Integrated Nutrient Management in Barley

By

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CERTIFICATE-I

This is to certify that this thesis entitled "**Integrated Nutrient Management in Barley**" submitted for the degree of **Masters of Science** in the subject of **Agronomy** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Sandeep Kumar**, Admission No. **2017A31M** under my guidance and supervision and that no part of this thesis has been submitted for any other degree.

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

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CERTIFICATE-II

This is to certify that this thesis entitled "**Integrated Nutrient Management in Barley**" submitted by **Sandeep Kumar**, Admission No. **2017A31M** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirements for the degree of **Masters of Science** in the subject of **Agronomy** has been approved by the student's advisory committee after an oral examination on the same in collaboration with external examiner.

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CHAPTER-I

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the world's fourth most important cereal after wheat, rice and maize. Barley ranks next to wheat both in acreage and production among *rabi* cereals in India. Barley is believed to be originated in Abyssinia and South East Asia. It is a hardy crop and can be successfully grown in adverse climatic conditions of drought, salinity and alkalinity. However, barley is preferred by farmers under low rainfall conditions. The barley crop need less water and is more tolerant to salinity and alkalinity condition than other winter cereals.

In recent years, about two thirds of barley crop has been used for feed, one-third for malting and about 2 per cent directly for food (Baik and Ullrich, 2008). The major use of barley is in brewing industries for manufacturing malt. Both barley grains and straw are highly digestible compared to wheat because they do not contain gluten.

Barley has immense potential as quality cereal especially for nutritional and medicinal point of view; hence, it is used in Ayurvedic medicines. Barley is also used to cure fever, common cold, asthma, skin diseases, sore throat, urinary disorders and digestive system. In developed countries barley is considered as a functional food and used in many bakery products and recipes. In western countries, porridges and soups are prepared from dehusked barley grains. It is preferably used in breweries. However, vinegar, cider and sugar syrups are other modes of utilizing barley.

Each 100 gm of barley grain comprise 10.6 g protein, 2.1 g fat, 64 g carbohydrates, 50 mg calcium, 3 g crude fibres, 6 mg iron, 31 mg vitamin B_1, 0.10 mg vitamin B_2 and 50 µg folate (Vaughan *et al.,* 2006). Barley is superior to wheat in some minerals and fibre contents and also contains water soluble fibre and oil compound which are found to be effective in lowering cholesterol level of blood.

Barley is grown on 656 thousand hectares area with 1747 thousand tonnes production and average yield of 2663 kg ha^{-1} and it is largely confined to North-West region (Indiastat, 2016-17).

Rajasthan ranks first in barley production (840.52 thousand tonnes), followed by Uttar Pradesh (460 thousand tonnes) and Madhya Pradesh (116 thousand tonnes). These three states altogether accounted for 83 per cent of total national barley production. Rajasthan had the maximum area under barley (275.94 thousand hectares) and contributed a share of 43 per cent to the total area and 54 per cent to the total production. The average crop productivity in barley was highest in the case of Punjab (3795 kg ha^{-1}) followed by Haryana (3650 kg ha^{-1}), Rajasthan (3046 kg ha^{-1}) and Uttar Pradesh (2706 kg ha^{-1}) (Indiastat, 2016-17).

Barley in Haryana is grown mainly in the South-Western zone with an area of 20 thousand hectare with production 73 thousand tones and average productivity 3650 kg ha^{-1} (Indiastat, 2016-17).

The imbalanced and indiscriminate use of high analysis chemical fertilizers has developed many problems like decline of soil organic matter, deterioration in the quality of crop produce, increase in salinity and sodicity, pests and diseases incidence and increase in soil pollutants (Chakarborti and Singh, 2004). Moreover, constant and sole use of inorganic fertilizers leads to create innumerable problems for example micronutrient insufficiency, imbalance use of nutrient in case of plant and soil system, pest attack, environmental degeneration and decline of soil health.

Organic matter is very important for the plant growth because it improves the chemical, physical and microbial properties of soil. It contains large amount of macro and micronutrients. Humic is a substance which is produce by the decomposition of organic material which is very useful for maximizing the yield and improving fertility status of soil. Nitrogen is the key element in achieving consistently high yields in cereals. Nitrogen is a constituent of many fundamental cell components such as nucleic acids, amino acids, enzymes, and photosynthetic pigments. The rate of uptake and partition of N is largely determined by supply and demand during various stages of plant growth. Vermicompost, which are stabilized organic materials produced by earthworms and microorganisms, have been reported to improve plant growth and yields in greenhouse crops (Edwards *et al*., 2004).

Biofertilizers are the preparations containing living cells or latent cells of efficient strains of microorganisms that helps in uptake of nutrients by their interaction in the rhizosphere when applied through seed or soil. There are various types of biofertilizers like *Rhizobium, Azotobacter, Azospirillum, Blue green algae* and *Azolla.* Biofertilizers add nutrients through the natural processes of N_2 fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances. Biofertilizers play an important role in the plant growth as well as they bring down the cost of chemical fertilizers e.g. nitrogen, phosphorous, and potassium. The microorganisms in biofertilizer restore the nutrient cycle and build up soil organic matter.

The occurrence of nitrogen fixing and phosphorous solubilizing bacteria such as *Azotobacter, Pseudomonas* and *Bacillus* etc within the rhizosphere of plants of economic importance is being recently harnessed in Indian agriculture. Inoculation of these bacteria has synergic and additive effects on plant growth besides reducing the cost of cultivation.

The microbes play an important role in the plants life cycle with the help of following activities such as decomposition, solublization, and fixation and also help in nutrients supplying. Biofertilizers improves mineralization of carbon and nitrogen by promoting soil microbial activities and narrowing down C: N ratio. Biomix which is a low cost input technology that contributed to pollution free atmosphere. It contains a combination of Nitrogen fixers, Phosphorus solubilizers and PGPR found to enhance the growth of cereals, oilseeds and legumes better and save about 20-25% inorganic fertilizers such as nitrogenous and phosphorus in case of rice, cotton, chili, groundnut, soybean and pulses.

Use of both organic manure and chemical fertilizer in appropriate proportion assume complementary and supplementary response to each other in crop production. The combined use of organic fertilizer, inorganic fertilizer and biofertilizers improve the physical properties of soil as well as the soil structure (Katyal, 2000).

It has also been recommended that the response of plant growth may be attributed to the hormone production by these bacteria or due to enhanced nutrient uptake from inoculated roots. Due to prolonged cultivation of crops with recommended dose of inorganic fertilizers alone, the productivity of soils has gone down and time has come to figure out the right and well matched level of fertilizers with these inoculations in case of barley production. Keeping the above aspects in view, the present investigations **“**Integrated nutrient management in barley” was planned with the following objectives:

1. To study the effect of INM on growth, yield and quality characters of barley
2. To work out the economics of various treatments

CHAPTER-II

REVIEW OF LITERATURE

In this chapter, an attempt has been made to review the available literature at different locations in India and abroad pertaining to the problem on various aspects of study on barley crop. Wherever necessary the references from related crops are also included to make the review more comprehensive and complete. The literature is reviewed under the following heads:

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2.2 Effect of Integrated Nutrient Management

2.2.1 Phenology

2.2.2 Crop growth

2.2.3 Yield attributes and yield

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2.1 Effect of chemical fertilizers

2.1.1 Phenology

Kumar (2001) working at Haryana found that heading and maturity of the crop were significantly delayed by 5 days with the application of 160 kg N (109.05 and 155.95 days respectively) over 80 kg N only (103.85 and 150.25 days, respectively) and 4 days with the application of 60 kg P_2O_5 (108.1 and 155.4 days, respectively) over 20 kg P_2O_5 (105 and 151.5 days, respectively). Gurmessa (2002) found that nitrogen application beyond 46 kg ha^{-1} delayed physiological maturity in case of wheat. Laghari *et al.* (2010) reported that application of 180-60-60 N-P-K kg ha^{-1}or higher fertilizer regimes prolonged maturity (147-148 days) and lodging (9.0-15.0%). Neelam and Nanwal (2013) reported in Mungbean-wheat (*desi*) system that days to flowering and days to physiological maturity under low fertility treatments had induced early flowering and early maturity as compared to higher fertility treatments. Their results were in confirmation with the results of Singh and Brar (1994). Similar results of delay in days to flowering and maturity due to higher doses of fertilizer application have also been reported by Bhagchand and Gautam (2000) also concluded that days to flowering and maturity are delayed due to higher doses of fertilizer application. Malik (2017) reported that various levels of fertilizer (50, 75 and 100 % RDF) didn't affect the days taken to emergence of barley significantly. Similar results for days to emergence as affected by varying levels of nitrogen and phosphorus application have been reported by Khan *et al.* (2014). Harfe (2017) showed that apart from 90 % crop emergence appeared in all the plots disregarding the nitrogen and phosphorus application rates. Crop emergence likely 50 % was observed in all plots in a period of eight days. As the Nitrogen level enhanced from 0 kg ha^{-1} to 69 kg ha^{-1}, days to 50 % flowering were deferred from 67.58 to 70.04 days. This showed that more rate of nitrogen delays flowering.

2.1.2 Growth

Singh *et al.* (2001) also reported that the increasing levels of nitrogen significantly increased the growth characters of malt barley up to the highest level of nitrogen. Kumar (2001) showed that enhancing levels of nitrogen fertilizer resulted in significantly enhanced plant height. Sharma and Gupta (2001) revealed that 100 % Nitrogen and Phosphorus (60 kg N ha^{-1} + 15 kg P_2O_5 ha^{-1}) recommended dose, produced significantly more dry matter/plant and taller plants over the lower levels of Nitrogen and Phosphorus. Mian *et al.* (2001) reported that the plant height was statistically similar among the treatments (40, 80 and 120 kg N ha^{-1}) and was poorest in control treatment (0 kg N ha^{-1}) in barley. Nehra *et al.* (2001) while working on wheat found maximum values of dry matter accumulation, leaf area index and chlorophyll content with recommended dose of NPK (120 kg N + 60 kg P_2O_5 + 60 kg K_2O ha^{-1}).

Barley crop response was positive towards graded doses of nitrogen upto 60 kg ha^{-1} in terms of the dry matter accumulation (Kumawat 2003). Moreno *et al.* (2003) reported maximum plant height and dry matter accumulation of barley with 120 kg N ha^{-1} as compared to lower doses. They also concluded that the deficiency of N is evident in the reduction of light interception by decreasing leaf area index, which results in lower grain yield.

Yadav *et al.* (2005) working under Faizabad condition to study the response of wheat to nitrogen after rice, observed that nitrogen level at 180 kg ha^{-l} increased plant height by 15.26 and 6.42 % over 120 and 150 kg ha^{-l}. Singh and Rai (2004) found that the growth parameters like plant height, dry matter, root nodulation, pods/plant were significantly increased with the inoculation with *Rhizobium* + PSB over single inoculation of *Rhizobium* or PSB and no inoculation in soybean. While Kumar and Yadav (2005) reported that application of 150 kg N ha^{-l} produced significantly higher values of growth characters, viz., shoots/metre (75.8 and 67.8), dry matter/metre (185.6 and 183.1 g) and plant height (83.6 and 82.7 cm) over 120 kg N ha^{-l} shoots/metre (71.8 and 63.8), dry matter/metre (178.4 and 175.9 g) and plant height (81.1 and 79.9 cm) during 1997-98 and 1998-99, respectively. Laghari *et al.* (2010) reported that fertilizer rates significantly enhanced plant height and nutrient uptake in wheat. Application of

120, 60 and 60 N, P and K kg ha^{-1} respectively, significantly increased tillers (409 /m^2), leaf area index (2.9) and crop growth rate (10.2 g /m^2 /day) over other treatments. Further increase in NPK showed non-significant response on these traits. However, application of 180-60-60 N-P-K kg ha^{-1} or higher fertilizer regimes recorded maximum plant height (84.2-84.7 cm), nodes/stem (5.3-5.4) and internodes length (12.9 cm). Neelam and Nanwal (2013) reported that the leaf area was significantly affected with increasing levels of N and P resulting into favorable effect on production and assimilation of leaf photosynthates. They also reported that application of 100% RDF resulted in significantly higher plant height over other treatments.

When nitrogen fertilizer rate enhanced from 0 to 69 kg ha^{-1}, then plant height enlarged from 82.63 cm to 94.18 cm. When phosphorus rate was enhanced from 0 to 30 kg ha^{-1} then plant height enhanced from 86.41 to 90.56 cm. Sharma *et al.* (2016) reported that the values of LAI, LAD, CGR and AGR were increasing up to 90 DAS and RGR up to 60 DAS growth stage and then decline up to maturity. However, LAR and NAR were found highest at 30 DAS and decreasing up to maturity stage. The value of dry matter, LAI, LAD, CGR, RGR, NAR and AGR were recorded higher with 125% RDF. The similar trend was observed in LAR up to 60 DAS, but at 90 DAS and maturity stage it was observed higher with 100% RDF. Malik in 2017 at Hisar reported that significantly taller plants, higher dry matter production and Leaf area index of barley were recorded with the application of 100% RDF than lower fertilizer levels (50 and 75 % RDF).

2.1.3 Yield attributes and yield

Sayed *et al.* (2000) showed that grain yield reached about 2.81 and 3.60 t ha^{-1} in the first and second season respectively due to application of 140 kg N + 35 kg P_2O_5 ha^{-1}, with about 40.18 and 95.7% increase over the control. He also found that the two higher doses of nitrogen (80 and 120 kg N ha^{-1}) produced the highest number of ears/m^2 due to more number of effective tillers. The highest number of grains per ear and 1000-grain weight was observed in 80 kg N ha^{-1} followed by 120 kg N ha^{-1} and the lowest was recorded in 0 kg N ha^{-1}. The highest dose of nitrogen (120 kg ha^{-1}) significantly reduced the number of grains per earhead and 1000-grain weight. The highest grain yield (2522 kg ha^{-1}) was obtained from 80 kg N ha^{-1} which was 73% higher than 0 kg N ha^{-1}. Paramjit *et al.* (2001) reported that the increasing levels of nitrogenous fertilizer up to 90 kg ha^{-1} significantly increased growth, yield and yield attributes of malt barley. Turk *et al.* (2003) reported increase in grain yield, grain weight per spike, spike length, spike per plant and spike/m^2 with the increase in nitrogen application. Singh and Singh (2005) at Varanasi reported significant increase in the ears/m^2, 1000-grain weight and grains/ear with increase in nitrogen up to the highest level tried in barley. Bhat *et al.* (2006) found that enhanced nitrogen application from 90 to 120 kg ha^{-1} resulted in significant increase in grain yield with no further increase at 150 kg ha^{-1}during both the years. Application of 120 kg N ha^{-1} provided a yield advantage of 9.4 and 6.0 per cent over 90 kg N ha^{-1} during 2003-04 and 2004-05, respectively though it was statistically at par with 150 kg ha^{-1}. Sharma and Verma (2010) evaluated in their experiment that the mean grain yield significantly increased from 41.9 to 45.8 q ha^{-1} with increase in nitrogen dose from 30 to 90 kg ha^{-1}. They also reported that nitrogen application increased the thousand-grain weight up to 60 kg ha^{-1}. Further increase in nitrogen application reduced the thousand-grain weight whereas increase in nitrogen application increased the grains per spike.

