was increased and higher applications of nitrogen, caused higher nitrate content in tubers, too. Contrary to this, Ciecko *et al.* (2010) reported the highest increment in the total and protein nitrogen content in potato tubers at 10% contribution of foliar nitrogen application.

4.5.3 Nitrogen uptake in plant

The nitrogen uptake by plant as influenced with different nitrogen scheduling has been presented in Table 4.17, Fig. 4.7 and analysis of variance has given in Appendix XXV.A, XXV.B and XXV.C. The analyzed data indicated that nitrogen application methods significantly affected to nitrogen uptake in plant.

Maximum nitrogen uptake in plant during first year (95.49 kg ha^{-1}) and second year (93.73 kg ha^{-1}) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). This was statistically at par to treatment T_8 (90.84 kg ha^{-1}), T_1 (85.87 kg ha^{-1}) and T_6 (80.95 kg ha^{-1}) in first year and in second year with treatments T_8 (88.46 kg ha^{-1}) and T_5 (85.06 kg ha^{-1}). In pooled data it was recorded maximum (94.66 kg ha^{-1}) with T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and was at par to treatment T_8 (89.79 kg ha^{-1}). The minimum was recorded (42.80, 43.18 and 43.15 kg ha^{-1}, both the years and pooled data respectively) with treatment T_{10} (No application of nitrogen).

Table 4.17: Effect of nitrogen scheduling on nitrogen uptake in plant and tuber

Treatments	Nitrogen uptake in plant (kg ha^{-1})			Nitrogen uptake in tuber (kg ha^{-1})			Total nitrogen uptake in plant (kg ha^{-1})		
	2014-15	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**
T_1	85.87	77.99	81.70	77.10	66.04	71.57	162.97	144.03	153.50
T_2	77.05	76.36	76.69	63.33	58.74	61.04	140.38	135.10	137.74
T_3	70.04	72.18	71.26	55.83	46.18	51.00	125.87	118.36	122.11
T_4	71.79	72.99	72.67	56.06	50.36	53.21	127.86	123.35	125.60
T_5	76.08	85.06	80.74	60.00	50.81	55.41	136.09	135.87	135.97
T_6	80.95	73.48	77.22	63.42	54.33	58.87	144.37	127.81	136.09
T_7	79.09	82.45	80.78	70.48	62.81	66.64	149.56	145.25	147.41
T_8	90.84	88.46	89.79	70.43	63.05	66.74	161.27	151.51	156.39
T_9	95.49	93.73	94.66	76.80	66.09	71.45	172.28	159.83	166.06
T_{10}	42.80	43.18	43.15	39.01	32.21	35.61	81.81	75.39	78.59
SEm.±	5.15	3.64	3.51	3.19	3.29	2.08	5.69	4.15	3.62
CD at 5%	15.41	10.89	10.50	9.55	9.85	6.22	17.04	12.43	10.84

From the above results it is cleared that split application of nitrogen at tuber initiation and bulking period lead to high nitrogen uptake in plant. The variation in nitrogen uptake in plant is due to the variation in dry weight of the plant which was maximum with treatment T_9 and T_8 so showed high nitrogen uptake. This was supported by Chandra (2015) who reported high nitrogen uptake is due to high dry matter yield. High nitrogen content in plants at higher level of nitrogen application together with higher dry matter production resulted in higher nutrient uptake (Singh and Lal, 2012).

4.5.4 Nitrogen uptake in tuber

The data pertaining to nitrogen uptake in potato tuber has been presented in Table 4.17, Fig. 4.7 and analysis of variance is shown in Appendix XXVI.A, XXVI.B and XXVI.C. It is evident from the Table 4.17 that nitrogen scheduling significantly affected the nitrogen uptake in tuber.

In first year, maximum nitrogen uptake in tuber (77.10 kg ha^{-1}) was recorded with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was at par to treatments T_9 (76.80 kg ha^{-1}), T_7 (70.48 kg ha^{-1}) and T_8 (70.43 kg ha^{-1}), respectively. In second year, it was recorded maximum (66.09 kg ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_1 (66.04 kg ha^{-1}), T_8 (63.05 kg ha^{-1}), T_7 (62.81 kg ha^{-1}) and T_2 (58.74 kg ha^{-1}), respectively. Pooled analysis over experimental years showed maximum nitrogen uptake in tuber (71.57 kg ha^{-1}) with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) which was at par to treatments T_9 (71.45 kg ha^{-1}), T_8 (66.74 kg ha^{-1}) and T_7 (66.64 kg ha^{-1}). Minimum nitrogen uptake in tuber (39.01, 32.21 and 35.61 kg ha^{-1} in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

Nitrogen uptake in tuber depends upon both nitrogen and dry matter content in tuber. Though treatment T_7 had high dry matter in tuber but due to low nitrogen content it showed less N uptake. In contrast treatment T_5 had high nitrogen content in tuber but due to less dry matter it also showed low N uptake. However, both the attributes are better with treatment T_1 so showed more N uptake in tuber. It might be due to synchrony between demand and supply of optimum amount of nitrogen. It observed that foliar application of nitrogen at tuber initiation and bulking stage increased dry matter content in tuber which ultimately increased nitrogen uptake. In contrast, Kelling *et al.* (2015) reported that application timing did not affect to nitrogen uptake in tuber. The uptake of urea is faster when it was sprayed on the leaves, but was cheaper to apply it to the soil as reported by Rizk *et al.* (2013).

4.5.5 Total nitrogen uptake in plant

The data regarding effect of nitrogen scheduling on total nitrogen uptake in plant is depicted in Table 4.17, Fig. 4.7 and analysis of variance is shown in Appendix XXVII.A, XXVII.B and XXVII.C. The data indicated that total nitrogen uptake in plant was significantly influenced by nitrogen application methods.

Table 4.17 indicated that maximum total nitrogen uptake in first year (172.28 kg ha^{-1}) and in second year (159.83 kg ha^{-1}) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which, was statistically at par to T_1 (162.97 kg ha^{-1}) and T_8 (161.27 kg ha^{-1}) in first year and in second year with treatment T_8 (151.51 kg ha^{-1}). Pooled data revealed maximum (166.06 kg ha^{-1}) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and was at par to treatment T_8 (156.39 kg ha^{-1}). Minimum (81.81, 75.39 and 78.59 kg ha^{-1} in both the years and pooled data, respectively) was recorded with treatment T_{10} (No application of nitrogen).

Treatments having more nitrogen uptake in plant as well as in tuber showed high total nitrogen uptake in plant as in case of T_9. Nitrogen applied at adequate amount and at proper time was found to be beneficial since it facilitates more production of photosynthates and dry matter yield which leads to high total nitrogen uptake in plant. The study revealed that treatments having split application of nitrogen showed more nitrogen uptake rather than recommended and control. In a study Zotarelli *et al.* (2015) reported maximum daily N uptake by potato crop between 55 and 60 DAP coinciding with onset of tuber bulking stage.

4.5.6 Nitrogen use efficiency

Effect of nitrogen scheduling on nitrogen use efficiency of potato has been presented in Table 4.18, Fig. 4.8 and analysis of variance is given in Appendix XXVIII.A, XXVIII.B and XXVIII.C. It was indicated from the data that nitrogen scheduling significantly affected nitrogen use efficiency of potato.

Table 4.18: Effect of nitrogen scheduling on nitrogen use efficiency and nitrogen apparent recovery

Treatments	Nitrogen use efficiency (%)			Nitrogen apparent recovery (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1	84.9	77.7	81.3	49.7	42.9	46.3
T_2	71.8	78.7	75.2	43.8	45.9	44.9
T_3	91.6	75.6	83.6	60.6	61.4	61.0
T_4	70.7	70.4	70.5	44.4	48.0	46.2
T_5	65.1	47.7	56.4	30.1	34.6	32.3
T_6	75.5	68.0	71.8	48.7	41.9	45.3
T_7	107.3	105.6	106.4	60.1	63.5	61.8
T_8	87.4	80.1	83.7	48.6	47.6	48.1
T_9	123.1	101.8	112.5	65.8	62.5	64.2
T_{10}	-	-	-	-	-	-
SEm.±	10.7	10.4	7.6	4.5	3.2	3.1
CD at 5%	32.3	31.4	22.9	13.4	9.5	9.2

In first year, the maximum nitrogen use efficiency (123.1%) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to treatment T_7 (107.3%) and T_3 (91.6%). In the second year, the maximum (105.6%) was recorded with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) which, was at par to all the treatments except T_4, T_6 and T_5. According to pooled data, the maximum nitrogen use efficiency (112.5%) was with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_7 (106.4%). It was minimum (65.1, 47.7 and 56.4%, in both the years and pooled data) recorded with T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP).

Nitrogen use efficiency indicates how much kg of tubers is produced by applying per kg of nitrogen. Inadequate and improper application of nitrogen leads to low NUE due to volatilization, leaching and fixation as with treatment T_5. Obtained findings revealed that nitrogen use efficiency increased with the split application of (basal + topdressing + foliar spray) nitrogen. It was due to the synchrony between nitrogen supply and plant nitrogen demand. Jamaati *et al.* (2010) reported that dividing total nitrogen dose into two or more applications would assist in enhancing nutrient efficiency, promote optimum yield, and mitigate the losses of nutrients. According to Peter *et al.* (2015) split nitrogen applications between pre-plant and in-season increase nitrogen use efficiency and simultaneously minimize leaching by preventing excess availability. Rens *et al.* (2016) reported 11% nitrogen use efficiency for the pre-plant application, while 62% in case of application at emergence and tuber initiation stages.

4.5.7 Nitrogen apparent recovery

The data related to apparent nitrogen recovery is depicted in Table 4.18, Fig. 4.8 and analysis of variance is presented in Appendix XXIX.A, XXIX.B and XXIX.C which clearly indicated that nitrogen apparent recovery was significantly affected by different nitrogen scheduling.