Malghani *et al.* (2010) reported that maximum growth parameters responded significantly to NPK fertilizers in wheat crop. The highest grain yield of 5168 Kg ha^{-1} was recorded with the application of 175-150-125 NPK Kg ha^{-1}. The increase in yield was 51.58% higher as compared to control (2502 Kg ha^{-1}), where no fertilizer was applied. Singh *et al.* (2013) also reported that the maximum grain yield was obtained with 93.75 kg N ha^{-1}, which was statistically at par with 78.5 kg N ha^{-1} and significantly higher than 62.5 kg N ha^{-1}. The highest straw yield was obtained with 93.75 kg N ha^{-1}, which was significantly higher than 78.5 and 62.5 kg N ha^{-1}. The highest harvest index was obtained with 62.5 kg N ha^{-1}, which was significantly higher than 78.5 and 93.75 kg N ha^{-1} in malt barley. The positive effect of nitrogen on the growth of stem and leaf area, were reflected into taller plants thus higher green area for light interception and photosynthesis that led to higher photo assimilates translocation and accumulation resulting in higher grain yield (Javaheri *et al.,* 2014).

Yousefi and Sadeghi (2014) reported in wheat that application of 100% recommended dose of urea resulted into significantly higher seed number (31.9), thousand grain weight (50.9 g), spike number (513.8), spike length (21.0 cm), spikelet number/spike (21.0), grain yield (4885.4 kg ha^{-1}) and biological yield (15370.0 kg ha^{-1}) as compared to 25, 50 and 75% recommended rate of urea.

Nega *et al.* (2015) in barley crop concluded that the biological yield enhanced with the enhancement in the rate of nitrogen fertilizer and maximum biological yield was obtained from 80.5 kg N ha^{-1} whereas the lowest biomass yield was obtained from plants grown without N-fertilizer. Plants supplied with highest rate of N had biological yields exceeding by 66.5% over plants in the control treatment. Highest plant stature, spike number, spike weight, spike length, number of spikelets per spike, 1000 grain weight, plant weight, thousand grain weight, chaff weight and harvest index was associated with 200 kg N ha^{-1} in barley (Alghabari and Al-Solaimani, 2015).

Kumar *et al.* (2017) showed that grain yield in barley increased significantly with increased nitrogen doses upto 150 kg N ha^{-1} during 2010-11 and 2011-12. The grain yield at 150 and 200 kg N ha^{-1} were statistically similar. Minimum grain yield was recorded in control (0 kg N ha^{-1}). Malik (2017) at Hisar reported that increasing levels of fertilizer resulted in significant higher yield attributes (number of spikes per meter row length, more number of grains per spike and test weight) and yield (grain, straw and biological yield) of barley. However, plant population, harvest and attraction index of barley were statistically similar under all the fertilizer levels.

2.1.4 Nutrient uptake

Fageria and Baligar (2001) reported that nitrogen uptake in grain has positive significant associations with grain yield. Katiyar and Uttam (2003) concluded that the increase in fertility levels increased the concentration and uptake of N, P and K in grains and straw. The highest value observed with application of 60 kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1} in respect of N, P and K uptake might have been due to greatest amount of dry matter production as a result of the highest grain and straw yield obtained under high fertility schedule. Kumar (2005) revealed that highest nitrogen, phosphorus and potassium uptake in grain was observed with the application of 125% of recommended dose of nitrogen. Similarly maximum phosphorus and potassium uptake by Stover was obtained by this treatment. Singh and Singh (2005) reported that the application recommended dose of fertilizer resulted in the maximum uptake of N, P and K, Grain and straw yields and protein content in grain was significantly higher over no fertilizer, 25, 50 and 75% of the recommended dose of fertilizer. Mekonen (2005) showed that the nitrogen content of grain and total nitrogen content were normally larger with applied nitrogen. Roy and Singh (2006) stated that there was significantly higher uptake of the NPK by grain and straw recorded with 90 kg N ha^{-1} and 30 kg P ha^{-1}. Woldeyesus *et al.* (2004) and Muurinen (2007) reported significant increase in straw nitrogen uptake with increased N rates. However, the split applications did not show significant increment as the rates of nitrogen increased. Nitrogen concentration in grain increased with increasing the dose of nitrogen from 70 to 100 kg N/acre in barley. The uptake of the N and P by grain and straw of barley crop was significantly higher with 100% NPK over control. This increase may be credit to better growth and yield of barley (Chakrawarti and Kushwah, 2007). Laghari *et al.* (2010) reported that fertilizer rates significantly enhanced plant and nutrient uptake in wheat. Application of 120, 60 and 60 N, P and K kg ha^{-1} respectively significantly over increased N uptake (94.2 kg ha^{-1}), P uptake (18.7 kg ha^{-1}) and K uptake (95.5 kg ha^{-1}). Neelam and Nanwal (2013) reported that application of higher dose of fertilizer resulted into higher uptake of N by wheat crop.

The higher grain nitrogen concentrations were obtained in response to levels of 100 kg N/acre and the lowest value of this parameter was obtained under 70 kg N/acre (Taalab *et al.,* 2015). They also reported that straw and grain nitrogen uptake was significantly affected by N fertilizer rate and nitrogen uptake by grain and straw of barley with 100 kg N/acre was higher than 70 kg N/acre. Malik in 2017 at Hisar reported that application of 100% RDF recorded significantly higher N content and N, P and K uptake in grain and straw than the lower fertilizer levels (50 and 75 % RDF).

2.1.5 Quality

Woldeyesus *et al.* (2004) and Muurinen (2007) revealed that proportion of bold grains increased with N up to 60 kg ha^{-1} but further increase reduced the proportion of bold grains and the proportion of thin grains decreased with increase in nitrogen from 30 to 60 kg N ha^{-1}. Singh and Singh (2005) observed significant increase in protein content of barley upto 90 kg N ha^{-1}.

Roy and Singh (2006) stated that the starch content of malt barley was significantly reduced with increased application of 30, 60 and 90 kg N ha^{-1} whereas protein content was found to increase significantly. Yadav *et al.* (2005) reported that there was a progressive increase in protein content in grain of wheat with increasing level of N from 120 to 180 kg ha^{-1}. Significantly higher protein content in grain was found with 150 and 180 kg N ha^{-1} over 120 kg N ha^{-1}. However, the difference between 150 and 180 kg N ha^{-1} was not significant. Husk content was lowest at 90 kg N ha^{-1} with three irrigations (Sharma and Verma, 2010). Thakral and Madan (2008) reported that the application of recommended dose of nitrogen through inorganic source proved best with 11.84% protein content in grain. Todarmal in 2013 reported that maximum malt recovery was recorded in no nitrogen application and it was to the tune of 88.90%. The difference between 90 and 120 kg N ha^{-1} was not significant for malt recovery. The similar trend was also observed with hot water extract. Nitrogen levels reduced hot water extract significantly over control and recorded the minimum value (75.75%) with 120 kg N ha^{-1}. The difference between 90 and 120 kg N ha^{-1} was non-significant for hot water extract. Nega *et al.* (2015) found that grain protein content, thousand kernel weight, kernel plumpness and hectoliter weight had a positive response to N-fertilizer rate and was higher at 69 kg N ha^{-1} while low values obtained from the control. Alghabari and Al-Solaimani (2015) reported that nitrogen rate of 200 kg N ha^{-1} produced grains which had the highest nitrogen and protein contents (2.64% - 16.52%) followed by 100 kg N ha^{-1} (2.52%) and the lowest nitrogen and protein contents were produced under no nitrogen fertilizer. Neelam and Nanwal (2013) reported that hectoliter weight and gluten content were not significantly affected due to varying fertility levels while sedimentation value was found highest in T_6 (50% N through FYM + biofertilizer N + rockphosphate + PSB) and highest protein content was recorded in treatment T_7 (100% RDF) during both the years of study. Malik in 2017 at Hisar reported that application of 100% RDF recorded significantly higher protein content and NDVI value of barley than the lower fertilizer levels (50 and 75% RDF).

2.1.6 Economics

Pandey *et al.* (2000) stated that fertilizer rate of 160, 80 and 60 kg N, P and K ha^{-1} recorded significantly higher yield attributes, *i.e.* tillers/metre row length, ear length, grains per ear and grain yield, but failed to achieve significant increase in net return than 120, 60 and 40 kg N, P and K ha^{-1} which accrued the maximum benefit: cost ratio.

Katiyar and Uttam (2003) opined that application of 60 kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1} also recorded the highest net returns. Kumar (2005) showed that in case of bajra-wheat cropping system gross returns, net returns and benefit cost ratio were highest (Rs.61,471.90, Rs.35,162.90 and 1.33, respectively) in the treatment of 125% recommended dose of nitrogen and the lowest was in the case of absolute control. Neelam and Nanwal (2013) reported that in mungbean-wheat cropping system highest systems gross returns were found in T_5 (1/3 N each applied in form of FYM + vermicompost + neemcake + 75% RDN) during both the years whereas net returns and B:C ratio were found highest under treatment T_7 (100% RDF) during first and second year, respectively. Chakrawarti and Kushwaha (2006) reported that the higher net profit was obtained with 90 kg N ha^{-1}, compared to 60, 30 Kg N ha^{-1} and control treatment in wheat crop. Todarmal (2013) at Hisar reported that highest net return of Rs. 27671 and benefit: cost ratio (1.99) was recorded from treatment applied with 120 kg N. The benefit: cost ratio with the application of 90 kg (1.98) and 120 kg N (1.99) was obtained nearly equal to each other. This might be due to less increase in grain yield and straw yield and more increase in cost of cultivation with each additional increase in nitrogen level after 90 kg N ha^{-1}. This is in confirmation of the results obtained by Singh and Singh (2005), Kumawat (2003) and Meena *et al.* (2012). Malik (2017) revealed that significantly higher value of net and gross returns of barley was observed with the application of 100 % RDF than the lower values (50 and 75% RDF). Highest B: C ratio was recorded with the application of 100 % RDF which differs significantly with lower levels of fertilizer application (50 and 100% RDF).

2.2 Effect of Integrated Nutrient Management

2.2.1 Phenology

Rathore and Gautam (2003) reported that biofertilizers resulted in a significant improvement in growth parameters over control and further observed that use of biofertilizers with low dose of N and P *i.e.* 40 kg N + 30 kg P_2O_5 ha^{-1}+ biofertilizers improved growth characters equal to higher dose of N and P *i.e.* 60 kg N + 45 kg P_2O_5 ha^{-1}. Rehman *et al.* (2010) reported that different levels of NPK and FYM alone or combination had significant effect on days to 50% heading and day to maturity. Nitrogen application beyond 46 kg ha^{-1} delayed the physiological maturity (Gurmessa 2002) and Abebe and Manchore (2016) reported that fertilizer application rate had significantly influenced days to heading and maturity of barley. Neelam and Nanwal (2013) recorded that the organic fertilizers alone or in combination with inorganic fertilizers did not influence any of the phenological events of wheat significantly. Harfe (2017) reported that that higher rate of nitrogen application delays flowering. Malik in 2017 at Hisar recorded that significantly lower days to 50% tillering were recorded with the application of 100% RDF as compared to 50% RDF and were at par with 75% RDF, whereas days taken to 50% heading, 50% anthesis and maturity were significantly increased with increasing levels of fertilizers.

2.2.2 Crop growth

Shukla and Warsi (2000) observed that all the growth characters (LAI, LAR, NAR, RGR and dry matter accumulation) were higher at high fertility (120:60:60 kg NPK ha^{-1}) than medium fertility. Maximum LAI was observed at 75 DAS (5.36), LAR at 30 DAS (163.74 cm/g), NAR at 60-75 DAS (8.31 g/m^2/day) and RGR at 30-45 (80.65 mg/g/day) crop growth periods. Grain yield and harvest index were also recorded with high fertility than low fertility.

Chaturvedi (2006) observed that integrated use of inorganic P and organic source (farmyard manure) proved significantly superior to alone application of P level (12.7, 19.5, 26.7 and 34.9 kg ha^{-1}). The analysis for respective years of experimentation further revealed that the maximum plant height (91.9 cm), total number of tillers/m^2 (1798), leaf number/m^2 (1070), leaf weight (275 g/m^2), leaf area index (2.48), dry matter accumulation (18.34 t ha^{-1}), number of grains per spike (47.5), 1000 grain-weight (45.2 g), seed yield (5.05 t ha^{-1}), straw yield (7.0 t ha^{-1}) and N, P and K uptake (49.3, 7.2 and 50.1 kg ha^{-1}), were recorded in the plots receiving phosphorus in combination with phosphate-solubilizing bacteria (*Pseudomonas striata*) and farmyard manure indicating that the combined application of phosphorus and farmyard manure with phosphorus-solubilizing bacteria had highest degree of influence on growth, yield and nutrients uptake of wheat thus emphasizing the need for P application in conjunction with solubilizers and organic source (farmyard manure) to wheat and other crops. Choudhary and Gautam (2006) reported that among nutrient management practices, growth and total productivity was found highest in pearlmillet with 60 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 10 t FYM ha^{-1} + bio-fertilizer. Malghani *et al.* (2010) reported that maximum growth parameters responded significantly to NPK fertilizers. However, application of 180-60-60 N-P-K kg ha^{-1} or higher fertilizer regimes recorded maximum plant height (84.2-84.7 cm), nodes/stem (5.3-5.4), internodes length (12.9 cm), prolonged maturity (147-148 days) and lodging (9.0-15.0%). Rehman *et al.* (2010) reported that different levels of NPK and FYM alone or combination had significant effect on tillers/m^2, leaf area index, plant height and grain yield. Maximum tillers/m^2 (330), plant height (82.4) and grain yield (2505 kg ha^{-1}) were recorded at 80:60:60 kg NPK ha^{-1}. Maximum leaf area index (2.50) was recorded at 80-60-30 kg ha^{-1}, while minimum leaf area index (2.23) was found at low level of 40-30-30 kg NPK ha^{-1}. Neelam and Nanwal (2013) reported that application of organic and inorganic sources of nutrients significantly improved the dry matter accumulation over 50% N through FYM + biofertilizers N + rock phosphate + PSB in wheat. Similar findings have been reported by Nisha *et al.* (2007) and Dubey and Dutt (2008). Seyedlar *et al.* (2014) reported that the nitrogen + PGPR + mycorrhiza treatment in french bean was the most effective treatment and resulted in the highest plant height (94 cm), the number of tillers (7.2), 1000 kernels weight (44.41 g), grain yield (8645.3 kg ha^{-1}) and biological yield (19762.5 kg ha^{-1}).

2.3.3 Yield attributes and yield

Khavazi *et al.* (2005) reported that application of *Azotobacter* and *Azospirillum* inoculums in controlled field trails in Iran resulted into improvements in the yield by more than 20% in wheat. Chaturvedi (2006) observed that the combined application of inorganic phosphorus and farmyard manure with phosphorus-solubilizing bacteria had highest degree of influence on yield and nutrients uptake of wheat thus emphasizing the need for P application in conjunction with solubilizers and organic source (farmyard manure) to wheat and other crops. Choudhary and Gautam (2006) reported that among nutrient management total productivity was found highest with 60 kg N ha^{-1}+40 kg P_2O_5 ha^{-1} +10 t FYM ha^{-1} + biofertilizer. Behera *et al.* (2007) found that the grain yield of durum wheat was significantly increased with integrated use of 50 or 100% NPK + poultry manure at 2.5 t ha^{-1} or farmyard manure at 10 t ha^{-1} compared with inorganic fertilizers alone. The yield improvement was 13.5 and 22.9% and 11.4 and 14.5% with farmyard manure and poultry manure at 50 and 100% recommended NPK respectively over the sole application of inorganic. The highest productivity was obtained when these organic sources were applied along with 100% NPK, indicating that NPK fertilizers alone did not provide adequate and balanced nutrition to realize the potential yield of the crop. Gopinath *et al.*, (2008) reported treatments that received vermicompost significantly increased yield compared to control treatment. Rather and Sharma (2009) observed that conjunctive use of PSB, Zn and FYM in collaboration with 100% recommended NPK produced significantly higher grain and straw yield of wheat as compared to its counterpart of 50% recommended dose of NPK, whether applied alone or in combination with FYM, PSB and zinc as well as with absolute control. The yield attributes like ear-head length (cm), number of grains/ear-head and 1000-grains weight (g) increased significantly by increasing fertility levels from 50% to 100% and with the integration of organics with inorganic. Laghari *et al.* (2010) reported that fertilizer rates significantly enhanced plant and nutrient uptake in wheat. Application of 120, 60 and 60 N, P and K kg ha^{-1}, respectively, significantly increased tillers ($409/m^2$), spike length (14.20 cm), grains /spike (47.60), grain weight /spike (2.5 g), seed index (47.6 g), biological yield (11.31 t ha^{-1}), grain yield (4.8 t ha^{-1}), harvest index (42%). Further increase in NPK showed non-significant response on these traits. However, application of 180-60-60 N-P-K kg ha^{-1} or higher fertilizer regimes recorded maximum plant height (84.2-84.7 cm), nodes/stem (5.3-5.4), internodes length (12.9 cm), prolonged maturity (147-148 days) and lodging (9.0-15.0%). Davari *et al.* (2012) reported that the combinations of FYM+ Cropping Residue (CR)+ Biofertilizers (B) and Vermicompost (VC)+ CR+B resulted in the highest increased growth and yield attributing characters of wheat and increased grain yield of wheat over the control by 81% and 89%. These combinations were significantly superior to all other combinations for all the growth, yield parameters and yield of wheat. Das *et al.* (2012) reported that FYM application @ 15 t ha^{-1} along with 100% NPK fertilizers produced maximum yields, nutrients uptake along with improvement in soil properties. Basak *et al.* (2013) reported that the application of 50% NPK along with organic manures significantly improved grain yield and mineral composition. Kaushik *et al.* (2013) reported that the wheat crop under vermicompost 3.00 t ha^{-1} +100% RDF recorded significantly higher grain (4.96 t ha^{-1}), straw (6.46 t ha^{-1}) and biological (11.42 t ha^{-1}) yields over vermicompost 1.50 and 3.00 t ha^{-1}, respectively. Seed inoculation of *Azospirillum* + PSB recorded significantly higher grain (4.92 t ha^{-1}), straw (6.38 t ha^{-1}) and biological yield (11.30 t ha^{-1}) over *Azospirillum* and control. Neelam and

Nanwal (2013) observed that highest yield of wheat (*Desi*) in mungbean-wheat cropping system was recorded with the application of 75% recommended dose of fertilizers integrated with organic manures followed by 100% recommended dose of fertilizers. Agegnehu *et al.* (2014) found that application of 60/20 kg NP ha^{-1} and 30/10 kg NP ha^{-1} with 50% manure and compost as N equivalence increased mean grain yield of wheat by 151% and 129%, respectively, compared to the control, and by 85% and 68% respectively compared to the farmers treatment (23/10 kg NP ha^{-1}). Similarly, the same treatments increased the grain yield by 141% and 122% compared to the control, and by 44% and 33% compared to the farmer's treatment. The application of compost or manure with half the recommended NP fertilizer rate resulted in a comparable yield as that of full NP dose, which could be considered as an alternative option for sustainable soil health and crop productivity. Yousefi and Sadeghi (2014) investigated that combined application of urea fertilizer; organic fertilizer like vermicompost had significant effects on grain yield and grain weight of wheat crop. The maximum yield in wheat was obtained with treatments 100% of the recommended urea with 10 and 15 t ha^{-1} vermicompost and 75% urea + 15 t ha^{-1} vermicompost, respectively. They concluded that the application of vermicompost and organic fertilizer can be reduced the dose of chemical fertilizer (urea) up to 25%. Malik in 2017 reported that among different combinations of biofertilizers, seed inoculation with *Biomix* recorded significantly higher yield attributes (number of spikes per meter row length, number of grains per spike and test weight), grain, straw and biological yield of barley. But harvest index of barley did not differ significantly due to seed inoculation with different combinations of biofertilizers during both the years of experimentation.

2.2.4 Nutrient uptake

With respect to the nutrient uptake, Atiyeh *et al.* (2000 and 2000) reported that P, K, S and Mg were significantly increased in vermicompost application as compared to conventional compost application. Bansal and Kapoor (2000) revealed significant reduction in C: N ratio and increase in mineral N with the application of vermicompost. They reported that contents of P, K and Cu remain unchanged in the soil. Significantly higher nutrient uptake and improvement in available nutrient status was observed with the integrated application of inorganic and organic manures.

Continuous addition of organic manure alone or in combination with inorganic fertilizers significantly influenced the total organic carbon, CO_2 evolution, microbial biomass, water soluble carbon, water soluble carbohydrates (Umesh and Prasad, 2014). Continuous application of 100% NPK along with lime, FYM and integrated management practices had beneficial impact on restoration of Soil Organic Carbon, maintaining soil fertility and yield sustainability of maize-wheat cropping system in Alfisols. Abrol *et al.* (2010) reported that the application of organic manures enhanced the water productivity and organic carbon status.

During six years 21% increase in OC was observed with the treatment receiving FYM at 10 t+40 kg N ha^{-1}. This treatment gave the highest yield response (38%) than the control. The results revealed that application of FYM is necessary to improve the soil quality and to sustain the wheat productivity in rainfed areas. Davari *et al.* (2012) reported that the combinations of FYM+RR+B and VC+RR+B resulted in the highest nutrient uptake by wheat grain. Neelam and Nanwal (2013) reported that lowest total nitrogen uptake was recorded in T_6 (50 % N through FYM + biofertilizer N + rockphosphate + PSB) and total nitrogen uptake was recorded significantly higher in treatment T_5 (1/3 N each applied in form of FYM + vermicompost + neemcake+ 75% RDF) in mung-wheat crops. Significantly lowest total potassium uptake was recorded in T_6 as compared to all other treatments in both the years. Highest total potassium uptake was recorded in T_5 during both the years. Kaushik *et al.* (2013) reported that the wheat crop under vermicompost 3.00 t ha^{-1}+100% RDF recorded significantly higher N, P, and K uptake over vermicompost 1.50 and 3.00 t ha^{-1}, alone.

2.2.5 Quality

Singh *et al.* (2003) reported that application of 5 t ha^{-1} farmyard manures significantly improved biomass which in turn increased uptake of N and P over control. N and P uptake increased significantly upto 120 kg N + 60 kg P_2O_5 ha^{-1}.

Choudhary and Gautam (2006) reported that among nutrient management total productivity was found highest with 60 kg N +40 kg P_2O_5 +10 t FYM ha^{-1} + bio-fertilizer. Behera *et al.* (2007) found that the quality parameters of durum grains, viz. protein content and hectoliter weight increased, while yellow berry content decreased with increasing levels of NPK compared with control. Sole application of inorganic fertilizers was equally efficient with their combined use with organics in improving the quality parameters. Mehrvarz and Chaichi (2008) revealed that the maximum grain protein (11.37%) was obtained with application of sole mycorrhiza. Sole and co-application of Mycorrhiza and phosphorus solubilizing bacteria had significantly positive influence on increasing the percentage of grain protein in barley. Mikhailouskaya and Bogdevitch (2009) revealed that the outcome of biological fertilizers such as *Azotobacter* caused a rise in protein and amino-acid development in barley seeds. Behera and Rautaray (2010) revealed protein content was greater and the hectoliter weight was lesser with 100% NPK in comparison to 50% NPK. Das *et al.* (2011) reported that the balanced application of fertilizer nutrients and combined use of manure and inorganic fertilizers enhances the grain quality of wheat over alone application of inorganic NPK fertilizers. Thalooth *et al.* (2012) showed that biofertilizers inoculation increased crude protein content, while the least values were observed without inoculated barley plants. Chavarekar *et al.* (2013) revealed that the treatment 100% recommended dose of nitrogen (RDN) through chemical fertilizers +*Azotobacter* recorded significantly higher protein percentage (10.8%) and hectoliter weight (59.4g). The malt extract affected inversely with the increase in nitrogen content and protein percentage of grain. Neelam and Nanwal (2013) reported that hectoliter weight and gluten content were not significantly affected due to various fertility levels however, sedimentation value was found highest in T_6 (50% N through FYM + biofertilizers N + rockphosphate + PSB) during both the years. Highest protein content was recorded in treatment T_7 (100% RDF) during both the years of study. Kaushik *et al.* (2013) reported that the Wheat crop under vermicompost 3.00 t ha^{-1} + 100% RDF recorded significantly higher protein content over vermicompost 1.50 and 3.00 t ha^{-1}. Vikhe (2014) reported that inoculation of wheat varieties with mutant of *Azotobacter chrococcum* resulted into greater uptake of NPK. Seyedlar *et al.* (2014) reported that the integrated nutrient management resulted in better quality of wheat. Dhiman and Dubey (2017) stated that quality parameters (protein and carbohydrate content) were highest in treatment where the inoculation with nitrogen fixer and phosphate solubilizers + 125% of nitrogen + 75% of phosphorus was done. Malik in 2017 observed that among different combination of biofertilizers, seed inoculation with *Biomix* produced highest protein content followed by seed inoculation with *Azospirillum + PSB and Azotobacter + PSB* in both the years of experimentation and various combinations of biofertilizers inoculation failed to influence NDVI value of barley.

2.2.6 Economics

Choudhary and Gautam (2006) reported that among various nutrient management practices highest net return was obtained with 60 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1} + bio-fertilizer. Application of 100% NPK + poultry manure was the most profitable treatment, followed by 100% NPK + FYM with the value of Rs. 38280 ha^{-1} and Rs. 37310 ha^{-1}, respectively (Behera *et al.*, 2007). Sharma *et al.* (2007) reported that by integration of FYM and *Azotobacter* with N through chemical fertilizers, productivity and monetary returns of wheat can be increased by maintaining or improving soil fertility. Rather and Sharma (2009) observed that integration of PSB, Zn, and FYM with 100% recommended NPK gave highest net income and benefit: cost ratio (1.54). Behera and Rautaray (2010) observed that maximal net returns were obtained from 100% NPK followed by biofertilizers + 50% NPK and minimum net returns were observed under the control treatment. Davari *et al.* (2012) reported that the combinations of FYM + RR + B and VC + RR + B resulted in the highest increased net return by 82% and 73%, respectively. These combinations were significantly superior to all other combinations for net profit of wheat. The results of this study show that VC + RR + B was the most productive treatment, while FYM + RR + B was the most economical treatment with respect to increasing net profit. Neelam and Nanwal (2013) reported that highest systems gross returns were found in 1/3 N each applied in form of FYM + vermicompost + neemcake + 75% RDF whereas net returns and B: C ratio was found highest under treatment 100% RDF in mungbean-wheat cropping system. Yadav *et al.* (2014) showed that integrated nutrient treatments of 40 kg N ha^{-1} + FYM + biofertilizers recorded significantly higher gross as well as net income than treatment of 120 kg N ha^{-1}. Malik in 2017 reported that in barley seed inoculation with *Biomix* resulted in significantly higher gross returns, net returns and benefit: cost ratio.

CHAPTER-III

MATERIALS AND METHODS

The materials used and methodology adopted to achieve the objectives of present field study entitled, **"**Integrated Nutrient Management in Barley**"** are described in this chapter.

3.1 Material

3.1.1 Location of experimental site

The experiment was conducted during *rabi* season of 2017-18 at Research Farm of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India) situated at 29°10' N latitude and 75° 46' E longitude at an elevation of 215.2 m above mean sea level.