Similarly, maximum nitrogen apparent recovery (65.8%) in first year was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which, was statistically similar to T_3 (60.6%) and T_7 (60.1%), respectively. In second year, it was recorded maximum (63.5%) with

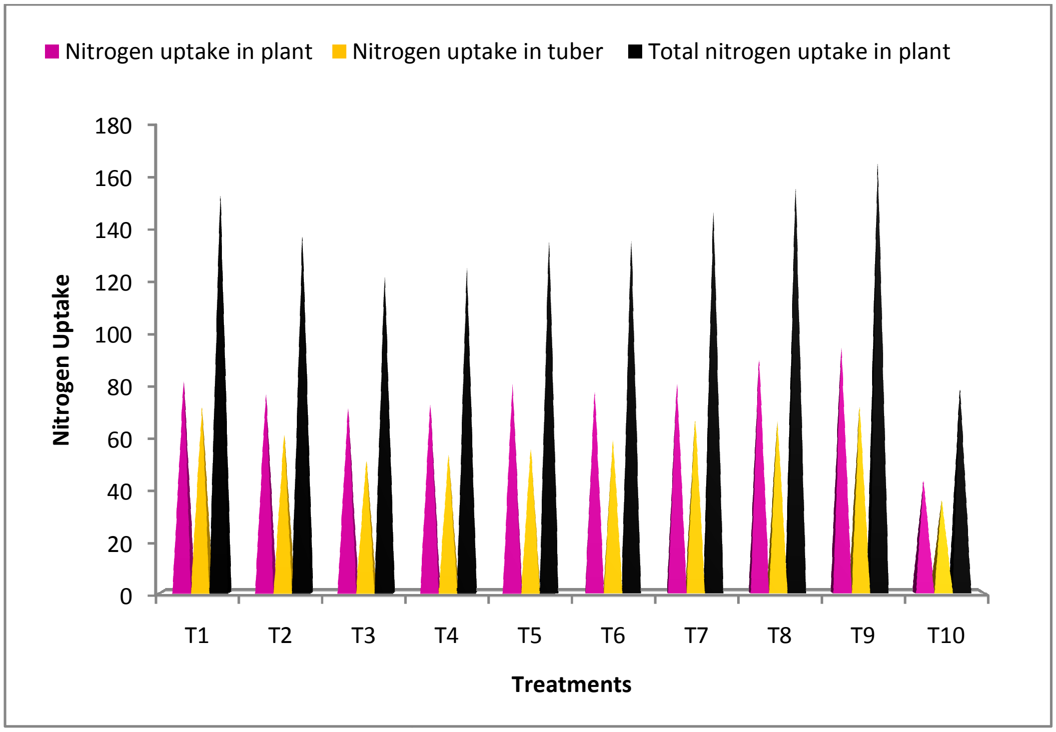

Fig. 4.7: Effect of nitrogen scheduling on nitrogen uptake in plant, in tuber and total nitrogen uptake

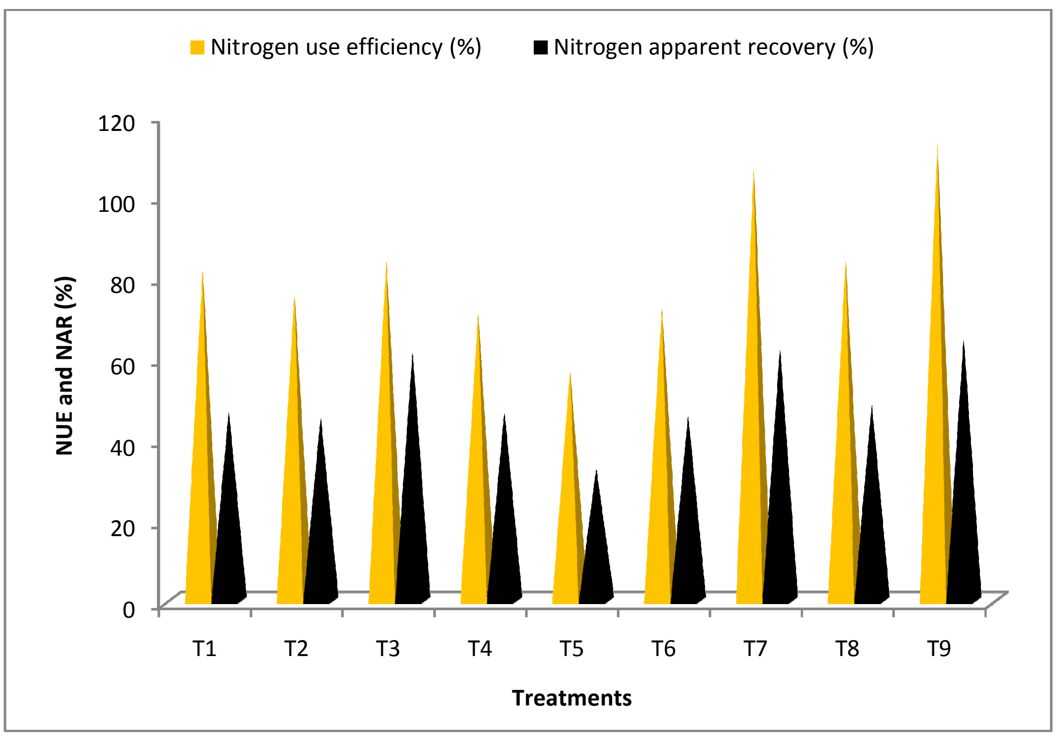

Fig. 4.8: Effect of nitrogen scheduling on nitrogen use efficiency and nitrogen apparent recovery

treatment T_7 and was at par to T_9 (62.5%) and T_3 (61.4%). Pooled analysis over the years showed maximum nitrogen apparent recovery (64.2%) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was at par to T_7 (61.8%) and T_3 (61%), respectively. Minimum (30.1, 34.6 and 32.3%) was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 dap + one foliar spray of urea @ 3% at 40 DAP).

Nitrogen apparent recovery depends upon total nitrogen uptake by plant and applied dose of nitrogen. More uptake relative to less nitrogen application leads to high apparent recovery as observed with treatments $T_{9,}$ T_7 and T_3. It was also observed that split application of nitrogen enhances nitrogen apparent recovery. It might also due to efficient nitrogen uptake with treatment with basal + topdressing + foliar spray as reported by Kumar (2015). Mustonen *et al.* (2010) also recorded that the fertilizer recovery in tubers clearly declined with increase in nitrogen supply. Jindong *et al.* (2007) stated that if the amount of applied N fertilizer is greater than the field capacity, the excessive N fertilizer leaches to underground waters, which is harmful to ecosystems. Therefore, the recommendations regarding fertilizer type, level and method of application for a crop and field must be based on genuine and delicate experiments.

4.6 Economics

4.6.1 Cost of cultivation

The cost of cultivation (total expenditure) was worked out for each treatment, based on prevalent wages, rates of critical inputs and average selling price of the produce during *rabi* season of 2014-15 and 2015-16. The data regarding economics of potato in respect to different scheduling depicted in Table 4.19 and 4.20 and general cost of cultivation has given in Appendix XXX. It was evident from the Table 4.19 and 4.20 that different nitrogen scheduling was differed in their economics.

In 2014-15 and 2015-16 the highest production cost of ₹129936.00 and ₹ 127860.00 per hectare was worked out with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) having ₹ 128316.00 and ₹ 126908.00 per hectare. The minimum production cost (₹118845.00 and ₹117943.00) was worked out with treatment T_{10} (No application of nitrogen).

Table 4.19: Potato economics per hectare as influenced by nitrogen scheduling in 2014-15

Treatments	General cost of cultivation (₹)	Additional cost of nitrogen application (₹)	Additional cost of bags (₹)	Total expenditure (₹)	Tuber yield (t ha^{-1})	Gross income (₹)	Net profit ha^{-1} (₹)	B-C ratio
T_1	110685.00	3739.00	13332.00	128023.00	33.33	199980.00	71957.00	1.56
T_2	110685.00	4248.00	11736.00	126904.00	29.34	176040.00	49136.00	1.39
T_3	110685.00	4386.00	10568.00	125850.00	26.42	158520.00	32670.00	1.26
T_4	110685.00	3877.00	10828.00	125606.00	27.07	162420.00	36814.00	1.29
T_5	110685.00	4805.00	12556.00	128297.00	31.39	188340.00	60043.00	1.47
T_6	110685.00	5066.00	11672.00	127657.00	29.18	175080.00	47423.00	1.37
T_7	110685.00	4001.00	12724.00	127664.00	31.81	190860.00	63196.00	1.50
T_8	110685.00	3739.00	13620.00	128316.00	34.05	204300.00	75984.00	1.59
T_9	110685.00	4310.00	14648.00	129936.00	36.62	219720.00	89784.00	1.69
T_{10}	110685.00	-	8000.00	118845.00	20.00	120000.00	1155.00	1.01

Sale price of potato: Rs. 6000/t

Table 4.20: Potato economics per hectare as influenced by nitrogen scheduling in 2015-16

Treatments	General cost of cultivation (₹)	Additional cost of nitrogen application (₹)	Additional cost of bags (₹)	Total expenditure (₹)	Tuber yield (t ha^{-1})	Gross income (₹)	Net profit ha^{-1}	B-C ratio
T_1	110685.00	3739.00	12331.00	126755.00	30.22	181337.00	54582.00	1.43
T_2	110685.00	4248.00	11430.00	126363.00	28.01	168082.00	41719.00	1.33
T_3	110685.00	4386.00	9418.00	124489.00	23.08	138498.00	14010.00	1.11
T_4	110685.00	3877.00	10128.00	124690.00	24.82	148947.00	24256.00	1.19
T_5	110685.00	4805.00	10662.00	126151.00	26.13	156789.00	30637.00	1.24
T_6	110685.00	5066.00	10727.00	126478.00	26.29	157748.00	31270.00	1.25
T_7	110685.00	4001.00	11995.00	126681.00	29.40	176404.00	49723.00	1.39
T_8	110685.00	3739.00	12484.00	126908.00	30.60	183584.00	56676.00	1.45
T_9	110685.00	4310.00	12865.00	127860.00	31.53	189195.00	61335.00	1.48
T_{10}	110685.00	-	7258.00	117943.00	17.79	106737.00	-11206.00	0.90

Sale price of potato: Rs. 6000/t

4.6.2 Total output (gross income)

The highest gross income in 2014-15 and 2015-16 of ₹ 219720.00 ha^{-1} and ₹ 189195.00 ha^{-1} was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) having total output of ₹ 204300.00 and ₹ 183584.00. The lowest gross income (₹ 120000.00 and ₹ 106737.00) was recorded with treatment T_{10} (No application of nitrogen).

4.6.3 Net profit

The net profit was obtained by subtracting gross income from total expenditure. In both the year the net profit per hectare was recorded conspicuously higher (₹ 89784.00 and ₹ 61335.00) with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) with net profit of ₹ 75984.00 and ₹ 56676.00. The minimum net profit (₹ 1155.00) was recorded with T_{10}, whereas a loss of ₹ 11206.00 was recorded in 2015-16 with this treatment.

4.6.4 Benefit-cost ratio

The B-C ratio is an indication of production efficiency of the treatment. It gives the value of rupees gained in production system by per invested. According to data given in Table 4.19 and Table 4.20, the highest B-C ratio (1.69 and 1.48 in both the year, respectively) was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) having 1.59 and 1.45. The lowest B-C ratio (1.01 and 0.90 in both the year, respectively) was recorded with treatment T_{10} (No application of nitrogen). Kumar (2015) was recorded maximum net return and B-C ratio with 50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP. Chadha *et al.* (2006) were recorded maximum B-C ratio (1.98) with highest net return of ₹ 72060 with 120 kg nitrogen applied in four splits. Love *et al.* (2005) recorded a trend for greater profitability for Summit Russet potato when the majority of N was applied during tuber bulking.

Growth of the plants at 60 DAP under treatment T10 (No application of nitrogen)

Growth of the plants at 60 DAP under treatment T1
(50% N of RDF as basal + 50% top dressing at 25 DAP)

Growth of the plants at 60 DAP under treatment T9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP)

Tuber yield per plot under treatment T10: (No application of nitrogen)

Tuber yield per plot under treatment T1: 50% N of RDF as basal + 50% top dressing at 25 DAP

Tuber yield per plot under treatment T9: 25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP

Summary and Conclusions

Chapter 5 SUMMARY AND CONCLUSION

The present investigation entitled "**Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L)**" was conducted at Vegetable Research Center of GBPUA & T, Pantanagar, U. S. Nagar, Uttarakhand, during the *rabi* season of 2014-15 and 2015-16. Based on pooled analysis the salient findings obtained during the course of investigation have been summarized as follows.

1. Nitrogen scheduling did not show any significant variation for plant emergence recorded at 20 and 30 DAP. However, maximum emergence per cent at 20 DAP was recorded with treatment T_{10} (No application of nitrogen) and minimum with treatment T_4 (50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP). At 30 days after planting, maximum emergence per cent was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP).

2. Significant effect of nitrogen scheduling on plant height was recorded at all the growth stages (45, 60 DAP and at de-haulming) of the crop except at 30 days after planting. Maximum plant height at 30 days after planting was recorded with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP), at 45 days after planting with treatment T_9 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP), at 60 days after planting with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) and finally at de-haulming stage it was recorded maximum with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). The minimum plant height was recorded with treatment T_{10} (No application of nitrogen).

3. Nitrogen scheduling did not affect the number of haulms per plant at all the growth stages. However, at 30 days after planting the highest number of haulms per plant (5) was counted in treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) whereas, at 45

DAP most of the treatments were showing 5 number of haulm per plant. At 60 days after planting all the treatments were showing 5 number of haulm per plant except treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which showed maximum number of haulm per plant and T_{10} (No application of nitrogen) in which minimum haulms per plant was recorded. Finally at de-haulming stage maximum number of haulm (6) was recorded with treatments T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). 5 haulms per plant were recorded in rest of the treatments.

4. Significant difference among nitrogen scheduling was observed with respect to leaves per plant. Maximum number of leaves per plant at all the intervals was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) except at 30 DAP where it was recorded maximum with treatment $T_{8.}$ It was counted minimum with treatment T_{10} (no application of nitrogen).

5. Diameter of haulm was significantly varied with nitrogen application methods at all the stages except 45 DAP. At 30 days after planting maximum diameter of haulm was recorded with treatment T_6 (50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP), at 45 and 60 days after planting it was with treatment T_2 (50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) and at de-haulming stage maximum haulm diameter was recorded with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP). The minimum haulm diameter was recorded with treatment T_{10} (No application of nitrogen) at all the growth stages.

6. Significant effect of all the nitrogen treatments on dry weight per plant was recorded at all the stages. The maximum dry weight per plant at all the intervals was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). Whereas, the minimum dry weight of the plant was recorded with treatment T_{10} (No application of nitrogen).

7. All the treatments were significantly varied with respect to the leaf area index. The maximum leaf area index before de-haulming was recorded with treatment T_1 (50%

N of RDF as basal + 50% top dressing at 25 DAP) whereas, the minimum leaf area index was recorded under treatment T_{10} (No application of nitrogen).

8. Chlorophyll content of the leaves was estimated before de-haulming. It was observed that all the nitrogen treatments significantly influenced leaf chlorophyll content. Maximum chlorophyll ‘a' and ‘b' content was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP). However, minimum with treatment T_{10} (No application of nitrogen).

9. Number of tubers per plant was significantly affected by all nitrogen treatments except 45 days after planting. At 30 days after planting the maximum number of tubers per plant (5, 6 and 6) was counted with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and in rest of the stages with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). The minimum number of tubers at all the stages was counted with treatment T_{10} (No application of nitrogen).

10. Similarly, all the treatments were significantly affected the fresh weight of tubers per plant at all the stages except at 45days after planting. Maximum fresh weight of tubers per plant at all the growth stages was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). However, minimum was recorded at 30 days after planting with treatment T_{10} (No application of nitrogen) and T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP), at 45days after planting with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) and in rest of the stags with treatment T_{10} (No application of nitrogen).

11. The maximum leaf area index was recorded with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP). The minimum LAI 2.7, 2.3 and 2.5 was recorded under treatment T_{10} (No application of nitrogen).

12. Significant effect of the nitrogen scheduling was recorded on grade wise number of tubers per hectare. Maximum small grade (0- 25 g) tubers was counted with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP), while maximum medium grade (26-50 g) tubers per hectare was counted with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP). Large grade tubers (51-75 g) was counted maximum with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and extra

large grade tubers was with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). Treatment T_8 was recorded 25.6% more number of large size tubers and treatment T_9 recorded 53.5% more number of extra large size tubers than recommended one.

13. Nitrogen scheduling significantly affected total number of tubers per hectare. It was recorded highest with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was 10.59% higher over recommended one. The lowest number of tubers per hectare was counted with the treatment T_{10} (no application of nitrogen).

14. Significant variation was recorded among different nitrogen scheduling with respect to grade wise yield per hectare. It was recorded maximum with treatment T_3 (25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP) for small grade and with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) for medium grade tubers. For large grade tuber yield treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) recorded maximum having 36% more tuber yield than recommended one, while for extra large grade tuber yield treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) was recorded maximum with 27.6% more yield than recommended practices.

15. Highest total tuber yield and marketable tuber yield was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by treatment T_8. Tuber yield per hectare of treatment T_9 was 7.23% higher over recommended practices. Minimum tuber yield was recorded with treatment T_{10} (no application of nitrogen).

16. In all the treatments small grade tubers contributes minimum in yield. However, in comparison to other treatments, treatment T_{10} have maximum contribution of small grade tubers (14.8%) and treatment T_5 have maximum contribution (28.2%) of medium grade tubers in total tuber yield per hectare while the contribution of large grade tubers was recorded maximum (37.7%) with treatment T_3 and of extra large grade tubers was with treatment T_9 (48.7%). On the other hand treatment T_9 had minimum contribution of small grade tubers (5.9%), T_3 had minimum (14%) contribution of medium grade tubers while

minimum contribution of large grade tubers (24.5%) was recorded with treatment T_4 and of extra large grade tubers with T_{10} (33.3%), respectively in comparison to other treatments.

17. The effect of nitrogen scheduling on harvest index was found significant and recorded maximum with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum with treatment T_{10} (No application of nitrogen). Treatment T_9 had 3.12% and 14.90% more harvest index over recommended and control.

18. All the treatments significantly affected to dry matter content of the tuber which was decreased with increase in nitrogen dose. It was recorded maximum with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) and was recorded minimum with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP).

19. In contrast protein content was increased with increase in nitrogen dose. It was significantly affected with different nitrogen scheduling. Maximum protein content was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum with treatment T_{10} (No application of nitrogen).

20. Significant effect of nitrogen scheduling on total soluble solids of tuber was recorded in the experiment. It was recorded maximum with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) and minimum with treatment T_{10} (No application of nitrogen).

21. Impact of nitrogen treatments on specific gravity of tuber was recorded maximum with treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP). Minimum specific gravity was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP).

22. Maximum available nitrogen content in soil after harvest was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) and minimum was recorded with treatment T_{10} (No application of nitrogen).

23. Nitrogen treatments showed a positive effect on nitrogen content of plant and was recorded highest with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). The lowest was recorded with treatment T_{10} (No application of nitrogen).

24. Similarly, maximum nitrogen content in tuber was recorded with treatment T_5 (50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and minimum with treatment T_{10} (No application of nitrogen).

25. The nitrogen uptake by plant was significantly varied with different nitrogen scheduling and was recorded highest with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP). The minimum was recorded with treatment T_{10} (No application of nitrogen).

26. The difference among nitrogen treatments with respect to nitrogen uptake in tuber was found significant and recorded maximum with treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) and minimum with treatment T_{10} (No application of nitrogen).

27. Different nitrogen scheduling showed a positive effect on total nitrogen uptake by plant and observed maximum with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP). The minimum was recorded with treatment T_{10} (No application of nitrogen).

28. Among different treatments, nitrogen use efficiency was ranged from 56.4% to 112.5% which was recorded highest with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) and lowest with treatment T_{10} (No application of nitrogen).

29. Similarly, maximum nitrogen apparent recovery was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP). It was recorded minimum with treatment T_{10}.

30. With respect to economics, treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) had maximum production cost of ` 129936.00 and ₹ 127860.00 per hectare in 2014-15 and 2015-16, respectively. The minimum production cost of ₹ 118845.00 and ₹ 117943.00 was recorded with treatment T_{10} (No application of nitrogen) in first and second year, respectively.

31. The highest gross income in 2014-15 and 2015-16 of ₹ 219720.00 ha^{-1} and ₹ 189195.00 ha^{-1} was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) followed by treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) having total output of ₹ 204300.00 ha^{-1} in 2014-15 and ₹ 183584.00 ha^{-1} in 2015-16. The lowest gross income (₹ 120000.00 ha^{-1} and ₹ 106737.00 ha^{-1}) was recorded with treatment T_{10} (No application of nitrogen).

32. The highest net profit of ₹ 89784.00 ha^{-1} and ₹ 61335.00 ha^{-1} in 2014-15 and 2015-16 among different nitrogen scheduling was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) which was 24.77% (in 2014-15) and 12.37% (in 2015-16) higher than recommended practice. The second highest treatment was T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) having ₹ 75984.00 and ₹ 56676.00 net profit in 2014-15 and 2015-16, respectively.

33. Similarly, the highest B-C ratio was recorded with treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) having 1.69 and 1.48 B-C ratio in first and second year, respectively. The second highest B-C ratio was recorded with treatment T_8 (25% N of RDF as basal + 75% top dressing at 25 DAP) having 1.59 and 1.45 in first and second year, respectively.

Based on the findings of present investigation, it could be concluded that treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) proved best with respect to growth, yield and economics which is the primary objective of farmers. This treatment not only recorded 7.23% more yield over the recommended treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) but also saved 15% nitrogen. Because the nitrogen use efficiency and nitrogen apparent recovery was better, the loss of valuable nitrogen to the environment is also minimized. On the other hand, with respect to quality, treatment T_7 considered best with high dry matter content and maximum specific gravity as required for processing industry. Hence on the basis of present investigation treatment T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) can be recommended to get maximum yield and net profit whereas, treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) can be recommended for quality potato production.