3.1.2 Climate and weather conditions

Hisar has semi-arid and subtropical climate with desiccating and hot dry winds during summer and severe cold during the winter season. During the hot summer months of May – June maximum temperature may rise to about 48°C, while minimum temperature during winter months of December – January may drop to sub-zero. The annual average rainfall is about 400 mm, out of which 70- 80% received during the monsoon period and rest during the winter and spring season. The mean weekly meteorological data recorded during the cropping season of 2017- 18 at meteorological observatory located at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar are given in Fig. 1 and Table 1.

Perusal data showed that only 2.3 mm rainfall was received during the crop growing season. The mean weekly maximum and minimum temperature ranged between 16 to 34.7 ºC and 3 ºC to 21 ºC, respectively .The mean weekly values for morning and evening relative humidity ranged between 56 to 100 and 24.7 to 75%, respectively. While sunshine hours ranged between 2.9 to 7.8 hours during the crop season.

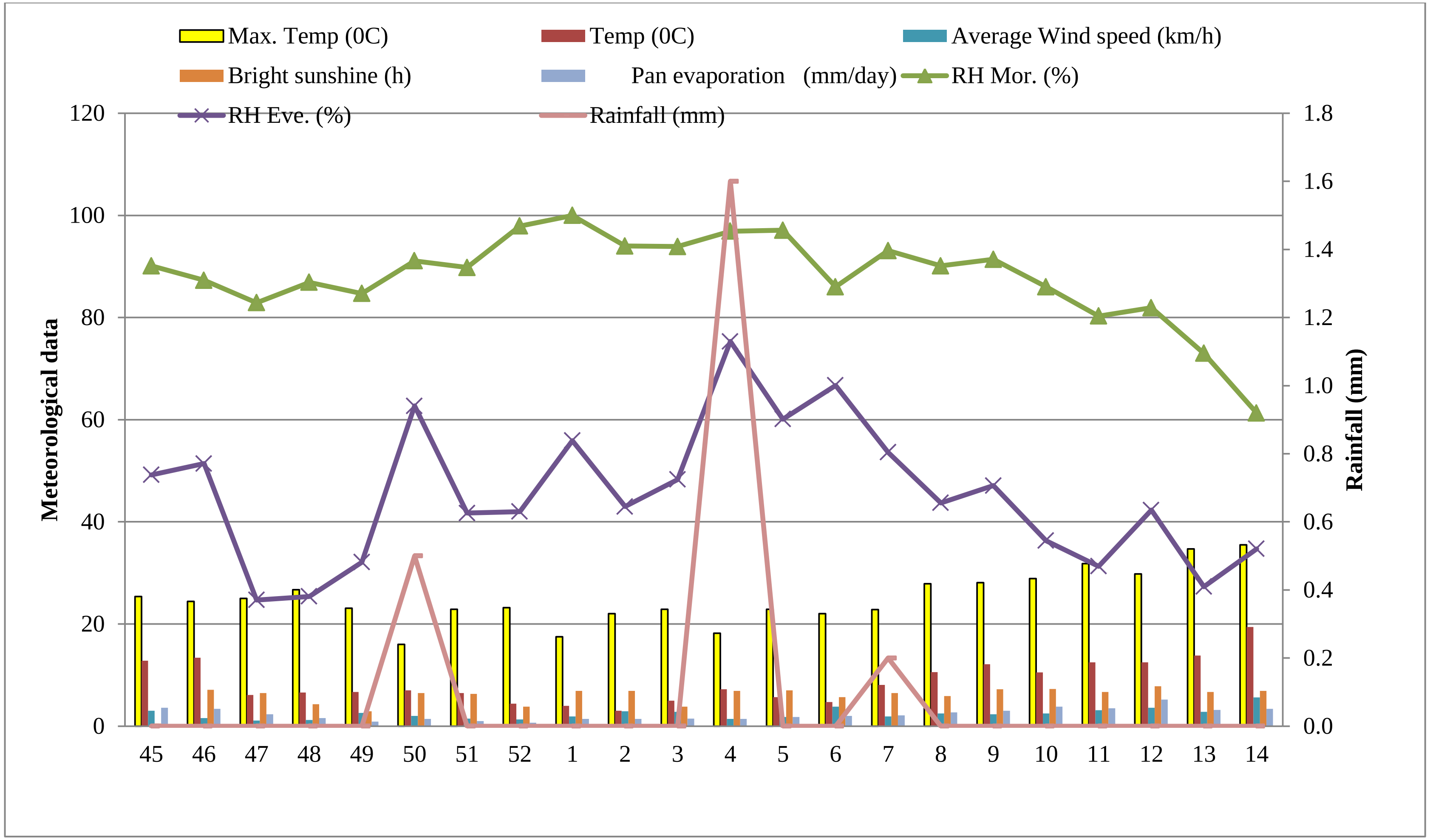

Figure 1: Mean weekly meteorological data during crop growth period

Table 1. Mean weekly value of weather parameter during crop season of 2017-18

Date	Week	Mean temperature (ºC)		Relative humidity (%)		Average Wind speed (km/ha)	Bright sunshine (h)	Pan evaporation (mm/day)	Rainfall (mm)
		Maximum	Minimum	Morning	Evening				
11-18 Nov	46	25.4	12.8	90.1	49.2	3.0	0.5	3.6	0.0
19 - 25 Nov	47	24.4	13.4	87.3	51.4	1.6	7.1	3.4	0.0
26 -02 Dec	48	25.0	6.1	82.9	24.7	1.1	6.5	2.3	0.0
03 – 9 Dec	49	26.7	6.6	86.9	25.4	1.2	4.3	1.6	0.0
10-6 Dec	50	23.1	6.7	84.7	32.1	2.6	2.9	0.9	0.0
17 – 23 Dec	51	16.0	7.0	91.1	62.7	2.0	6.5	1.4	0.5
24 – 30 Dec	52	22.9	6.5	89.8	41.7	1.5	6.3	1.0	0.0
31 Dec–6 Jun	1	23.2	4.4	97.9	42.0	1.3	3.8	0.7	0.0
07- 13 Jun	2	17.5	4.0	100.0	55.9	1.9	6.9	1.4	0.0
14- 20 Jun	3	22.0	3.0	94.0	43.0	2.9	6.9	1.4	0.0
21 – 27 Jun	4	22.9	5.0	93.9	48.3	2.8	3.8	1.5	0.0
28 - 03 Feb	5	18.2	7.2	96.9	75.3	1.4	6.9	1.4	1.6
04 – 10 Feb	6	22.9	5.7	97.1	60.1	1.8	7.0	1.8	0.0
11 - 17 Feb	7	22.0	4.7	86.0	66.7	3.8	5.7	2.0	0.0
18– 24 Feb	8	22.8	8.1	93.1	53.6	1.9	6.5	2.1	0.2
25 – 03 Mar	9	27.9	10.6	90.1	43.7	2.5	5.9	2.7	0.0
04 – 10 Mar	10	28.1	12.1	91.4	47.1	2.3	7.2	3.0	0.0
11 – 17 Mar	11	28.9	10.5	86.0	36.3	2.5	7.3	3.8	0.0
18 - 24 Mar	12	31.8	12.5	80.3	31.3	3.1	6.7	3.5	0.0
25 – 31 Mar	13	29.8	12.5	81.9	42.3	3.6	7.8	5.2	0.0
01 - 08 April	14	34.7	13.8	73.0	27.3	2.8	6.7	3.2	0.0
9 -15 April	15	35.5	19.4	61.3	34.7	5.6	6.9	3.4	0.0

3.3.3 Cropping history of experimental field

The previous crops grown in the experimental field are presented in Table 2

Years	Kharif crop	Rabi crop
2015-16	Fallow	Wheat
2016-17	Dhaincha	Wheat
2017-18	Mungbean	Barley (experimental field)

3.3.4 Soil studies

The soil samples were collected randomly from five different places from the experimental field at 0-15 cm depth before sowing. Composite samples were prepared and analyzed to know the physiochemical properties of soil. The results of analysis along with methods used for determination are presented in Table 3.

According to the results obtained soil has sandy loam texture and slightly alkaline on p^H scale. Organic carbon and nitrogen content was low with medium phosphorus and high potassium availability.

Table 3: Physicochemical properties of soil of experimental field

Soil properties		Values	Methods used
A.	**Mechanical composition of soil (%)**		
	Sand	62.80	International Pipette Method (Piper 1966)
	Silt	19.50	
	Clay	16.90	
B.	**Chemical composition of soil**		
	pH	7.8	Glass electrode pH meter (Jackson 1973)
	EC (dSm-1)	0.27	Conductivity bridge meter (Richards 1954)
	Organic carbon (%)	0.38	Walkey and Black Wet oxidation method (Jackson 1973)
C.	**Nutrients available (kg ha^{-1})**		
	Available N	134	Alkaline permanganate method (Subbiah and Asija 1956)
	Available P	16	Olsen's method (Olsen *et al*. 1954)
	Available K	374	Flame photometric method (Richards 1954)

3.2 Methods

3.2.1 Experimental details and layout

The experiment was laid out in Randomized Block Design with three replications (Fig. 2). The details of the treatments are given in next subset.

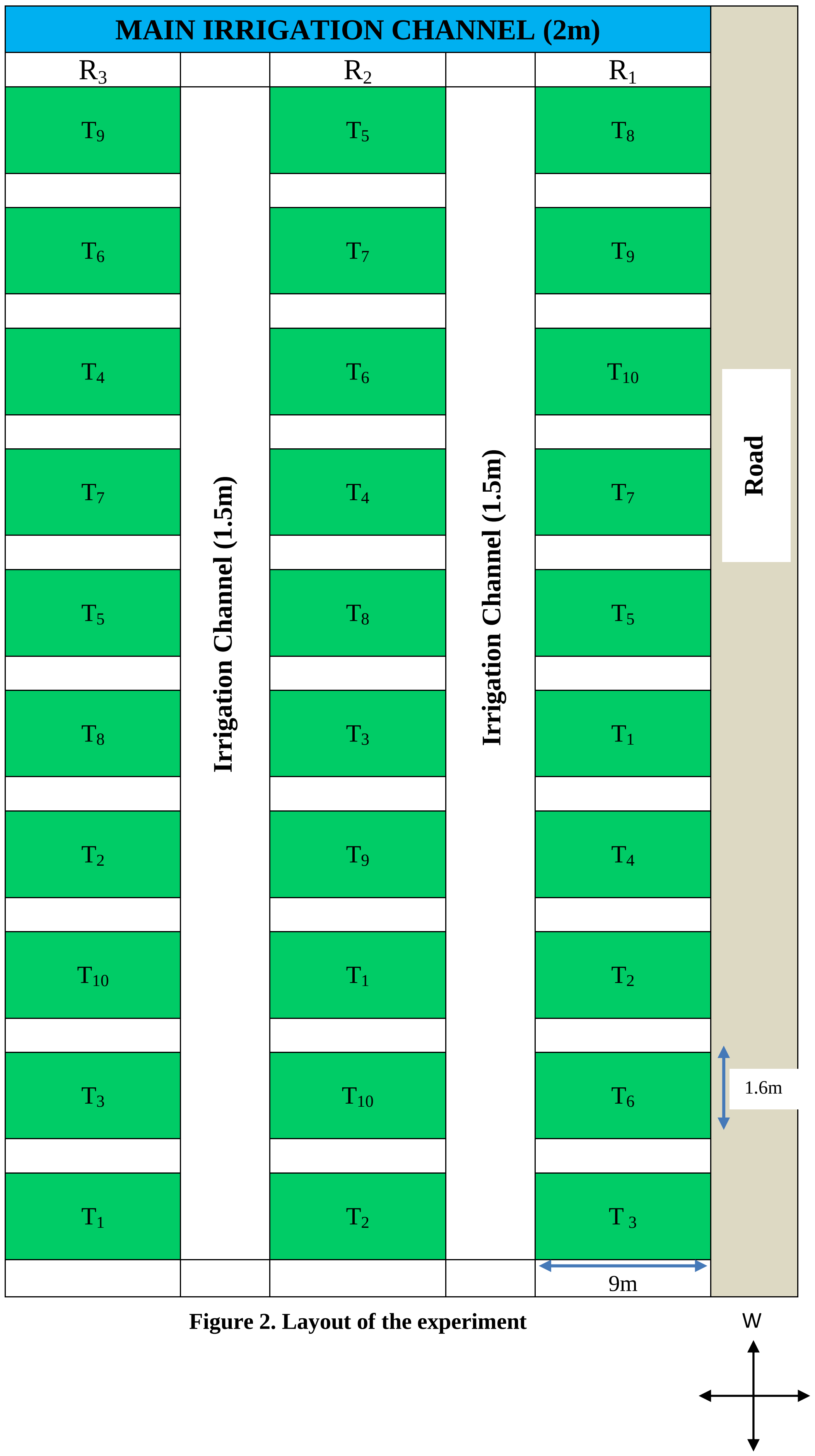

Figure 2. Layout of the experiment

3.2.2 Treatments

Treatment details

T_1: Control

T_2: *Biomix*

T_3: Vermicompost @ 5t ha^{-1}

T_4: *Biomix* + Vermicompost @ 5t ha^{-1}

T_5: 50 % RDN + *Vermicompost* @ 5t ha^{-1}

T_6: 75 % RDN + *Vermicompost* @ 5t ha^{-1}

T_7: 50% RDN + *Biomix* + Vermicompost @ 5t ha^{-1}

T_8: 75 % RDN + *Biomix*+ Vermicompost @ 5t ha^{-1}

T_9: 100 % RDN (60 kg N ha^{-1})

T_{10}: 100 % RDN (60 kg N ha^{-1}) + *Biomix* + Vermicompost @ 5t ha^{-1}

Treatment combination	10 x 3 = 30
Design :	Randomized Block Design
Replications	3
Gross Plot size	2 m x 10 m
Net Plot Size	1.6 m x 9 m
Variety :	BH-902
Season :	Rabi season of 2017-2018
Location :	Research farm of Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar

3.2.3 Observations:

A) Phenology (DAS)

- Days to emergence
- Days to tillering
- Days to flag leaf emergence
- Days to booting
- Days to anthesis
- Days to maturity

B) Growth Parameters

- Plant population (no./mrl) at 20 DAS
- Plant height (cm) at 30, 60, 90 DAS and at maturity.
- Dry matter accumulation (g/ m^2) at 30, 60, 90 DAS and at maturity.
- Number of tillers (no. /mrl) at 30, 60, 90 DAS and at maturity.
- Leaf Area Index at 30, 60 and 90 DAS.