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Appendices

Appendix-I.A

Weekly weather data during the crop season of potato 2014-15

Week no. and Month	Date with duration	Temperature (°C)		Humidity (%)		Rainfall (mm)	Sun Shine (Hours)	Pan Evp. (mm)
		Max.	Min.	Max.	Min.			
43 Oct	22-28	30.9	16.6	91	55	0	37.1	2.5
44 Oct.-Nov.	29-04	28.5	13.1	91	46	0	30.1	2.6
45 Nov.	05-11	29.2	12.8	93	46	0	57.4	2.5
46 Nov.	12-18	27.9	9.5	93	34	0	53.9	2.9
47 Nov.	19-25	26.3	8.6	93	38	0	56.0	2.4
48 Nov.-Dec.	26-02 D	26.2	8.7	95	41	0	55.3	2.3
49 Dec.	03-09	24.3	9.9	97	49	0	34.3	1.8
50 Dec.	10-16	20.8	8.2	97	57	040.1	30.1	2.1
51 Dec.	17-23	16.8	7.4	97	78	0	28.7	1.2
52 Dec.	24-31	18.5	4.9	97	57	0	36.4	1.1
1 Jan.	01-07 J	19.1	11.5	94	77	021.8	19.6	1.4
2 Jan.	08-14	15.7	8.4	95	75	0	21.0	0.8
3 Jan.	15-21	15.8	8.1	97	71	0	17.5	1.2
4 Jan.	22-28	18.4	8.6	97	75	011.0	25.2	1.2
5 Jan.-Feb.	29-04 F	18.4	8.1	97	62	0	32.9	1.5

Appendix-I.B

Weekly weather data during the crop season of potato 2015-16

Week no. and Month	**Date with duration**	**Temperature (^oC)**		**Humidity (%)**		**Rainfall (mm)**	**Sun Shine (Hours)**	**Pan Evp. (mm)**
		Max.	**Min.**	**Max.**	**Min.**			
43 Oct	19-25	33.0	12.5	85	47	0	50.0	2.8
44 Oct-Nov.	26-1 N	32	13.8	91	42	0	44.9	2.3
45 Nov.	2-8	31.1	10.9	91	31	0	48.5	1.9
46 Nov.	9-15	27.6	10.9	94	38	20.0	54.1	2.4
47 Nov.	16-22	30.0	9.9	92	37	0	54.3	1.8
48 Nov	23-29	27.4	10.4	92	39	0	27.9	1.6
49 Nov.-Dec.	30-6 D	28.5	9.8	94	38	0	28.4	2
50 Dec.	7-13	26.2	9.4	91	38	Trace	10.1	1.3
51 Dec.	14-20	21.5	3.4	96	49	0	23.3	1.4
52 Dec.	12-27	21.5	2.8	95	46	0	46.2	1.6
53 Dec.-Jan	28-3 J	25	4.4	93	31	0	43.1	1.4
1 Jan.	4-10	25	4.9	95	35	0	31.6	1.1
2 Jan.	11-17	22.4	6.4	95	47	0	20.8	1
3 Jan.	18-24	20.8	3.4	95	45	0	18.3	1.9
4 Jan.	24-31	21.7	2.7	88	39	Trace	27.8	1

Appendix- II.A

Analysis of variance (ANOVA) of emergence per cent of potato at 20 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1,325.749	662.871	4.879	
Treatment	9	1,171.768	130.196	0.958	NS
Error	18	2,445.292	135.850		
Total	29	4,942.809			

Appendix- II.B

Analysis of variance (ANOVA) of emergence per cent of potato at 20 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	178.625	89.303	2.036	
Treatment	9	431.553	47.950	1.094	NS
Error	18	789.126	43.840		
Total	29	1,399.305			

Appendix- II.C

Pooled analysis of variance (ANOVA) of emergence per cent of potato

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	136.018	68.009	1.295	
Treatment	9	600.656	66.740	1.271	NS
Error	18	944.960	52.498		
Total	29	1,681.635			

Appendix- II.D

Analysis of variance (ANOVA) of emergence per cent of potato at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	408.387	204.193	6.490	
Treatment	9	313.333	34.8148	1.106	NS
Error	18	566.247	31.4582		
Total	29	1,287.94			

Appendix- II.E

Analysis of variance (ANOVA) of emergence per cent of potato at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	6.131	3.065	0.151	
Treatment	9	161.177	17.908	0.887	NS
Error	18	363.301	20.183		
Total	29	530.585			

Appendix- II.F

Pooled analysis of variance (ANOVA) of emergence per cent of potato

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	81.821	40.910	3.279	
Treatment	9	180.963	20.107	1.611	NS
Error	18	224.558	12.475		
Total	29	476.549			

Appendix- III.A

Analysis of variance (ANOVA) of plant height of potato at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.639	1.819	0.204	
Treatment	9	43.736	4.860	0.548	NS
Error	18	159.755	8.875		
Total	29	207.129			

Appendix- III.B

Analysis of variance (ANOVA) of plant height of potato at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	102.591	51.295	1.888	
Treatment	9	90.402	10.045	0.370	NS
Error	18	488.852	27.158		
Total	29	681.844			

Appendix- III.C

Pooled analysis of variance (ANOVA) of plant height of potato at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	26.053	13.025	1.725	
Treatment	9	21.436	2.382	0.315	NS
Error	18	135.887	7.549		
Total	29	183.376			

Appendix- III.D

Analysis of variance (ANOVA) of plant height of potato at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	29.590	14.796	3.207	
Treatment	9	541.140	60.127	13.035	**
Error	18	83.026	4.613		
Total	29	653.756			

Appendix- III.E

Analysis of variance (ANOVA) of plant height of potato at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.646	1.823	0.621	
Treatment	9	255.300	28.367	9.663	**
Error	18	52.843	2.936		
Total	29	311.789			

Appendix- III.F

Pooled analysis of variance (ANOVA) of plant height of potato at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	12.973	6.488	2.757	
Treatment	9	322.647	35.850	15.233	**
Error	18	42.361	2.353		
Total	29	377.980			

Appendix- III.G

Analysis of variance (ANOVA) of plant height of potato at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	91.138	45.566	6.400	
Treatment	9	308.548	34.283	4.816	**
Error	18	128.142	7.119		
Total	29	527.829			

Appendix- III.H

Analysis of variance (ANOVA) of plant height of potato at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	132.880	66.439	8.862	
Treatment	9	467.632	51.959	6.932	**
Error	18	134.926	7.496		
Total	29	735.439			

Appendix- III.I

Pooled analysis of variance (ANOVA) of plant height of potato at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	15.778	7.889	2.826	
Treatment	9	295.401	32.822	11.757	**
Error	18	50.251	2.792		
Total	29	361.430			

Appendix- III.J

Analysis of variance (ANOVA) of plant height of potato at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	41.376	20.689	6.396	
Treatment	9	250.766	27.863	8.617	**
Error	18	58.200	3.233		
Total	29	350.342			

Appendix- III.K

Analysis of variance (ANOVA) of plant height of potato at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.345	0.171	0.764	
Treatment	9	468.590	52.066	23.287	**
Error	18	40.245	2.236		
Total	29	509.180			

Appendix- III.L

Pooled analysis of variance (ANOVA) of plant height of potato at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	12.216	6.106	4.736	
Treatment	9	313.959	34.884	27.034	**
Error	18	23.227	1.290		
Total	29	349.402			

Appendix- IV.A

Analysis of variance (ANOVA) of number of haulms per plant at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.121	0.603	0.729	
Treatment	9	3.395	0.377	0.456	NS
Error	18	14.879	0.827		
Total	29	18.395			

Appendix- IV.B

Analysis of variance (ANOVA) of number of haulms per plant at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2.562	1.280	3.354	
Treatment	9	9.528	1.059	2.773	*
Error	18	6.872	0.382		
Total	29	18.962			

Appendix- IV.C

Pooled analysis of variance (ANOVA) of number of haulms per plant at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.803	0.401	1.703	
Treatment	9	5.007	0.556	2.361	NS
Error	18	4.242	0.236		
Total	29	10.052			

Appendix- IV.D

Analysis of variance (ANOVA) of number of haulms per plant at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.509	0.254	0.370	
Treatment	9	3.750	0.417	0.607	NS
Error	18	12.351	0.686		
Total	29	16.610			

Appendix- IV.E

Analysis of variance (ANOVA) of number of haulms per plant at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.079	0.396	0.859	
Treatment	9	6.071	0.675	1.462	NS
Error	18	8.302	0.461		
Total	29	14.453			

Appendix- IV.F

Pooled analysis of variance (ANOVA) of number of haulms per plant at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.149	0.743	0.266	
Treatment	9	4.141	0.460	1.649	NS
Error	18	5.021	0.279		
Total	29	9.310			

Appendix- IV.G

Analysis of variance (ANOVA) of number of haulms per plant at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.092	0.462	0.166	
Treatment	9	1.810	0.201	0.724	NS
Error	18	5.003	0.278		
Total	29	6.906			

Appendix- IV.H

Analysis of variance (ANOVA) of number of haulms per plant at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.901	0.450	0.720	
Treatment	9	10.822	1.202	1.923	NS
Error	18	11.255	0.625		
Total	29	22.977			

Appendix- IV.I

Pooled analysis of variance (ANOVA) of number of haulms per plant at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.376	0.188	1.062	
Treatment	9	4.898	0.544	3.075	*
Error	18	3.186	0.177		
Total	29	8.460			

Appendix- IV.J

Analysis of variance (ANOVA) of number of haulms per plant at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.163	0.813	0.180	
Treatment	9	2.076	0.231	0.513	NS
Error	18	8.094	0.450		
Total	29	10.333			

Appendix- IV.K

Analysis of variance (ANOVA) of number of haulms per plant at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.049	0.524	0.991	
Treatment	9	8.602	0.956	1.807	NS
Error	18	9.521	0.529		
Total	29	19.172			

Appendix- IV.L

Pooled analysis of variance (ANOVA) of number of haulms per plant at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.100	0.497	0.219	
Treatment	9	4.231	0.470	2.075	NS
Error	18	4.079	0.227		
Total	29	8.409			

Appendix- V.A

Analysis of variance (ANOVA) of number of leaves per plant at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	24.067	12.033	0.741	
Treatment	9	98.967	10.996	0.678	NS
Error	18	291.933	16.219		
Total	29	414.967			

Appendix- V.B

Analysis of variance (ANOVA) of number of leaves per plant at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2.067	1.033	0.404	
Treatment	9	231.367	25.707	10.074	**
Error	18	45.933	2.552		
Total	29	279.367			