C) Yield Attributes and Yield

- Spike length (cm)
- Number of grains/spike
- Test weight (g)
- Grain yield (kg ha^{-1})
- Straw yield (kg ha^{-1})
- Biological yield (kg ha^{-1})
- Harvest index (%)
- Attraction index (%)

(D) Quality Studies

- Protein content (%)
- Hectoliter weight (g)
- Malt content (%)
- Proportion of bold and thin grain (%)

(E) Soil Studies

- N, P and K content in soil before sowing and after harvest

(G) Chemical Studies

- N, P and K content and uptake in grain and straw of barley

(H) Economics

- Gross returns (Rs ha^{-1})
- Net returns (Rs ha^{-1})
- Benefit-Cost Ratio

3.3 Cultural operations

Table 4: Schedule of cultural operations carried out in the experimental field

A.	**Pre sowing irrigation**		
Sr. No.	**Nature of operations**	**Operation date/Time**	**Details of operations**
1.	Pre-sowing irrigation	18.11.17	Irrigation was done with canal water about ten days before sowing
2.	Seed bed preparation	29.11.17	At proper moisture condition, the field was ploughed twice with disc harrow and once with cultivator followed by planking two days before sowing
3.	Layout and fertilizer/ manure application	30.11.17	Layout was performed and recommended dose of fertilizer applied
4.	Sowing	01.12.17	Sowing of barley was done manually with the help of hand plough by *pora* method
B.	**Post sowing operations**		
1.	Final layout	05.12.17	Final layout, channels and bunds were prepared
2.	Weeding	Removed by hand pulling from time to time in all the plots throughout the crop season	
3.	Irrigation	16.01.18	Flooding method
4.	Harvesting	20.04.18	Done manually with the help of sickles by cutting the crop just above the ground level. Bundles were made separately on each plot and left in the field for sun drying.
5	Threshing	07.05.18	Before threshing the biological yield was recorded for each net plot. Done with the help of mini plot thresher. The grains collected from each net plot were weighed

3.4 Observations recorded

3.4.1 Crop phenological observations

Three plants in each plot were tagged after germination used to record the number of days taken for initiation of different phenophases *i.e.* Days to emergence, Days to 50% tillering, Days to 50% heading, Days to 50% anthesis and Days taken to maturity.

3.4.2 Crop growth studies

A. Plant population

In each plot three places were selected randomly, for counting the number of plant per meter row length at 20 days after sowing. Means were taken for statistical analysis.

B. Plant height

In each plot, plant height of five randomly selected plants were measured from ground surface to terminal growing point of main shoot at 30, 60, 90 DAS and at harvest. Means were taken for statistical analysis.

C. Dry matter accumulation

Plants in 0.5 m row length from the second row on either side in each plot, were cut close to the ground at 30, 60, 90 DAS and at harvest to record dry matter accumulation per metre row length. At the time of selection it was taken care that area of 0.50 m near the bunds was excluded for sampling. These samples were first sun dried and then oven dried at 65 ± 2°C till a constant weight was obtained at each stage. After drying, the samples were weighed for recording dry weight in grams per metre row length.

D. Leaf area Index

Leaves separated from the plants harvested for dry matter accumulation were used to measure leaf area with the help of leaf area meter (LI-3000 Leaf Area Meter LI-COR Ltd. Nebraska, USA).The leaf area index was worked out with the help of following formula:

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Total land area}}$$

3.4.3 Yield and yield attributes

A. Spike length

At the time of harvest, three spikes were selected in each plot for measured of its length. Means were taken for statistical analysis.

B. Number of grains per spike

From the spikes selected for measuring spike length, the grains were threshed from these spikes and the number of grains was counted manually and the grains per spikes were workout. Means were taken for statistical analysis.

C. Test weight

A composite sample of grains was taken from the produce of each net plot and each sample was spread on table and 1000- grains were counted manually for test weight.

D. Grain yield

After threshing with the help of mini plot thresher the grain yield was recorded for each net plot area and then it was converted into kg ha^{-1}.

E. Straw yield

Straw yield (kg ha^{-1}) was obtained by subtracting grain yield from biological yield for each plot and expressed in kg ha^{-1}.

F. Biological yield

Sun dried weight of all harvested plants in each plot was recorded and then converted in biological yield (kg ha^{-1}).

G. Harvest index (HI)

Harvest index (%) is the ratio of grain yield to biological yield and expressed in percent. It was calculated for each plot by using following formula:

$$\text{Harvest Index} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \times 100$$

H. Attraction index (AI)

Attraction index is the ratio of grain yield to straw yield and multiplied by 100. It was calculated for each plot by using following formula:

$$\text{Attraction Index} = \frac{\text{Grain Yield}}{\text{Straw Yield}} \times 100$$

3.4.4 Grain quality analysis

A. Protein content

Protein content (%) in grain from each plot was calculated by multiplying the percentage of nitrogen in grain with 6.25.

B. Hectoliter weight

This parameter merits consideration for millers as it positively correlated with the flour recovery. This was measured with the hectoliter weight equipment at wheat-barley laboratory at College of Agriculture, CCS HAU, Hisar. The instrument uses 100 ml volume of barley grain. Weight of measured quantity of grains gives the value in kg/hectolitre.

C. Bold and thin grain percentage

Bold and thin grain was determined by using sortimeter. 100 grains of barley of each sample were taken and they were allowed to pass through the sieve of size of 10 mm. The thin grains were passed out in the container and the bold grains were left on the sieve. Thus the percentage of bold and thin grains was calculated.

D. Malt content percentage

Malting process of barley grains were carried out as per the method suggested by (Singh and Sosulski, 1985). Properly cleaned, weighted samples of barley grains were steeped in water at 15°C in an incubator for a period of 60 hours. Water was changed every 8-10 hours and an air rest of 1 hour was given after 24 hours during steeping. Then steeped samples taken in a muslin cloth were placed in a wooden box with wire mesh bottom for germination in an incubator at 15°C and relative humidity of more than 90 percent. They were allowed to germinate for a period of 5 days. Then the green malt was kilned in an oven at 45°C for 4 hours. Roots from the kilned malt were removed. Weight of malt and roots was recorded separately to calculate malt yield.

$$\text{Malt content}(\%) = \frac{\text{Malt weight}}{\text{Sample weight}} \times 100$$

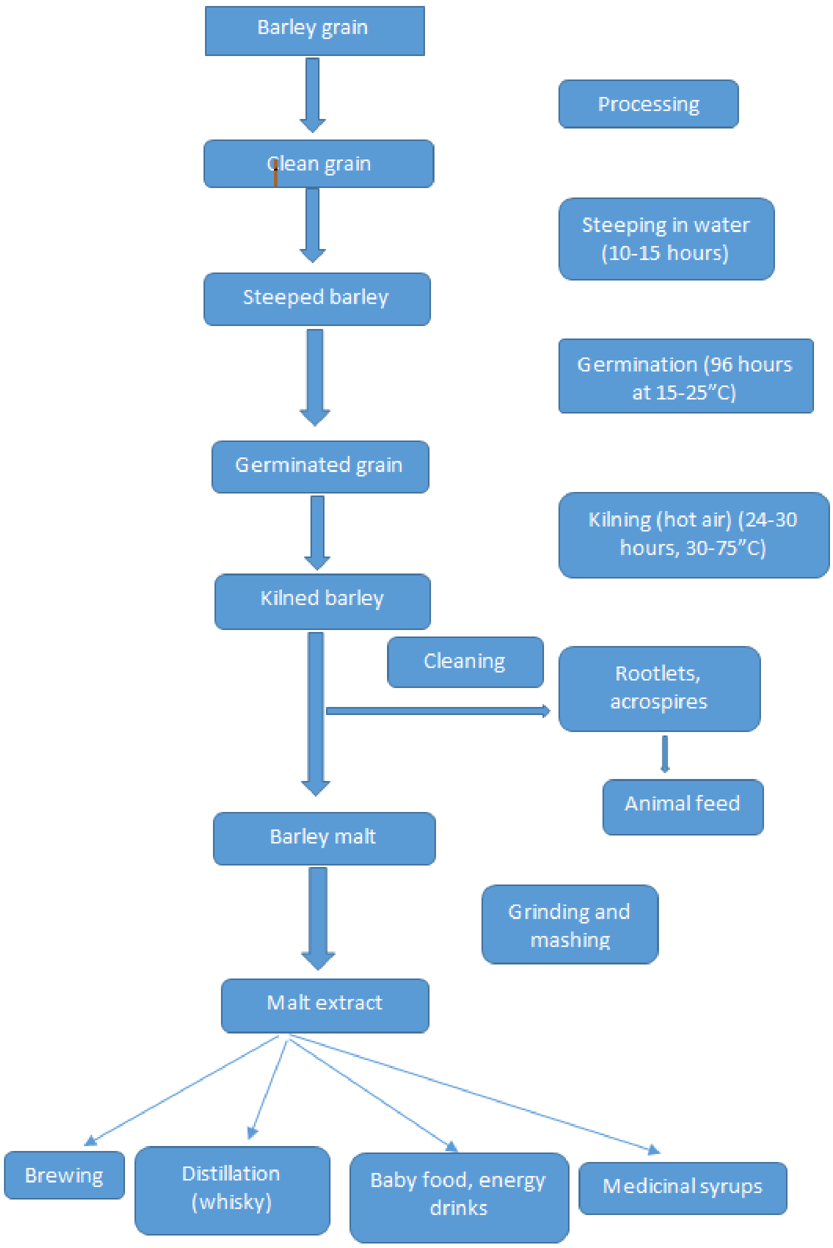

Fig. 3. Malt processing of barley

3.4.5 Grain nutrient analysis: NPK content and uptake by crop

For analysis of N, P and K, oven dried plant material and grain from each plot was grinded separately with grinder and analysis the Nitrogen (Nessler's reagent method, Lindner, 1944), phosphorus (Vanadomolybdo-phosphoric acid yellow colour method, Jackson, 1973) and potassium (Flame photometer method, Richards, 1954) content in sample were analyzed. The uptake (N, P and K) of each nutrient was computed as:

$$\text{Nutrient uptake by grain (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in grain (\%)} \times \text{Grain yield(kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in straw (\%)} \times \text{straw yield(kg ha}^{-1}\text{)}}{100}$$

3.4.6 Soil analysis

The composite soil samples from 0-15 cm depth were analyzed before sowing and after harvesting for determining the available nitrogen, phosphorus and potassium.

A. **Nitrogen estimation:** Available N in soil was determined according to alkaline permanganate method by Subbiah and Asija (1956).

B. **Phosphorus estimation:** Available P in soil was determined by Olsen's method (Jackson 1973).

C. **Potassium estimation:** Available K in soil was extracted by neutral normal ammonium acetate and estimated by flame photometer (Piper, 1966).

3.4.7 Statistical analysis

The experimental data for various growth, yield, yield attributing characters, nutrient contents uptake and quality parameters was statistically analyzed by the methods of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985). The significance of treatment effects as well as significance of differences between means of two treatments was computed with the help of "F" (variance ratio) test. Critical differences (CD) were sorted out as described by Gomez and Gomez (1983) as follows:

$$CD = \sqrt{\frac{\text{EMS x 2}}{n}} \quad \text{x} \quad \text{t-value for error d.f. at 5\% level of significance}$$

Where,

CD = Critical difference

n = Number of observations of that factor for which CD is to be calculated.

t = Value of Fisher's table for error degree of freedom at 5% level of significance.

3.4.8 Economics

The expenditure incurred on individual treatment was worked out from the detail assessment of the fixed and variable costs involved such as land preparation, seed, plant protection, chemicals and labour engaged in different operations. Gross income for all treatment was calculated separately taking into consideration grain and stover yield of barley crop. Thereafter, net returns were calculated after subtracting expenditure incurred on the individual treatment from the gross expenditure of the same treatment.

To ascertain the economic viability treatment wise benefits cost (B: C) ratio was calculated using the following formula:

$$B{:}C = \frac{Gross\ return\ (\mathrm{Rs.\,ha^{-1}})}{\mathrm{Cost\ of\ cultivation\ (Rs.\,ha^{-1})}}$$

CHAPTER-IV

EXPERIMENTAL RESULTS

The results of the experiment "Integrated Nutrient Management in barley" conducted at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar during *Rabi* 2017-18 are presented in this chapter with the help of tables and appropriate figures.

4.1 Phenological studies

The data pertaining to days taken to different phenological events of barley are presented in Table 5 and Fig. 3. The data indicates that the various combinations of nitrogen fertilizer, *biomix* and vermicompost failed to produce any significant variation in days taken to emergence and tillering in barley. Days taken to tillering were between 30.12-33.28 DAS and anthesis between 79.09-89.35 DAS. However, the treatments T_{10} (100% RDN) had taken numerically more number of days for seedling emergence and tillering.

Perusal of data reveals that number of days taken to flag leaf emergence; booting, anthesis and maturity of barley were significantly affected due to various combinations of nitrogen fertilizer, *biomix* and vermicompost. Treatment T_{10} (100 % RDN) took highest number days to flag leaf emergence, booting, anthesis and maturity as compared to other treatments. Minimum number of days to flag leaf emergence, booting, anthesis and maturity were recorded in treatment T_1 (control). However, days taken to booting in treatment T_1 (Control) was at par with treatment T_2 *(biomix)* and T_3 (vermicompost @ 5t ha^{-1}). While days to flag leaf emergence with treatment T_1 (Control) was at par with treatment $T_{2,}$ T_3 and $T_{4.}$ Days taken to anthesis were increased by ten days under treatment T_{10} (89.35 DAS) as compared to T_1 (79.09 DAS). In general various combinations of nitrogen fertilizer, *biomix* and vermicompost had taken numerically more number of days for maturity of barley as compared to control (136.96 DAS). Days taken to maturity of barley were in treatment T_{10} (100% RDN) being at par with treatments T_4 to T_9 were significantly higher than other treatments. Further, days taken to maturity were reduced by five days under treatment T_1 (Control) as compared to T_{10} (100% RDN). Days taken to maturity of barley were between 136.96-141.09 DAS.

Table 5: Effect of integrated nutrient management practices on different phenological stages (DAS) of barley

Treatments	Days to					
	Emergence	**Tillering**	**Flag leaf emergence**	**Booting**	**Anthesis**	**Maturity**
T_1 : Control	6.89	30.12	66.23	70.01	79.09	136.96
T_2 : *Biomix*	6.93	30.67	67.33	70.13	79.23	137.89
T_3 : Vermicompost @ 5 t ha^{-1}	7.09	30.99	67.36	71.33	80.65	137.53
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	7.13	31.12	68.02	72.89	81.11	138.11
T_5 : 50 % RDN + *Vermicompost* @ 5 t ha^{-1}	7.21	31.24	69.31	73.19	82.45	138.41
T_6 : 75 % RDN + *Vermicompost* @ 5 t ha^{-1}	7.39	31.56	71.14	74.08	84.13	139.05
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	7.47	32.36	71.68	74.66	85.67	139.84
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	7.57	32.63	72.19	75.09	86.12	140.36
T_9 : RDN (60 kg N ha^{-1})	7.61	33.19	72.53	77.46	88.18	140.87
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	7.79	33.28	73.09	79.29	89.35	141.09
SEm ±	0.32	0.51	0.75	0.83	0.94	1.01
CD at 5 %	NS	NS	2.25	2.49	2.82	3.03

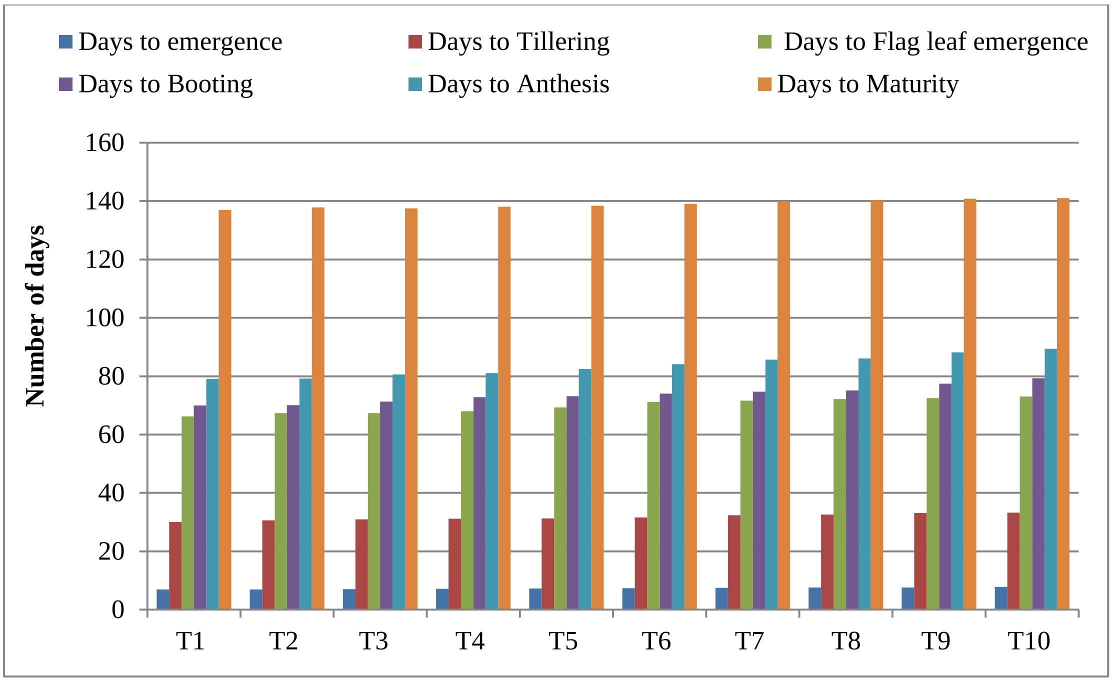

Fig 4: **Effect of integrated nutrient management practices on different phenological stages (DAS) of barley**

4.2 Growth studies

4.2.1 Plant height

Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on plant height of barley is presented in Table 6 and Fig. 4. Perusals of data indicate that irrespective of the treatments, plant height of barley increased with the advancement of crop age. The increase in plant height was maximum between 30 to 60 DAS and minimum between 90 DAS and maturity stage.

Table 6: **Plant height of barley as influenced by integrated nutrient management practices at different growth stages**

Treatments	**Plant height (cm)**			
	30 DAS	**60 DAS**	**90 DAS**	**At Maturity**
T_1 : Control	21.11	52.83	75.08	79.14
T_2 : *Biomix*	22.86	56.27	82.16	85.78
T_3 : Vermicompost @ 5 t ha^{-1}	24.34	59.43	85.23	88.22
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	25.56	60.22	86.76	90.15
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	25.74	62.63	87.55	91.02
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	27.09	65.54	90.19	92.29
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	27.83	66.94	91.11	93.62
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	28.44	67.36	91.72	93.99
T_9 : RDN (60 kg N ha^{-1})	29.09	70.58	92.34	96.09
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	29.56	72.19	93.09	97.01
SEm ±	0.45	0.88	1.01	1.22
CD at 5 %	1.37	2.63	3.04	3.68

Significantly taller plants were recorded in treatment T_{10} at all the stages of crop growth. However, the difference in plant height of barley in treatment T_8, T_9 and T_{10} at 30 DAS, T_9 and T_{10} at 60 DAS and T_6 to T_{10} at 90 DAS were not significant. Similarly, plant height at maturity in treatment T_7, $T_{8,}$ T_9 and T_{10} were recorded at par with each other. The plant height at maturity was 17.87 cm, 16.95 cm and 14.85 cm more in treatment $T_{10,}$ T_9 and T_8 as compared to the control treatment, respectively. The magnitude of plant height recorded under various treatments varied from 79.14 cm under T_1 to 97.01cm under T_{10} at maturity. Lowest plant height was recorded in T_1 (Control) treatment at all the stages of crop growth.

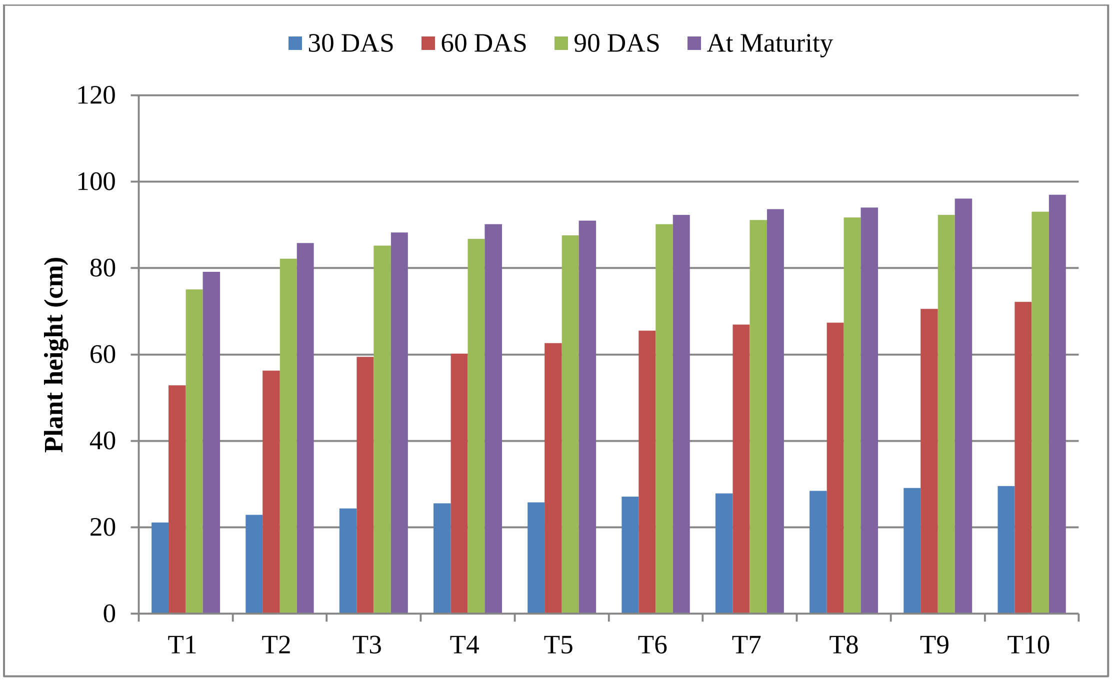

Fig 5: Plant height of barley as influenced by integrated nutrient management practices at different growth stages

4.2.2 Dry matter accumulation (g/m^2)

Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on dry matter accumulation (g/m^2) at different stages of crop growth is presented in Table 7 and fig. 6. Perusals of data indicate that irrespective of the treatments, dry matter accumulation at various growth stages of barley increased progressively from vegetative to harvest phase. The rate of dry matter accumulation (g/m$^{2)}$ was slow up to initial 30 days and highest between 30 to 60 DAS and thereafter the increase was at a decreasing rate up to maturity. Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_{10} at all the stages of crop growth resulted in highest dry matter accumulation. The difference in dry matter accumulation at 30 DAS in treatment T_7 to T_{10} were not significant. Similarly, the difference in dry matter accumulation at 60 DAS in treatment T_6 to T_{10} were also not significant. At 90 DAS dry matter accumulation in treatment T_4 to T_{10} were at par with each other. Similarly, at maturity also dry matter accumulation in treatment T_{10} being at par with T_3 to T_9 was significantly higher than treatment T_1 and T_2.

Table 7: Dry matter accumulation per plant of barley as influenced by integrated nutrient management practices at different growth stages

Treatments	Dry matter accumulation (g/m^2)			
	30 DAS	60 DAS	90 DAS	At Maturity
T_1 : Control	29.2	144	570	958
T_2 : *Biomix*	33.1	177	609	1161
T_3 : Vermicompost @ 5 t ha^{-1}	35.5	180	612	1189
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	36.2	188	621	1250
T_5 : 50 % RDN + *Vermicompost* @ 5 t ha^{-1}	37.1	190	626	1281
T_6 : 75 % RDN + *Vermicompost* @ 5 t ha^{-1}	38.6	210	637	1302
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	39.7	213	642	1312
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	39.2	220	646	1321
T_9 : RDN (60 kg N ha^{-1})	40.2	224	647	1324
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	40.8	229	651	1337
SEm ±	0.7	7.4	10.2	55.8
CD at 5 %	2.1	22.8	31.8	172.7

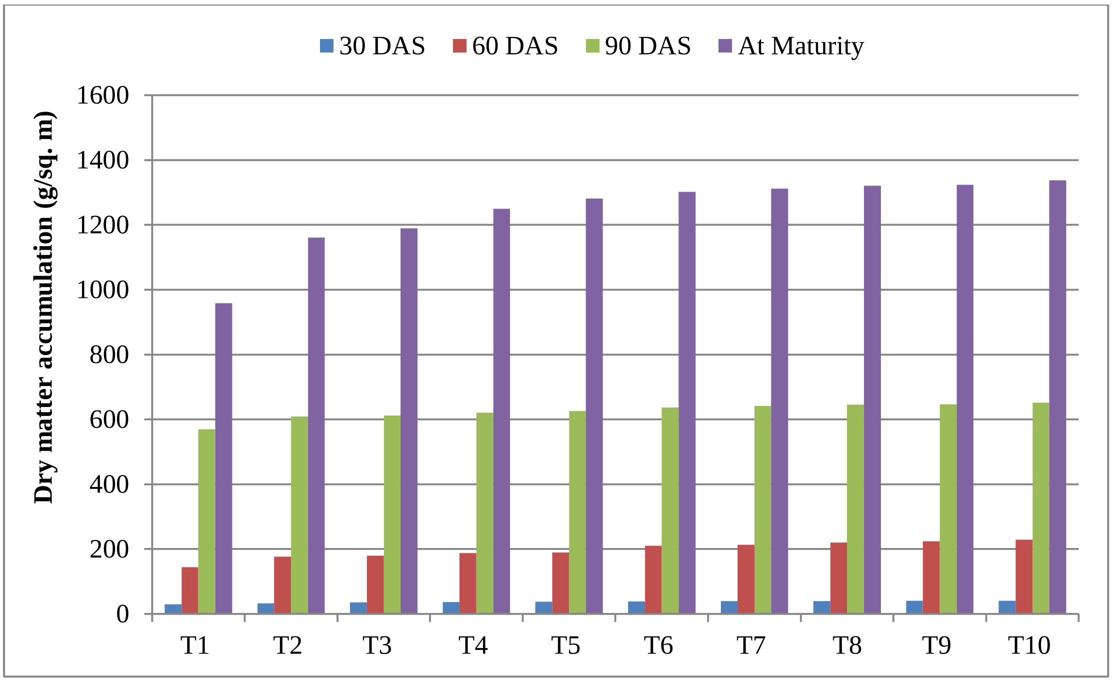

Fig 6: Dry matter accumulation per plant of barley as influenced by integrated nutrient management practices at different growth stages

4.2.3 Leaf area index

The data pertaining to leaf area index as influenced by various combinations of nitrogen fertilizer, *biomix* and vermicompost revealed that leaf area index of barley increased with the age of the crop irrespective of the treatments as presented in Table 8 and Fig. 7. Among various combinations of nitrogen fertilizer, *biomix* and vermicompost leaf area index at 30 DAS was highest in treatment T_{10}, being significantly higher than other treatments but statically at par with treatment T_8 and $T_{9.}$ Similarity at 60 DAS the difference in leaf area index value of barley in treatment $T_{8,}$ T_9 and T_{10} were not significant but higher than other treatments. Similarly, at 90 DAS also leaf area index value of barley in treatment $T_{8,}$ T_9 and T_{10} were at par with each other but significantly higher than other treatments. Treatment T_1 (Control) being at par with treatment T_2 at all the stages of crop growth produced leaf area index significantly lower than rest of the treatments.