Appendix- V.C

Pooled analysis of variance (ANOVA) of number of leaves per plant at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	9.267	4.633	1.106	
Treatment	9	134.800	14.978	3.576	*
Error	18	75.400	4.189		
Total	29	219.467			

Appendix- V.D

Analysis of variance (ANOVA) of number of leaves per plant at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	115.267	57.633	3.660	
Treatment	9	474.700	52.744	3.350	*
Error	18	283.400	15.744		
Total	29	873.367			

Appendix- V.E

Analysis of variance (ANOVA) of number of leaves per plant at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	79.800	39.899	2.847	
Treatment	9	372.700	41.411	2.956	*
Error	18	252.200	14.011		
Total	29	704.700			

Appendix- V.F

Pooled analysis of variance (ANOVA) of number of leaves per plant at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	80.067	40.033	4.360	
Treatment	9	411.333	45.704	4.978	**
Error	18	165.267	9.181		
Total	29	656.667			

Appendix- V.G

Analysis of variance (ANOVA) of number of leaves per plant at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	8.267	4.132	0. 192	
Treatment	9	809.467	89.941	4.197	**
Error	18	385.733	21.430		
Total	29	1,203.467			

Appendix- V.H

Analysis of variance (ANOVA) of number of leaves per plant at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	6.467	3.2330	0.186	
Treatment	9	754.033	83.781	4.820	**
Error	18	312.867	17.381		
Total	29	1,073.367			

Appendix- V.I

Pooled analysis of variance (ANOVA) of number of leaves per plant at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	4.067	2.033	0.196	
Treatment	9	787.867	87.541	8.475	**
Error	18	185.933	10.330		
Total	29	977.867			

Appendix- V.J

Analysis of variance (ANOVA) of number of leaves per plant at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	42.467	21.233	2.713	
Treatment	9	808.533	89.837	11.479	**
Error	18	140.867	7.826		
Total	29	991.867			

Appendix- V.K

Analysis of variance (ANOVA) of number of leaves per plant at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	71.667	71.667	35.833	0.427	
Treatment	896.533	99.615	4.625	1.443	**
Error	387.667	21.537			
Total	1,355.867				

Appendix- V.L

Pooled analysis of variance (ANOVA) of number of leaves per plant at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	42.200	21.233	2.713	
Treatment	9	832.033	92.448	11.847	**
Error	18	140.467	7.804		
Total	29	1,014.700			

Appendix- VI.A

Analysis of variance (ANOVA) of diameter of haulm at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.640	0.820	2.318	
Treatment	9	5.780	0.642	1.816	NS
Error	18	6.367	0.354		
Total	29	13.787			

Appendix- VI.B

Analysis of variance (ANOVA) of diameter of haulm at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.825	0.912	9.157	
Treatment	9	2.453	0.273	2.734	*
Error	18	1.794	0.100		
Total	29	6.072			

Appendix- VI.C

Pooled analysis of variance (ANOVA) of diameter of haulm at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.241	0.620	6.470	
Treatment	9	3.347	0.372	3.878	**
Error	18	1.726	0.096		
Total	29	6.315			

Appendix- VI.D

Analysis of variance (ANOVA) of diameter of haulm at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2.116	1.057	1.415	
Treatment	9	10.239	1.138	1.522	NS
Error	18	13.453	0.747		
Total	29	25.808			

Appendix- VI.E

Analysis of variance (ANOVA) of diameter of haulm at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.568	0.284	0.206	
Treatment	9	5.412	0.601	0.437	NS
Error	18	24.791	1.377		
Total	29	30.771			

Appendix- VI.F

Pooled analysis of variance (ANOVA) of diameter of haulm at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.125	0.623	0.926	
Treatment	9	7.485	0.832	1.236	NS
Error	18	12.113	0.673		
Total	29	19.722			

Appendix- VI.G

Analysis of variance (ANOVA) of diameter of haulm at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.722	0.360	0.921	
Treatment	9	10.837	1.204	3.075	*
Error	18	7.049	0.392		
Total	29	18.609			

Appendix- VI.H

Analysis of variance (ANOVA) of diameter of haulm at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.024	0.120	0.298	
Treatment	9	9.033	1.004	2.483	*
Error	18	7.275	0.404		
Total	29	16.333			

Appendix- VI.I

Pooled analysis of variance (ANOVA) of diameter of haulm at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.236	0.235	0.117	
Treatment	9	6.529	0.725	2.568	*
Error	18	5.085	0.283		
Total	29	11.850			

Appendix- VI.J

Analysis of variance (ANOVA) of diameter of haulm at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.063	0.314	0.162	
Treatment	9	4.609	0.512	2.648	*
Error	18	3.481	0.193		
Total	29	8.153			

Appendix- VI.K

Analysis of variance (ANOVA) of diameter of haulm at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.890	0.445	1.043	
Treatment	9	20.388	2.265	5.312	**
Error	18	7.677	0.427		
Total	29	28.956			

Appendix- VI.L

Pooled analysis of variance (ANOVA) of diameter of haulm at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.235	0.117	0.991	
Treatment	9	8.071	0.897	7.559	**
Error	18	2.135	0.119		
Total	29	10.442			

Appendix- VII.A

Analysis of variance (ANOVA) of dry weight of plant at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	24.136	12.068	0.752	
Treatment	9	155.766	17.307	1.079	NS
Error	18	288.733	16.041		
Total	29	468.635			

Appendix- VII.B

Analysis of variance (ANOVA) of dry weight of plant at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	41.504	20.751	3.136	
Treatment	9	64.450	7.161	1.082	NS
Error	18	119.109	6.617		
Total	29	225.063			

Appendix- VII.C

Pooled analysis of variance (ANOVA) of dry weight of plant at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	19.243	9.621	2.981	
Treatment	9	102.892	11.432	3.543	*
Error	18	58.080	3.227		
Total	29	180.214			

Appendix- VII.D

Analysis of variance (ANOVA) of dry weight of plant at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	66.616	33.307	4.829	
Treatment	9	279.717	31.080	4.507	**
Error	18	124.132	6.896		
Total	29	470.465			

Appendix- VII.E

Analysis of variance (ANOVA) of dry weight of plant at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.784	0 .892	0 .187	
Treatment	9	198.094	22.010	4.633	**
Error	18	85.516	4.751		
Total	29	285.395			

Appendix- VII.F

Pooled analysis of variance (ANOVA) of dry weight of plant at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	21.928	10.964	3.957	
Treatment	9	90.471	10.052	3.628	*
Error	18	49.868	2.770		
Total	29	162.268			

Appendix- VII.G

Analysis of variance (ANOVA) of dry weight of plant at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	83.581	41.790	3.919	
Treatment	9	314.923	34.991	3.282	*
Error	18	191.923	10.662		
Total	29	590.428			

Appendix- VII.H

Analysis of variance (ANOVA) of dry weight of plant at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	36.712	18.355	2.511	
Treatment	9	324.208	36.023	4.929	**
Error	18	131.555	7.309		
Total	29	492.475			

Appendix- VII.I

Pooled analysis of variance (ANOVA) of dry weight of plant at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	34.658	17.329	3.676	
Treatment	9	306.716	34.080	7.230	**
Error	18	84.843	4.713		
Total	29	426.217			

Appendix- VII.J

Analysis of variance (ANOVA) of dry weight of plant at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2.701	1.350	0.168	
Treatment	9	438.262	48.696	6.075	**
Error	18	144.275	8.015		
Total	29	585.238			

Appendix- VII.K

Analysis of variance (ANOVA) of dry weight of plant at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	23.247	11.623	2.433	
Treatment	9	335.079	37.231	7.796	**
Error	18	85.960	4.776		
Total	29	444.286			

Appendix- VII.L

Pooled analysis of variance (ANOVA) of dry weight of plant at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	6.754	3.377	0 .857	
Treatment	9	375.725	41.747	10.602	**
Error	18	70.878	3.938		
Total	29	453.356			

Appendix- VIII.A

Analysis of variance (ANOVA) of leaf area index at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.038	0.190	0.192	
Treatment	9	15.478	1.720	17.408	**
Error	18	1.778	0.099		
Total	29	17.294			

Appendix- VIII.B

Analysis of variance (ANOVA) of leaf area index at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.109	0.542	0.283	
Treatment	9	24.632	2.737	14.307	**
Error	18	3.443	0.191		
Total	29	28.184			

Appendix- VIII.C

Pooled analysis of variance (ANOVA) of leaf area index at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.058	0.291	0.649	
Treatment	9	18.878	2.098	46.693	**
Error	18	0.809	0.045		
Total	29	19.745			

Appendix- IX.A

Analysis of variance (ANOVA) of chlorophyll content (a) at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.001	0.523E-3	2.925	
Treatment	9	0.091	0.010	56.757	**
Error	18	0.003	0.000		
Total	29	0.096			

Appendix- IX.B

Analysis of variance (ANOVA) of chlorophyll content (a) at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.001	0.558-3E	0.372	
Treatment	9	0.091	0.010	13.468	**
Error	18	0.014	0.001		
Total	29	0.105			

Appendix- IX.C

Pooled analysis of variance (ANOVA) of chlorophyll content (a) at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	0.207E-03	0.686	
Treatment	9	0.078	0.009	28.766	**
Error	18	0.005	0.000		
Total	29	0.084			

Appendix- IX.D

Analysis of variance (ANOVA) of chlorophyll content (b) at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	0.127E-03	0.170	
Treatment	9	0.037	0.004	5.481	**
Error	18	0.013	0.001		
Total	29	0.050			

Appendix- IX.E

Analysis of variance (ANOVA) of chlorophyll content (b) at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	0.125E-03	0.256	
Treatment	9	0.060	0.007	13.529	**
Error	18	0.009	0.000		
Total	29	0.069			

Appendix- IX.F

Pooled analysis of variance (ANOVA) of chlorophyll content (b) at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	0.1607E-03	0.416	
Treatment	9	0.031	0.003	8.992	**
Error	18	0.007	0.000		
Total	29	0.038			

Appendix- X.A

Analysis of variance (ANOVA) of number of tubers per plant at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	4.504	2.252	1.973	
Treatment	9	13.548	1.505	1.319	NS
Error	18	20.545	1.141		
Total	29	38.596			

Appendix- X.B

Analysis of variance (ANOVA) of number of tubers per plant at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	4.779	2.389	0.579	
Treatment	9	33.348	3.705	0.899	NS
Error	18	74.178	4.121		
Total	29	112.305			

Appendix- X.C

Pooled analysis of variance (ANOVA) of number of tubers per plant at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.343	1.670	1.902	
Treatment	9	20.073	2.230	2.539	*
Error	18	15.812	0.878		
Total	29	39.228			

Appendix- X.D

Analysis of variance (ANOVA) of number of tubers per plant at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.948	0.473	0.307	
Treatment	9	19.856	2.206	1.432	NS
Error	18	27.736	1.541		
Total	29	48.540			

Appendix- X.E

Analysis of variance (ANOVA) of number of tubers per plant at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.304	1.651	1.028	
Treatment	9	15.171	1.686	1.049	NS
Error	18	28.914	1.606		
Total	29	47.388			

Appendix- X.F

Pooled analysis of variance (ANOVA) of number of tubers per plant at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.855	0.927	1.311	
Treatment	9	14.136	1.571	2.222	NS
Error	18	12.726	0.707		
Total	29	28.717			

Appendix- X.G

Analysis of variance (ANOVA) of number of tubers per plant at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.774	0 .386	4.147	
Treatment	9	59.944	6.660	71.401	**
Error	18	1.679	0.093		
Total	29	62.397			

Appendix- X.H

Analysis of variance (ANOVA) of number of tubers per plant at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.572	0.285	0.428	
Treatment	9	55.471	6.163	9.236	**
Error	18	12.012	0.667		
Total	29	68.055			

Appendix- X.I

Pooled analysis of variance (ANOVA) of number of tubers per plant at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.303	0.151	0 .833	
Treatment	9	49.130	5.459	30.010	**
Error	18	3.274	0.182		
Total	29	52.707			

Appendix- X.J

Analysis of variance (ANOVA) of number of tubers per plant at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.128	0.636	0.476	
Treatment	9	61.116	6.791	50.788	**
Error	18	2.407	0.134		
Total	29	63.651			

Appendix- X.K

Analysis of variance (ANOVA) of number of tubers per plant at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.218	0.608	1.293	
Treatment	9	36.708	4.079	8.665	**
Error	18	8.473	0.471		
Total	29	46.399			

Appendix- X.L

Pooled analysis of variance (ANOVA) of number of tubers per plant at de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.226	0.112	0 .759	
Treatment	9	40.760	4.529	30.547	**
Error	18	2.669	0.148		
Total	29	43.654			

Appendix- XI.A

Analysis of variance (ANOVA) of weight of tubers per plant at 30 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	6.221	3.110	1.462	
Treatment	9	49.397	5.489	2.581	*
Error	18	38.272	2.126		
Total	29	93.890			

Appendix- XI.B

Analysis of variance (ANOVA) of weight of tubers per plant at 30 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.059	1.529	0.269	
Treatment	9	67.982	7.554	1.330	NS
Error	18	102.261	5.681		
Total	29	173.302			

Appendix- XI.C

Pooled analysis of variance (ANOVA) of weight of tubers per plant at 30 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.500	1.749	1.662	
Treatment	9	54.101	6.011	5.711	**
Error	18	18.948	1.053		
Total	29	76.548			

Appendix- XI.D

Analysis of variance (ANOVA) of weight of tubers per plant at 45 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	988.855	494.425	0.836	
Treatment	9	10,146.928	1,127.436	1.907	NS
Error	18	10,640.200	591.122		
Total	29	21,775.983			

Appendix- XI.E

Analysis of variance (ANOVA) of weight of tubers per plant at 45 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	73.103	36.543	0 .509	
Treatment	9	3,805.467	422.830	0.589	NS
Error	18	12,916.165	717.565		
Total	29	16,794.735			

Appendix- XI.F

Pooled analysis of variance (ANOVA) of weight of tubers per plant at 45 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	386.183	193.087	0.536	
Treatment	9	6,258.859	695.429	1.933	
Error	18	6,475.952	359.775		
Total	29	13,120.994			

Appendix- XI.G

Analysis of variance (ANOVA) of weight of tubers per plant at 60 DAP in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	711.070	355.525	0.855	
Treatment	9	23,459.423	2,606.603	6.275	**
Error	18	7,477.438	415.413		
Total	29	31,647.931			

Appendix- XI.H

Analysis of variance (ANOVA) of weight of tubers per plant at 60 DAP in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	273.371	136.662	1.824	
Treatment	9	21,947.381	2,438.598	32.560	**
Error	18	1,348.119	74.895		
Total	29	23,568.870			

Appendix- XI.I

Pooled analysis of variance (ANOVA) of weight of tubers per plant at 60 DAP

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	320.107	160.075	1.014	
Treatment	9	20,924.375	2,324.931	14.736	**
Error	18	2,839.812	157.767		
Total	29	24,084.294			

Appendix- XI.J

Analysis of variance (ANOVA) of weight of tuber per plant at de-haulming in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3,071.425	1535.500	1.805	
Treatment	9	98,988.409	10,998.712	12.936	**
Error	18	15,304.087	850.227		
Total	29	117,363.921			

Appendix- XI.K

Analysis of variance (ANOVA) of weight of tubers per plant at de-haulming in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	388.678	194.350	0.567	
Treatment	9	101,483.782	11,275.976	32.916	**
Error	18	6,166.301	342.572		
Total	29	108,038.760			

Appendix- XI.L

Pooled analysis of variance (ANOVA) of weight of tubers per plant de-haulming

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1,310.749	655.500	2.030	
Treatment	9	97,980.019	10,886.669	33.731	**
Error	18	5,809.420	322.746		
Total	29	105,100.188			

Appendix- XII.A

Analysis of variance (ANOVA) of number of < 25g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	264.014	132.012	0 .361	
Treatment	9	11,590.950	1,287.883	3.527	*
Error	18	6,572.398	365.133		
Total	29	18,427.363			

Appendix- XII.B

Analysis of variance (ANOVA) of number of < 25g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1,771.648	885.825	3.050	
Treatment	9	15,287.515	1,698.613	5.849	**
Error	18	5,226.985	290.388		
Total	29	22,286.148			

Appendix- XII.C

Pooled analysis of variance (ANOVA) of number of < 25g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	831.508	415.756	2.212	
Treatment	9	12,213.140	1,357.016	7.223	**
Error	18	3,381.842	187.880		
Total	29	16,426.489			

Appendix- XII.D

Analysis of variance (ANOVA) of number of 26-50g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	282.763	141.375	0.891	
Treatment	9	12,779.976	1,419.997	8.957	**
Error	18	2,853.756	158.542		
Total	29	15,916.495			

Appendix- XII.E

Analysis of variance (ANOVA) of number of 26-50g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	117.910	58.956	0.107	
Treatment	9	12,340.182	1,371.131	2.497	*
Error	18	9,884.650	549.147		
Total	29	22,342.743			

Appendix- XII.F

Pooled analysis of variance (ANOVA) of number of 26-50g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	137.925	68.981	0 .350	
Treatment	9	12,370.404	1,374.489	6.985	**
Error	18	3,542.153	196.786		
Total	29	16,050.482			

Appendix- XII.G

Analysis of variance (ANOVA) of number of 51-75g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	459.913	229.937	0 .559	
Treatment	9	30,319.680	3,368.853	8.195	**
Error	18	7,399.714	411.095		
Total	29	38,179.307			

Appendix- XII.H

Analysis of variance (ANOVA) of number of 51-75g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	51.063	25.537	0 .247	
Treatment	9	36,342.008	4,038.001	3.914	**
Error	18	18,569.790	1,031.655		
Total	29	54,962.862			

Appendix- XII.I

Pooled analysis of variance (ANOVA) of number of 51-75g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	80.280	40.131	0.986	
Treatment	9	32,365.752	3,596.195	8.844	**
Error	18	7,318.848	406.603		
Total	29	39,764.879			

Appendix- XII.J

Analysis of variance (ANOVA) of number of > 75g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1,757.406	878.681	1.929	
Treatment	9	37,388.418	4,154.269	9.122	**
Error	18	8,197.462	455.415		
Total	29	47,343.285			

Appendix- XII.K

Analysis of variance (ANOVA) of number of > 75g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	355.037	355.025	177.512	
Treatment	9	47,520.035	5,280.004	40.061	**
Error	18	2,372.385	131.799		
Total	29	50,247.457			

Appendix- XII.L

Pooled analysis of variance (ANOVA) of number of > 75g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	366.109	183.043	1.178	
Treatment	9	40,857.314	4,539.702	29.219	**
Error	18	2,796.584	155.366		
Total	29	44,020.007			

Appendix- XIII.A

Analysis of variance (ANOVA) of total number of tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2,632.770	1316.100	1.281	
Treatment	9	161,561.728	17,951.303	17.476	**
Error	18	18,489.764	1,027.209		
Total	29	182,684.262			

Appendix- XIII.B

Analysis of variance (ANOVA) of total number of tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	5,405.173	2702.700	1.412	
Treatment	9	183,892.897	20,432.544	10.675	**
Error	18	34,452.857	1,914.048		
Total	29	223,750.927			

Appendix- XIII.C

Pooled analysis of variance (ANOVA) of total number of tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3,125.791	1562.900	1.657	
Treatment	9	171,363.252	19,040.361	20.199	**
Error	18	16,967.390	942.633		
Total	29	191,456.432			

Appendix- XIV.A

Analysis of variance (ANOVA) of yield of < 25g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.103	0.516E-01	0.146	
Treatment	9	7.034	0.782	2.209	NS
Error	18	6.370	0.354		
Total	29	13.508			

Appendix- XIV.B

Analysis of variance (ANOVA) of yield of < 25g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.316	0 .157	0.412	
Treatment	9	9.907	1.101	2.874	*
Error	18	6.894	0.383		
Total	29	17.117			

Appendix- XIV.C

Pooled analysis of variance (ANOVA) of yield of < 25g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.44E-01	0 .218E-01	0.135	
Treatment	9	7.356	0.817	5.055	**
Error	18	2.910	0.162		
Total	29	10.310			

Appendix- XIV.D

Analysis of variance (ANOVA) of yield of 26-50g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.406	0 .202	0 .115	
Treatment	9	78.932	8.770	4.985	**
Error	18	31.667	1.759		
Total	29	111.005			

Appendix- XIV.E

Analysis of variance (ANOVA) of yield of 26-50g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	17.360	8.680	3.601	
Treatment	9	57.693	6.410	2.660	*
Error	18	43.381	2.410		
Total	29	118.434			

Appendix- XIV.F

Pooled analysis of variance (ANOVA) of yield of 26-50g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	4.456	2.228	1.726	
Treatment	9	64.167	7.130	5.524	**
Error	18	23.233	1.291		
Total	29	91.857			

Appendix- XIV.G

Analysis of variance (ANOVA) of yield of 51-75g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2.663	1.331	1.067	
Treatment	9	94.949	10.550	8.460	**
Error	18	22.447	1.247		
Total	29	120.058			