Table 8: Leaf Area Index of barley as influenced by integrated nutrient management practices at different growth stages

Treatments	**LAI**		
	30 DAS	**60 DAS**	**90 DAS**
T_1 : Control	0.47	1.16	1.61
T_2 : *Biomix*	0.54	1.31	1.84
T_3 : Vermicompost @ 5 t ha^{-1}	0.69	1.49	2.08
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	0.71	1.63	2.23
T_5 : 50 % RDN + *Vermicompost* @ 5 t ha^{-1}	0.92	1.72	2.47
T_6 : 75 % RDN + *Vermicompost* @ 5 t ha^{-1}	1.01	1.84	2.61
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	1.08	1.94	2.73
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	1.14	2.04	2.89
T_9 : RDN (60 kg N ha^{-1})	1.21	2.11	2.97
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	1.26	2.19	3.08
SEm ±	0.04	0.08	0.11
CD at 5 %	0.12	0.23	0.33

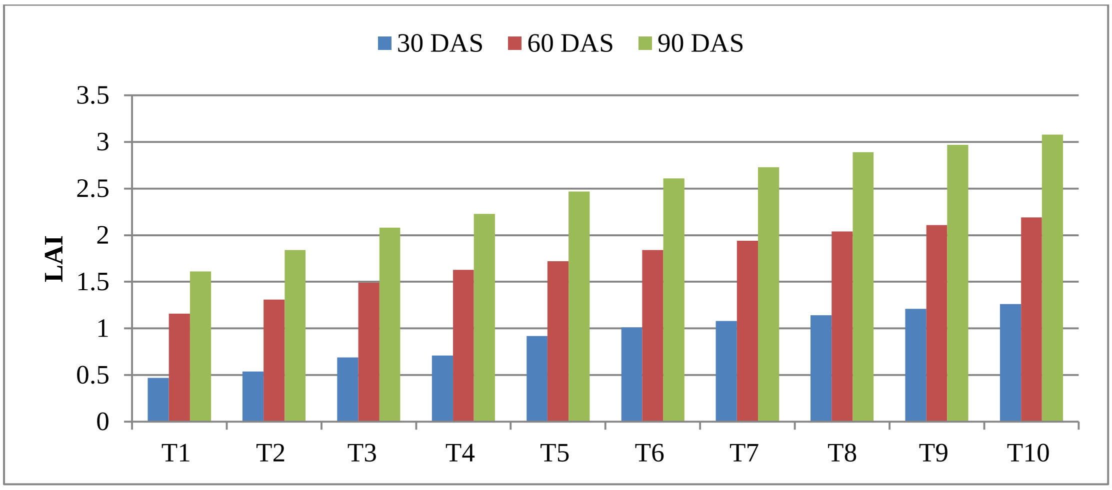

Fig 7: Leaf Area Index of barley as influenced by integrated nutrient management practices at different growth stages

4.2.4 Number of tillers

Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on number of tillers per metre row length at different stages of crop growth is presented in Table 9 and fig. 8.

Table 9: Effect of integrated nutrient management practices on no. of tillers of barley

Treatments	No. of tillers / m.r.l.			
	30 DAS	60 DAS	90 DAS	At Maturity
T_1 : Control	52.42	93.4	110.3	96.4
T_2 : *Biomix*	52.76	98.6	114.4	98.8
T_3 : Vermicompost @ 5 t ha^{-1}	53.53	104.4	120.9	102.2
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	55.22	106.6	124.3	106.4
T_5 : 50 % RDN + *Vermicompost* @ 5 t ha^{-1}	55.47	111	128.4	109.7
T_6 : 75 % RDN + *Vermicompost* @ 5 t ha^{-1}	63.84	116.6	131.3	113.7
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	57.28	114.5	130.6	111.9
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	65.97	112	134.2	117.8
T_9 : RDN (60 kg N ha^{-1})	66.17	115.8	137.3	118.1
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	66.46	116.1	142.1	121.5
SEm ±	2.6	5.51	6.08	4.72
CD at 5 %	7.73	16.37	18.07	14.01

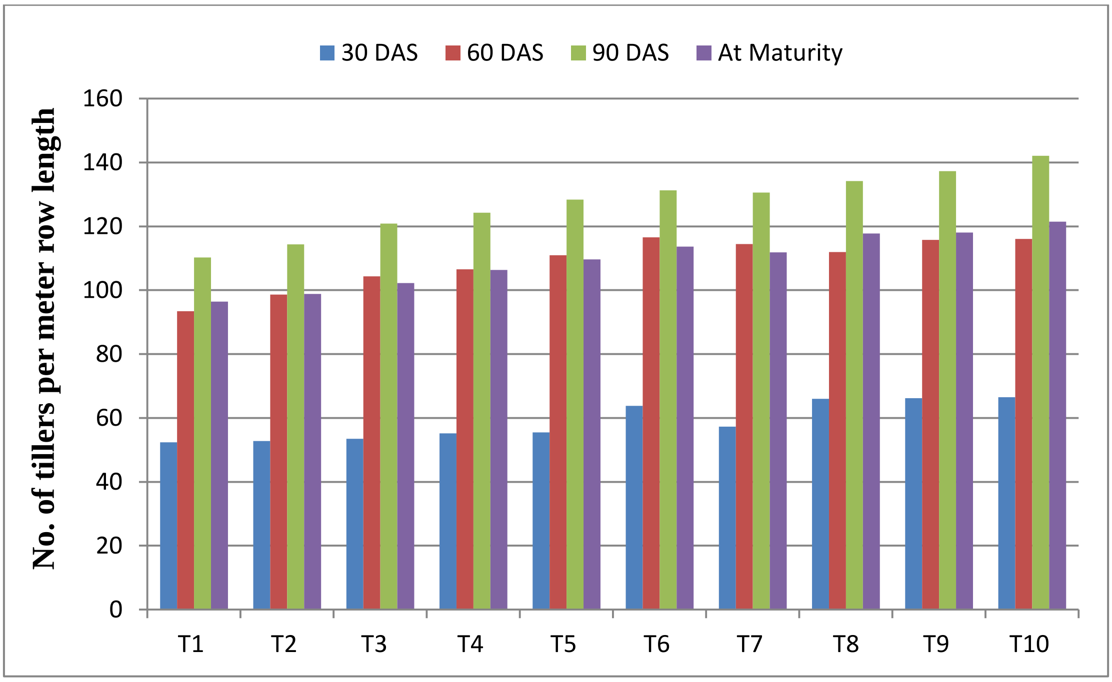

Fig 8: Effect of integrated nutrient management practices on no. of tillers of barley

Perusals of data indicate that irrespective of the treatments, number of tillers in barley increased slightly up to 90 DAS and thereafter marginally decreased at maturity. Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_{10} at all the stages of crop growth resulted in highest number of tillers/mrl. The difference in number of tillers per metre row length at 30 DAS in treatment T_8 to T_{10} were not significant. Similarly, the difference in number of tillers/mrl of barley at 60 DAS in treatment T_3 to T_{10} were also not significant. At 90 DAS number of tillers/mrl in treatment T_4 to T_{10} were at par with each other. Similarly, at maturity also number of tillers/mrl in treatment T_{10} being at par with T_5 to T_9 were significantly higher than treatment T_1 to T_4.

4.2.5 Plant population

After a close look at the data in Table 10, it was observed that no variations in plant population of barley at 20 DAS was observed due various combinations of nitrogen fertilizer**,** *biomix* and vermicompost. Plant population at 20 DAS in barley range between 34.27- 36.77 during the experimentation.

4.3 Yield attributes and yield

4.3.1 Spike length (cm)

A close perusal of the data relating to spike length (Table 10) revealed that various combinations of nitrogen fertilizer, *biomix* and vermicompost significantly affected the spike length of barley as presented in Table 10 and fig. 9. Perusals of data indicate that spike length was highest in treatment T_{10} (7.66 cm), being significantly higher than other treatments but statically at par with treatment T_6 (6.81 cm), T_8 (7.23 cm) and T_9 (7.41 cm). Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_1 (5.73 cm) recorded significantly lowest spike length than rest of the treatments.

4.3.2 Number of grains/spike

A close perusal of the data in Table 10 and Fig. 9 on number of grains per spike under various combinations of nitrogen fertilizer, *biomix* and vermicompost significantly influenced the number of grains per spike of barley. Number of grains/spike was recorded highest in treatment T_{10} (43.48), being significantly higher than other treatments but statically at par with treatment T_6 to T_9. Difference in number of grains/spike in treatment $T_{2,}$ T_3 and T_4 were also not significant. The range of number of grains/spike of barley varied from 29.68 to 43.48. Least number of grains/spike was recorded in treatment T_1 (29.68).

4.3.3 Test weight

A perusal of data in Table 10 and Fig. 9 on test weight of barley revealed that various combinations of nitrogen fertilizer, *biomix* and vermicompost did not markedly differ with each other in respect of test weight. However, it was numerically higher in treatment T_{10} followed by T_9. The range of test weight was between 41.84 to 43.88%.

Table 10: Effect of integrated nutrient management practices on plant population and yield attributes of barley

Treatments	Plant population at 20 DAS	Spike length (cm)	Number of grains per spike	1000 grain weight (g)
T_1 : Control	34.27	5.73	29.68	41.84
T_2 : *Biomix*	34.42	6.05	32.02	41.89
T_3 : Vermicompost @ 5 t ha^{-1}	34.73	6.16	33.16	41.86
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	34.91	6.28	34.68	41.82
T_5 : 50 % RDN + *Vermicompost* @ 5 t ha^{-1}	35.04	6.44	37.72	42.04
T_6 : 75 % RDN + *Vermicompost* @ 5 t ha^{-1}	35.72	6.81	40.48	42.12
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	35.42	6.63	41.26	42.93
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	35.81	7.23	42.87	43.45
T_9 : RDN (60 kg N ha^{-1})	35.27	7.41	43.07	43.81
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	36.77	7.66	43.48	43.88
SEm ±	1.60	0.29	1.66	0.61
CD at 5 %	NS	0.87	4.93	NS

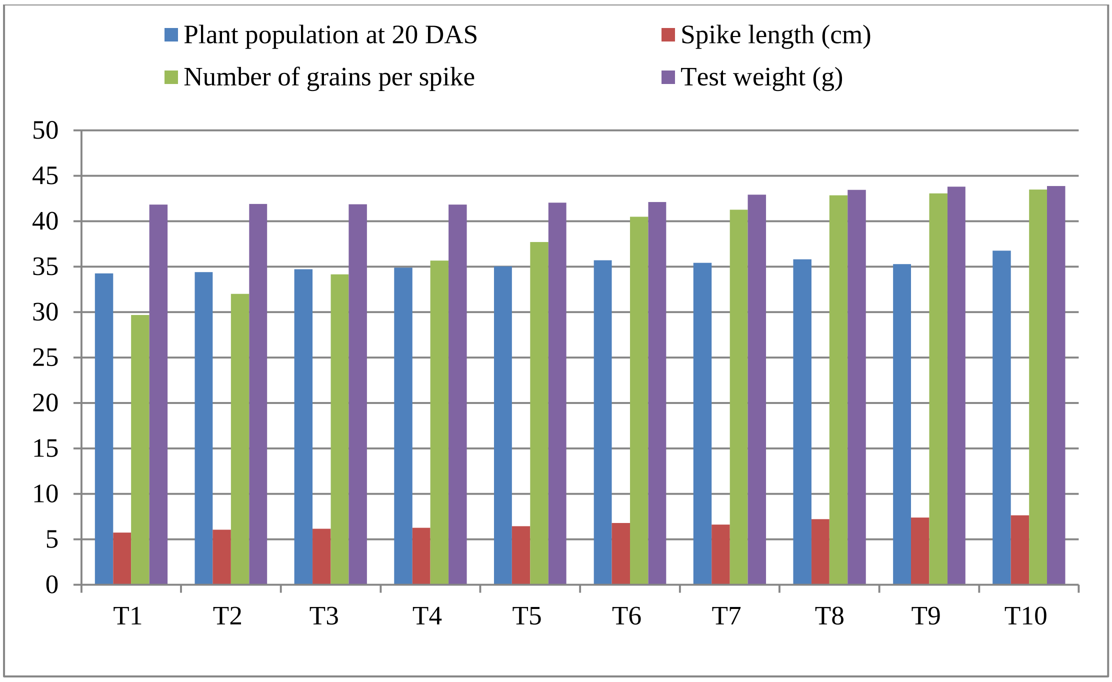

Fig 9: Effect of integrated nutrient management practices on plant population and yield attributes of barley

4.3.4 Grain yield

Response of barley to various combinations of nitrogen fertilizer, *biomix* and vermicompost is presented in Table 11 and depicted in Fig. 10. A thorough look on data indicated that grain yield of barley was significantly affected due to various treatments. There was significant increase in grain yield of barley with the increasing nitrogen fertilizer, however, treatment T_{10} (100 % RDN) being at par with treatment $T_{6,}$ $T_{7,}$ T_{8} and T_9 resulted in significantly higher grain yield of barley (4042 kg ha^{-1}). Least value for grain yield was recorded in treatment T_1 (2415 kg ha^{-1}). However, the difference in grain yield of barley in treatment T_1 (Control) and treatment T_2 (*Biomix*) were not significant.

4.3.5 Straw yield

The straw yield of any crop is an important criterion for evaluating efficiency of various treatments as it reflects the crop growth. Straw yield of barley as influenced by various treatment are presented in Table 11 and Fig. 10. Perusal of data revealed that straw yield of barley was significantly affected due to various combinations of nitrogen fertilizer, *biomix* and vermicompost. Significant increase in straw yield was obtained with the application of nitrogen.

Among various combinations of nitrogen fertilizer, *biomix* and vermicompost straw yield was maximum in treatment T_{10}, being significantly higher than treatment $T_{1,}$ $T_{2,}$ T_3 and T_4, but statically at par with treatment T_5, $T_{6,}$ $T_{7,}$ T_8 and T_9 . Treatment T_1 (Control) being at par with treatment T_2 produced straw yield significantly lower than rest of the treatments.

4.3.6 Biological yield

After a close look at the data in Table 11 and Fig. 10, on biological yield of barley as influenced by various combinations of nitrogen fertilizer, *biomix* and vermicompost, it was observed that biological yield of barley was recorded highest with treatment T_{10} with biological yield of 12199 kg ha^{-1}. But, the difference in biological yield of barley in treatment T_5 to T_{10} were not significant. Significantly lower value for biological yield was recorded in treatment T_1 (7406 kg ha^{-1}) which was statistically at par with treatment T_2 (*Biomix*).

4.3.7 Harvest index

The data pertaining to harvest index of barley as influenced by various combinations of nitrogen fertilizer, biomix and vermicompost is presented in Table 11 and Fig. 10. Perusal of data revealed that various combinations of nitrogen fertilizer, *biomix* and vermicompost did not affect the harvest index of barley significantly however, it was numerically higher in treatment T_4 followed by T_3. The range of harvest index was between 32.22 to 34.25%.