Appendix- XIV.H

Analysis of variance (ANOVA) of yield of 51-75g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3.243	1.621	1.764	
Treatment	9	90.876	10.097	10.990	**
Error	18	16.538	0.919		
Total	29	110.657			

Appendix- XIV.I

Pooled analysis of variance (ANOVA) of yield of 51-75g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.132	0 .657	0.161	
Treatment	9	83.390	9.266	22.693	**
Error	18	7.349	0.408		
Total	29	90.871			

Appendix- XIV.J

Analysis of variance (ANOVA) of yield of > 75g tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2.178	1.088	0.623	
Treatment	9	212.381	23.598	13.522	**
Error	18	31.414	1.745		
Total	29	245.973			

Appendix- XIV.K

Analysis of variance (ANOVA) of yield of > 75g tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.403	0 .201	0 .151	
Treatment	9	233.752	25.972	19.580	**
Error	18	23.877	1.326		
Total	29	258.032			

Appendix- XIV.L

Pooled analysis of variance (ANOVA) of yield of > 75g tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.205	0 .102	0 .127	
Treatment	9	212.636	23.626	29.369	**
Error	18	14.480	0.804		
Total	29	227.322			

Appendix- XV.A

Analysis of variance (ANOVA) of total tuber yield in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.176	0 .587	0 .167	
Treatment	9	597.167	66.352	18.897	**
Error	18	63.202	3.511		
Total	29	661.545			

Appendix- XV.B

Analysis of variance (ANOVA) of total tuber yield in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	25.568	12.784	2.589	
Treatment	9	468.959	52.107	10.556	**
Error	18	88.851	4.936		
Total	29	583.378			

Appendix- XV.C

Pooled analysis of variance (ANOVA) of total yield of tuber

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	6.181	3.091	1.557	
Treatment	9	522.613	58.068	29.255	**
Error	18	35.728	1.985		
Total	29	564.522			

Appendix- XVI.A

Analysis of variance (ANOVA) of marketable tuber yield in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.830	0 .415	0.133	
Treatment	9	664.109	73.790	23.713	**
Error	18	56.013	3.112		
Total	29	720.952			

Appendix- XVI.B

Analysis of variance (ANOVA) of marketable tuber yield in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	25.251	12.625	2.636	
Treatment	9	527.861	58.651	12.246	**
Error	18	86.212	4.790		
Total	29	639.323			

Appendix- XVI.C

Pooled analysis of variance (ANOVA) of marketable tuber yield

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	5.723	2.861	1.539	
Treatment	9	585.509	65.057	34.997	**
Error	18	33.460	1.859		
Total	29	624.692			

Appendix- XVII.A

Analysis of variance (ANOVA) of harvest index (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.474	2.868	1.072	
Treatment	9	631.710	70.190	27.348	**
Error	18	46.198	2.567		
Total	29	678.382			

Appendix- XVII.B

Analysis of variance (ANOVA) of harvest index (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	17.460	5.016	1.553	
Treatment	9	257.809	28.645	9.914	**
Error	18	52.008	2.889		
Total	29	327.277			

Appendix- XVII.C

Pooled analysis of variance (ANOVA) of harvest index (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	5.895	2.610	1.880	
Treatment	9	312.098	34.678	23.130	**
Error	18	26.986	1.499		
Total	29	344.979			

Appendix- XVIII.A

Analysis of variance (ANOVA) of dry matter content of potato tubers (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1.141	0 .569	1.123	
Treatment	9	31.572	3.508	6.915	**
Error	18	9.131	0.507		
Total	29	41.843			

Appendix- XVIII.B

Analysis of variance (ANOVA) of dry matter content of potato tubers (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.556	0.277	0.486	
Treatment	9	21.430	2.381	4.174	**
Error	18	10.269	0.570		
Total	29	32.254			

Appendix- XVIII.C

Pooled analysis of variance (ANOVA) of dry matter content of potato tubers (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.775	0 .387	1.305	
Treatment	9	25.341	2.816	9.471	**
Error	18	5.351	0.297		
Total	29	31.467			

Appendix- XIX.A

Analysis of variance (ANOVA) of protein content of potato tubers (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.648	0 .324	3.112	
Treatment	9	4.721	0.525	5.037	**
Error	18	1.875	0.104		
Total	29	7.244			

Appendix- XIX.B

Analysis of variance (ANOVA) of protein content of potato tubers (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.126	0.628E-01	1.142	
Treatment	9	3.253	0.361	6.567	**
Error	18	0.991	0.055		
Total	29	4.370			

Appendix- XIX.C

Pooled analysis of variance (ANOVA) of protein content of potato tubers (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.232	0 .115	2.541	
Treatment	9	3.821	0.425	9.310	**
Error	18	0.821	0.046		
Total	29	4.873			

Appendix- XX.A

Analysis of variance (ANOVA) of T.S.S. of potato tubers (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.021	.103E-01	0.504	
Treatment	9	13.077	1.453	70.682	**
Error	18	0.370	0.021		
Total	29	13.468			

Appendix- XX.B

Analysis of variance (ANOVA) of T.S.S. of potato tubers (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.387	0.193	2.656	
Treatment	9	9.035	1.004	13.796	**
Error	18	1.310	0.073		
Total	29	10.731			

Appendix- XX.C

Pooled analysis of variance (ANOVA) of T.S.S. of potato tubers (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.065	0. 323	1.075	
Treatment	9	10.555	1.173	39.040	**
Error	18	0.541	0.030		
Total	29	11.161			

Appendix- XXI.A

Analysis of variance (ANOVA) of specific gravity of potato tubers (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.001	.567E-03	0.580	
Treatment	9	0.009	0.001	0.974	NS
Error	18	0.018	0.001		
Total	29	0.027			

Appendix- XXI.B

Analysis of variance (ANOVA) of specific gravity of potato tubers (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	0.160E-03	0.481	
Treatment	9	0.007	0.001	2.487	*
Error	18	0.006	0.000		
Total	29	0.014			

Appendix- XXI.C

Pooled analysis of variance (ANOVA) of specific gravity of potato tubers (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	.537E-04	0.182	
Treatment	9	0.008	0.001	2.868	*
Error	18	0.005	0.000		
Total	29	0.013			

Appendix- XXII.A

Analysis of variance (ANOVA) of available nitrogen content in soil after harvest in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2,329.230	1164.600	3.337	
Treatment	9	10,136.564	1,126.285	3.227	*
Error	18	6,281.426	348.968		
Total	29	18,747.220			

Appendix- XXII.B

Analysis of variance (ANOVA) of available nitrogen content in soil after harvest in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	1,188.962	594.487	2.298	
Treatment	9	9,647.633	1,071.959	4.145	**
Error	18	4,655.128	258.618		
Total	29	15,491.723			

Appendix- XXII.C

Pooled analysis of variance (ANOVA) of available nitrogen content in soil after harvest

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	464.358	232.168	2.115	
Treatment	9	7,905.193	878.355	8.004	**
Error	18	1,975.262	109.737		
Total	29	10,344.813			

Appendix- XXIII.A

Analysis of variance (ANOVA) of nitrogen content (%) in plant in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.026	1.350	0 .168	
Treatment	9	2.133	0.237	21.433	**
Error	18	0.199	0.011		
Total	29	2.358			

Appendix- XXIII.B

Analysis of variance (ANOVA) of nitrogen content (%) in plant in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.012	11.623	2.433	
Treatment	9	1.930	0.214	13.279	**
Error	18	0.291	0.016		
Total	29	2.233			

Appendix- XXIII.C

Pooled analysis of variance (ANOVA) of nitrogen content (%) in plant

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.000	3.377	0.857	
Treatment	9	1.917	0.213	34.206	**
Error	18	0.112	0.006		
Total	29	2.030			

Appendix- XXIV.A

Analysis of variance (ANOVA) of nitrogen content (%) in tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.003	0.001	0.890	
Treatment	9	0.085	0.009	6.292	**
Error	18	0.027	0.001		
Total	29	0.114			

Appendix- XXIV.B

Analysis of variance (ANOVA) of nitrogen content (%) in tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.017	0.870E-02	3.246	
Treatment	9	0.123	0.014	5.115	**
Error	18	0.048	0.003		
Total	29	0.189			

Appendix- XXIV.C

Pooled analysis of variance (ANOVA) of nitrogen content (%) in tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	0.006	0.003	2.198	
Treatment	9	0.096	0.011	8.452	**
Error	18	0.023	0.001		
Total	29	0.124			

Appendix- XXV.A

Analysis of variance (ANOVA) of nitrogen uptake (kg/ha) by plant in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	568.449	284.220	3.576	
Treatment	9	5,635.110	626.123	7.878	**
Error	18	1,430.643	79.480		
Total	29	7,634.202			

Appendix- XXV.B

Analysis of variance (ANOVA) of nitrogen uptake (kg/ha) by plant in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	35.290	17.645	0 .444	
Treatment	9	5,102.965	566.996	14.282	**
Error	18	714.615	39.701		
Total	29	5,852.869			

Appendix- XXV.C

Pooled analysis of variance (ANOVA) of nitrogen (kg/ha) uptake by plant

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	170.195	85.098	2.308	
Treatment	9	5,170.624	574.514	15.582	**
Error	18	663.675	36.871		
Total	29	6,004.493			

Appendix- XXVI.A

Analysis of variance (ANOVA) of nitrogen uptake (kg/ha) by tubers in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	53.419	26.707	0 .874	
Treatment	9	3,552.118	394.680	12.930	**
Error	18	549.451	30.525		
Total	29	4,154.988			

Appendix- XXVI.B

Analysis of variance (ANOVA) of nitrogen uptake (kg/ha) by tubers in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	27.177	13.585	0. 418	
Treatment	9	3,065.247	340.583	10.499	**
Error	18	583.898	32.439		
Total	29	3,676.321			

Appendix- XXVI.C

Pooled analysis of variance (ANOVA) of nitrogen uptake (kg/ha) by tubers

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	13.301	6.653	0.514	
Treatment	9	3,278.484	364.276	28.163	**
Error	18	232.822	12.935		
Total	29	3,524.607			

Appendix- XXVII.A

Analysis of variance (ANOVA) of total nitrogen uptake (kg/ha) by plant in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	286.546	143.262	1.473	
Treatment	9	17,643.525	1,960.392	20.168	**
Error	18	1,749.617	97.201		
Total	29	19,679.687			

Appendix- XXVII.B

Analysis of variance (ANOVA) of total nitrogen uptake (kg/ha) by plant in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	76.370	38.203	0 .738	
Treatment	9	14,946.639	1,660.738	32.109	**
Error	18	931.008	51.723		
Total	29	15,954.017			

Appendix- XXVII.C

Pooled analysis of variance (ANOVA) of nitrogen (kg/ha) uptake by plant

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	138.107	69.062	1.757	
Treatment	9	16,065.097	1,785.011	45.441	**
Error	18	707.074	39.282		
Total	29	16,910.277			

Appendix- XXVIII.A

Analysis of variance (ANOVA) of nitrogen use efficiency (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	2,383.123	1191.568	3.488	
Treatment	8	8,545.315	1,068.164	3.127	*
Error	16	5,464.666	341.542		
Total	26	16,393.104			

Appendix- XXVIII.B

Analysis of variance (ANOVA) of nitrogen use efficiency (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	9,850.251	4925.122	15.195	
Treatment	8	7,239.738	904.967	2.792	*
Error	16	5,185.813	324.113		
Total	26	22,275.802			

Appendix- XXVIII.C

Pooled analysis of variance (ANOVA) of nitrogen use efficiency (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	3,612.317	1806.156	10.492	
Treatment	8	7,406.781	925.848	5.379	**
Error	16	2,754.114	172.132		
Total	26	13,773.212			

Appendix- XXIX.A

Analysis of variance (ANOVA) of nitrogen apparent recovery (%) in 2014-15

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	381.748	190.872	3.154	
Treatment	8	9,608.639	1,067.627	17.643	**
Error	16	1,089.199	60.511		
Total	26	11,079.586			

Appendix- XXIX.B

Analysis of variance (ANOVA) of nitrogen apparent recovery (%) in 2015-16

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	208.262	104.130	3.467	
Treatment	8	9,249.523	1,027.725	34.226	**
Error	16	540.493	30.027		
Total	26	9,998.278			

Appendix- XXIX.C

Pooled analysis of variance (ANOVA) of nitrogen apparent recovery (%)

Source of Variation	D.F.	SS	MS	F-Calculated	Significance
Replication	2	288.463	144.233	5.143	
Treatment	8	9,314.690	1,034.966	36.911	**
Error	16	504.714	28.040		
Total	26	10,107.867			

Appendix- XXX

General cost of cultivation of potato (per hectare)

S. No.	Particulars	Quantity	Rate (Rs.)	Total cost (Rs.)
Field preparation				
1.	By tractor	2.5 hours	450/ha	1125.00
2.	Labour	04	220/L/day	880.00
3.	Ridge making by tractor	2.5 hours	450/ha	1125.00
4.	Earthing-up by tractor	3.5 hours	450/ha	1575.00
5.	Digging by tractor	4 hours	450/ha	1800.00
6.	Transportation by tractor	2 hours	450/ha	900.00
7.	Lifting of bags	10 labours	220/L/day	2200.00
8.	Irrigation	2 × 4 hours/ha/irr.		480.00
9.	Labour	4 labours/irr.	220/L/day	880.00
Fertilizers				
10.	Urea	As per treatments	570/q	
11.	SSP (100 kg P/ha)	625 kg	800/q	5000.00
12.	MOP (120 kg K/ha)	200 kg	1700/q	3400.00
13.	Basal placement of fertilizers (Except urea)	4	220/L/day	880.00
14.	Seed tubers	30 q	2000/q	60000.00
15.	Planting	25 labours	220/L/day	5500.00
Fungicides, weedicides and insecticides				
16.	Matco	2.5 × 2 spray	1650/kg	8250.00
17.	Metacystox	1.5 lit. × 2 spray	700/lit.	2100.00
19.	Phorate	10 kg	80/kg	800.00
20.	Spraying of chemicals	12 labours	220/L/day	2640.00
21.	De-haulming	10 labours/ha	220/L/day	2200.00
22.	Collection of tubers	15 labours/ha	220/L/day	3300.00
23.	Grading	10 labours/ha	220/L/day	2200.00
24.	Bagging	10 labours/ha	220/L/day	2200.00
25.	Land rent	6 months	100/year	50.00
26.	Cost of gunny bags (50 kg capacity)	As per yield	25/bag	
27.	Sutali	As per yield	40/kg	
28.	Wooden basket	30 baskets	40/basket	1200.00
	General cost of cultivation			110685.00

VITAE

The author was born on September 30, 1989 at Roorkee in Haridwar district of Uttarakhand. She passed High School and intermediate from Government GirlsInter College, Khatima, U. S. Nagar, Uttarakhand in the year 2005 and 2007, respectively. She completed graduation from H. N. B. Govt. P. G. College, Khatima, Kumaun University, Nainital in 2010. She completed masters in Agriculture (Vegetable Science) from G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, in 2014. Thereafter she joined Ph. D. degree with major in Horticulture (Vegetable Science) in 2014 at the same university. She was recipient of university fellowship. She qualified ICAR-NET in Vegetable Science during 2014.

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ABSTRACT

Name	: Pooja Pandey	**Id. No.**	: 42650
Sem. and Year of Admission	: 1st Sem. 2014-15	**Degree**	: Ph.D.
Major	: Horticulture (Vegetable Science)	**Department**	: Vegetable Science
Minor	: 1. Soil Science : 2. Genetics and Plant Breeding		
Thesis Title	: "Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)"		
Advisor	: Dr. Manoj Raghav		

The present investigation entitled "Effect of nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.)" was carried out during winter season of two consecutive years 2014-15 and 2015-16 at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar, Uttarakhand. The experiment was laid out in randomized block design with three replications having ten treatments in each.

During the study, observations for growth characters, yield characters, quality attributes, nitrogen uptake, nitrogen use efficiency and apparent recovery were analyzed. Besides of this, to assess the profitability, cost of cultivation, net profit and benefit-cost ratio also were worked out.

Two year investigation revealed that nitrogen scheduling significantly influenced the performance of potato crop. Among all the treatments, T_9 (25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP) was proved best with respect to overall plant growth, tuber yield (36.62 t ha^{-1} and 31.53 t ha^{-1}) and nitrogen apparent recovery (65.8 % and 62.5 %) and also registered maximum benefit-cost ratio (1.69 and 1.48) during both the years, respectively. It not only recorded 7.23 % higher yield over recommended treatment T_1 (50% N of RDF as basal + 50% top dressing at 25 DAP) but also save 15 % nitrogen (25 kg ha^{-1}). While, treatment T_7 (50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP) produced maximum quality tubers having dry matter (19.4 % and 19.3 %) and specific gravity (1.09 g/cm^3) during both the years, respectively.

Based on overall performance, it could be concluded that under prevalent climatic conditions of *tarai* region of Uttarakhand, 25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP can be recommended to get maximum potato tuber yield and higher net return whereas, 50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP can be recommended to get quality tubers.

(Manoj Raghav)
Advisor

(Pooja Pandey)
Authoress

सारांश

नाम	: पूजा पाण्डेय	**परिचयांक संख्या**	: 42650
सत्र एवं प्रवेश वर्ष	: प्रथम, 2014-15	**उपाधि**	: पीएच. डी.
मुख्य विषय	: उद्यान विज्ञान (सब्जी विज्ञान)	**विभाग**	: सब्जी विज्ञान
गौण विषय	: 1- मृदा विज्ञान 2- आनुवांशिकी एवं पादप प्रजनन		

शोध शीर्षक : "समयक्रमानुसार नत्रजन का आलू (*सोलेनम ट्युबरोसम* एल.) की वृद्धि, उपज तथा गुणवत्ता पर प्रभाव"

सलाहकार : डॉ. मनोज राघव

समयक्रमानुसार नत्रजन का आलू (*सोलेनम ट्युबरोसम* एल.) की वृद्धि, उपज तथा गुणवत्ता पर प्रभाव आँकलन हेतु एक द्विवर्षीय शोध, गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिक विश्वविद्यालय, पंतनगर, ऊधम सिंह नगर, उत्तराखण्ड के सब्जी अनुसंधान केंद्र में वर्ष 2014-15 तथा 2015-16 की रबी ऋतु में आयोजित किया गया । प्रयोग का तीन अनुकरण एवं दस उपचारों के साथ यादृच्छिक खण्ड अभिकल्पना में परीक्षण किया गया । अध्ययन के दौरान आलू की वृद्धि, ऊपज तथा गुणवत्ता के साथ–साथ पौधे द्वारा नत्रजन उद्ग्रहण, नत्रजन उपयोग दक्षता एवं नत्रजन की पुनः प्राप्ति सम्बन्धी आँकड़े एकत्र किए गये । इसके अलावा विभिन्न उपचारों की उत्पादन लागत, सकल आय, शुद्ध आय तथा लाभ–लागत अनुपात का भी आंगणन किया गया ।

उक्त अध्ययन से यह ज्ञात हुआ कि विभिन्न नत्रजन उपचारों ने आलू की फसल को सार्थक रूप से प्रभावित किया। दोनों वर्षों में, उपचार टी– 9 (जिसमें पच्चीस प्रतिशत नत्रजन बुआई के समय + पचास प्रतिशत खड़ी फसल में बुआई के पच्चीस दिन बाद + तीन प्रतिशत यूरिया का बुआई के चालीस दिन बाद पर्णीय छिड़काव) में अधिकतम कन्द ऊपज (36.62 तथा 31.53 टन प्रति हेक्टेयर), नत्रजन की पुनः प्राप्ति (65.8 तथा 62.5%) एवं लाभ–लागत अनुपात (1.69 तथा 1.48) आँका गया। उक्त उपचार द्वारा, संस्तुत उपचार टी–1 से न केवल 7.23% अधिक उपज दर्ज की गयी बल्कि 15% (25 किग्रा. प्रति हे.) यूरिया की बचत भी हुई। जबकि दोनों वर्षों में, कन्द की अधिकतम गुणवत्ता जैसे शुष्क पदार्थ (19.4 तथा 19.3%) एवं विशिष्ट गुरुत्व (1.09 एवं 1.09 ग्रा. प्रति घनसेमी.) उपचार टी– 7 (जिसमें पचास प्रतिशत नत्रजन बुआई के समय + तीन प्रतिशत यूरिया का बुआई के पच्चीस एवं चालीस दिन बाद पर्णीय छिड़काव) में, पायी गयी ।

अतः प्रस्तुत शोध के आधार पर यह निष्कर्ष निकलता है कि उत्तराखण्ड के तराई क्षेत्र की जलवायु में आलू की अधिक ऊपज एवं शुद्ध लाभ के लिए उपचार टी– 9 (जिसमें पच्चीस प्रतिशत नत्रजन बुआई के समय + पचास प्रतिशत खड़ी फसल में बुआई के पच्चीस दिन बाद + तीन प्रतिशत यूरिया का बुआई के चालीस दिन बाद पर्णीय छिड़काव) की संस्तुति दी जा सकती है, जबकि अधिक गुणवत्तायुक्त आलू प्राप्त करने के लिए उपचार टी– 7 की अनुशंसा दी जा सकती है।

(मनोज राघव)
सलाहकार

पूजा
(पूजा पाण्डेय)
लेखिका