4.3.8 Attraction index

The data pertaining to attraction index of barley as influenced by various combinations of nitrogen fertilizer, *biomix* and vermicompost is presented in Table 11 and Fig. 10. Perusal of data revealed that various combinations of nitrogen fertilizer, *biomix* and vermicompost fail to influence attraction index of barley. The range of attraction index was between 47.98 to 52.08%.

Table 11: Effect of integrated nutrient management practices on yield, harvest and attraction index of barley

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Attraction Index (%)
T_1 : Control	2415	4991	7406	32.61	48.39
T_2 : *Biomix*	2665	5255	7920	33.65	50.71
T_3 : Vermicompost @ 5 t ha^{-1}	3049	5933	8982	33.95	51.39
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	3262	6263	9525	34.25	52.08
T_5 : 50 % RDN + *Vermicompost* @ 5 t ha^{-1}	3567	7434	11001	32.42	47.98
T_6 : 75 % RDN + *Vermicompost* @ 5 t ha^{-1}	3761	7827	11588	32.46	48.05
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	3772	7935	11707	32.22	47.54
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	3862	7995	11857	32.57	48.31
T_9 : RDN (60 kg N ha^{-1})	3979	8005	11984	33.2	49.71
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	4042	8157	12199	33.13	49.55
SEm ±	133	258	413	1.91	2.62
CD at 5 %	401	767	1227	NS	NS

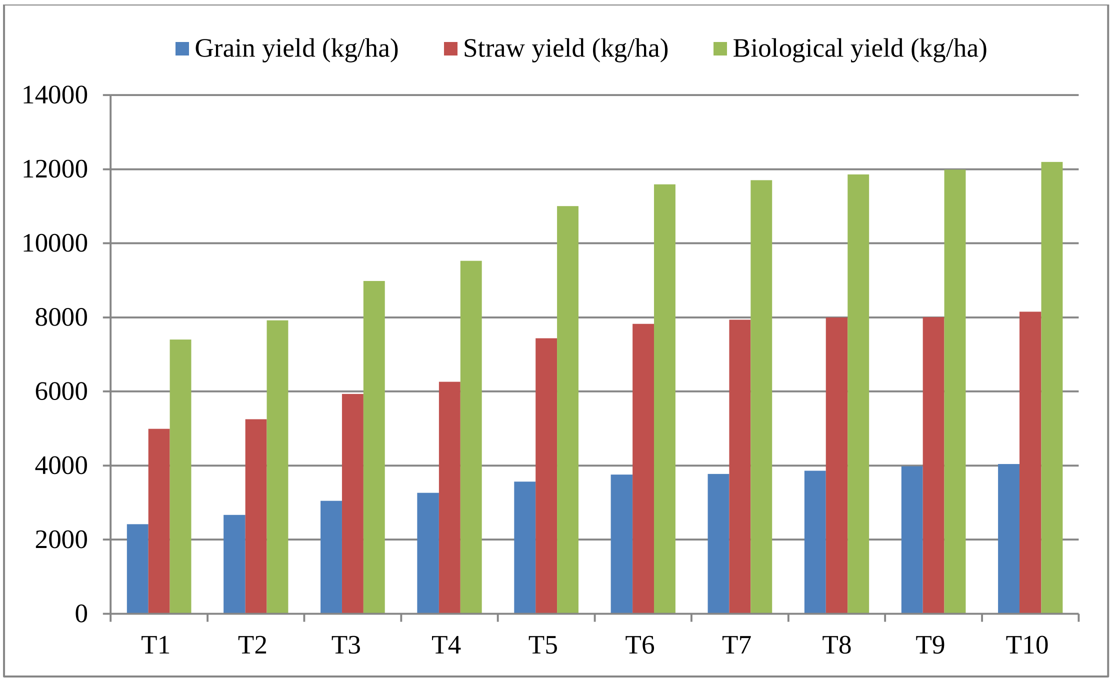

Fig 10: Effect of integrated nutrient management practices on yield, harvest and attraction index of barley

4.4 Quality characters

4.4.1 Proportion of thin and bold grains

The data pertaining to proportion of thin and bold grains percentage of barley are presented in Table 12. A perusal of data revealed boldness as well as thinness of barley grain is genetic in nature and various combinations of nitrogen fertilizer, *biomix* and vermicompost fail to influence boldness as well as thinness of barley grain. The range of bold grain (%) was between 77.08 (T_1) to 78.83 % (T_{10}) while range of thin grain (%) was between 5.06 (T_1) to 5.56 % (T_{10}).

4.4.2 Hectoliter weight

Data pertaining to hectoliter weight of barley is presented in Table 12. A perusal data in Table 12 on hectoliter weight of barley grain showed that there was no significant effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on hectoliter weight of barley. The range of hectoliter weight of barley was between 53.69 (T_1) to 56.88 % (T_{10}).

4.4.3 Protein content

A thoughtful perception of data on the protein content is presented in Table 12. Protein content of barley grain proved significant relation with various combinations of nitrogen fertilizer, *biomix* and vermicompost. Treatment T_{10} (11.74 %) being at par with treatment T_3 to T_9 resulted in significantly higher protein content of barley. Least value for protein content was recorded in treatment T_1 (8.50%). However, the difference in protein content of barley in treatment T_1 (Control) and treatment T_2 (*Biomix*) were not significant.

4.4.4 Malt content

Data pertaining to malt content of barley as influenced by various combinations of nitrogen fertilizer, *biomix* and vermicompost is presented in Table 12. Perusal of data revealed that among various combinations of nitrogen fertilizer**,** *biomix* and vermicompost treatment T_1 being at par with treatment T_2 recorded significantly higher value of malt content of barley than treatment T_3 to $T_{10.}$ Lowest value of malt content of barley was recorded in treatment T_{10} (80.18).

Table 12: Effect of integrated nutrient management practices on hectoliter weight, protein and malt content (%) and proportion of bold and thin grain of barley

Treatments	**Hectoliter weight (%)**	**Protein content (%)**	**Malt content (%)**	**Bold grain (%)**	**Thin grain (%)**
T_1 : Control	53.69	8.5	84.78	77.08	5.06
T_2 : *Biomix*	53.9	9.41	84.15	77.21	5.14
T_3 : Vermicompost @ 5 t ha^{-1}	54.65	10.07	83.38	77.61	5.16
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	54.84	10.16	83.08	77.16	5.31
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	55.07	10.25	82.46	78.08	5.16
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	55.89	10.48	82.49	77.73	5.28
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	55.95	10.53	82.1	78.44	5.34
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	56.02	10.78	82.97	77.81	5.51
T_9 : RDN (60 kg N ha^{-1})	56.77	11.15	81.13	78.56	5.49
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	56.88	11.74	80.18	78.83	5.56
SEm ±	1.66	0.59	1.11	0.82	0.13
CD at 5 %	NS	1.74	3.36	NS	NS

4.5 Nutrient studies

4.5.1 Nitrogen content and uptake by grain and straw

The data pertaining to nitrogen content (%) and uptake (kg ha^{-1}) in grains and straw of barley are presented in Table 13. The data indicate that various combinations of nitrogen fertilizer, *biomix* and vermicompost significantly influenced the N content in grain and straw, its uptake in grain and straw and total N uptake. Increasing fertilizer of fertilizer resulted in significant increase in N content and its uptake in grain and straw of barley.

N content in grain was recorded highest in treatment T_{10} (1.88%), being significantly higher than other treatments but statically at par with treatment $T_{7\ to}$ $T_{9.}$ Significantly lower value for N content in grain was recorded in treatment T_1 (1.43%) which was statistically lower than rest of the treatments. The N content in grain in treatment T_2 to T_7 was also statistically at par with each other.

Similarly, treatment T_{10} being at par with T_4 to T_9 was significantly superior in N content in straw as compared to all other treatments. The difference in N content in straw in treatment T_1 (0.31%), T_2 (0.33%) and T_3 (0.34%) were not significant.

Treatment T_{10} (75.99, 32.63, 108.62 kg ha^{-1}) produced significantly higher N uptake in grain and straw and total N uptake of barley followed by treatment T_9 (71.22, 30.42, 101.64 kg ha^{-1}) and T_8 (66.81, 29.58, 96.39 kg ha^{-1}). However, the difference in N uptake by grain and total N uptake of barley in treatment $T_{8,}$ T_9 and T_{10} were not significant. The range of total N uptake in barley was between 50 (T_1) to 108.62 kg ha^{-1} (T_{10}). Similarly the difference in N uptake by straw in treatment T_7 *to* T_{10} was not significant.

Table 13: Effect of integrated nutrient management practices on N content (%) and its uptake (kg ha^{-1}) by barley

Treatments	N content (%)		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
T_1 : Control	1.43	0.31	34.53	15.47	50
T_2 : *Biomix*	1.51	0.33	40.24	17.34	57.58
T_3 : Vermicompost @ 5 t ha^{-1}	1.55	0.34	47.26	20.17	67.43
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	1.58	0.36	51.54	22.55	74.09
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	1.61	0.36	57.43	26.76	84.19
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	1.65	0.35	62.06	27.39	89.45
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	1.69	0.37	63.75	29.36	93.11
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	1.73	0.37	66.81	29.58	96.39
T_9 : RDN (60 kg N ha^{-1})	1.79	0.38	71.22	30.42	101.64
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	1.88	0.40	75.99	32.63	108.62
SEm ±	0.07	0.02	3.59	1.15	3.74
CD at 5 %	0.22	0.05	10.71	3.4	11.11

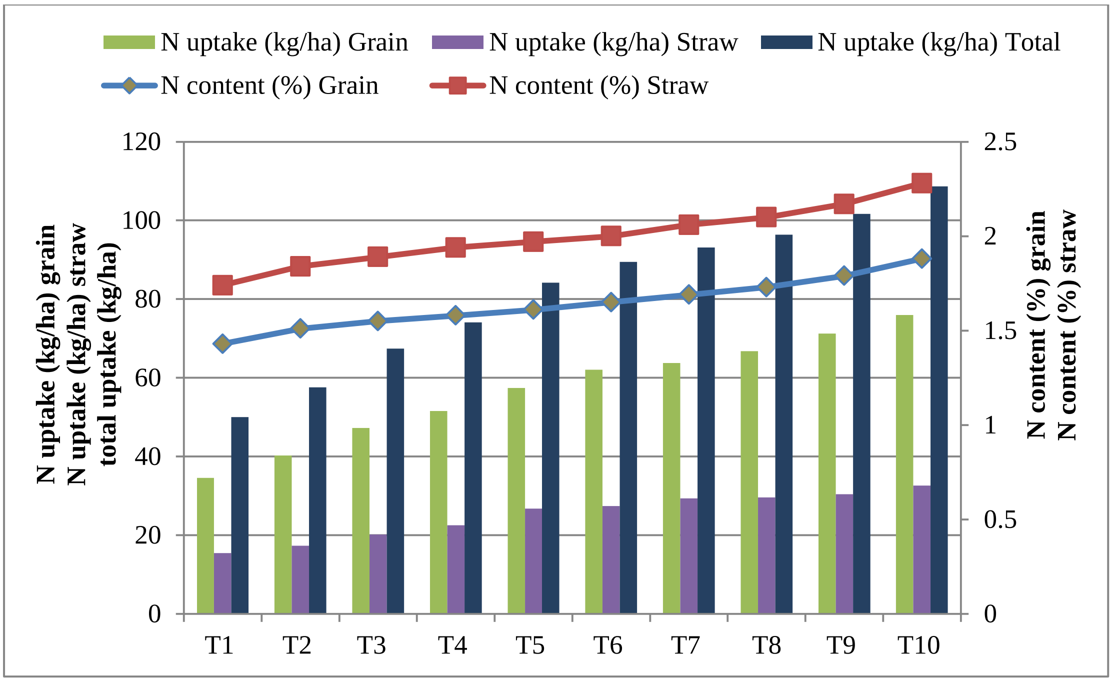

Fig 11: Effect of integrated nutrient management practices on N content (%) and its uptake (kg ha^{-1}) by barley

4.5.2 Phosphorus content and uptake by grain and straw

The data pertaining to phosphorus content (%) and uptake (kg ha^{-1}) in grains and straw and total K uptake by barley are presented in Table 14. The data indicate that various combinations of nitrogen fertilizer, *biomix* and vermicompost significantly influenced the P content in grain and P uptake in grain and straw and total K uptake.

P content in grain was highest in treatment T_{10} (0.44 %), being significantly higher than T_1 to T_7 but statically at par with treatment T_8 and $T_{9.}$ Significantly lower value for P content in grain was recorded in treatment T_1 (0.34 %). But the difference in N content in grain in treatment T_1 *to* T_7 was not significant.

Perusal of data revealed that various combinations of nitrogen fertilizer, *biomix* and vermicompost significantly influence P content in straw of barley also. P content in straw was highest in treatment T_{10} (0.27 %), being significantly higher than T_1 to T_5 but statically at par with treatment T_6 to $T_{9.}$

Significantly higher P uptake by grain and straw were recorded in treatment T_{10} (17.78 and 22.02 kg ha^{-1}), being statistically at par with treatment T_8 and $T_{9.}$ Similarly significantly higher total P uptake was observed in treatment T_{10} (39.80 kg ha^{-1}). However, the difference in total P uptake of barley in treatment T_6 to T_{10} was not significant. Total P uptake was lowest in treatment T_1 (18.19 kg ha^{-1}) and it was followed by treatment T_2 (21.15 kg ha^{-1}).

Table 14: Effect of integrated nutrient management practices on P content (%) and its uptake (kg ha^{-1}) by barley

Treatments	P content (%)		P uptake (kg ha^{-1})		Total P uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
T_1 : Control	0.34	0.20	8.21	9.98	18.19
T_2 : *Biomix*	0.36	0.22	9.59	11.56	21.15
T_3 : Vermicompost @ 5 t N ha^{-1}	0.36	0.23	10.98	13.65	24.63
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	0.35	0.24	11.42	15.03	26.45
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	0.37	0.22	13.2	16.35	29.55
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	0.36	0.23	13.54	18	31.54
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	0.38	0.24	14.33	19.04	33.37
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	0.4	0.26	15.45	20.79	36.24
T_9 : RDN (60 kg N ha^{-1})	0.42	0.25	16.71	20.01	36.72
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	0.44	0.27	17.78	22.02	39.8
SEm ±	0.02	0.02	0.93	0.76	2.31
CD at 5 %	0.05	0..05	2.77	2.26	7.03

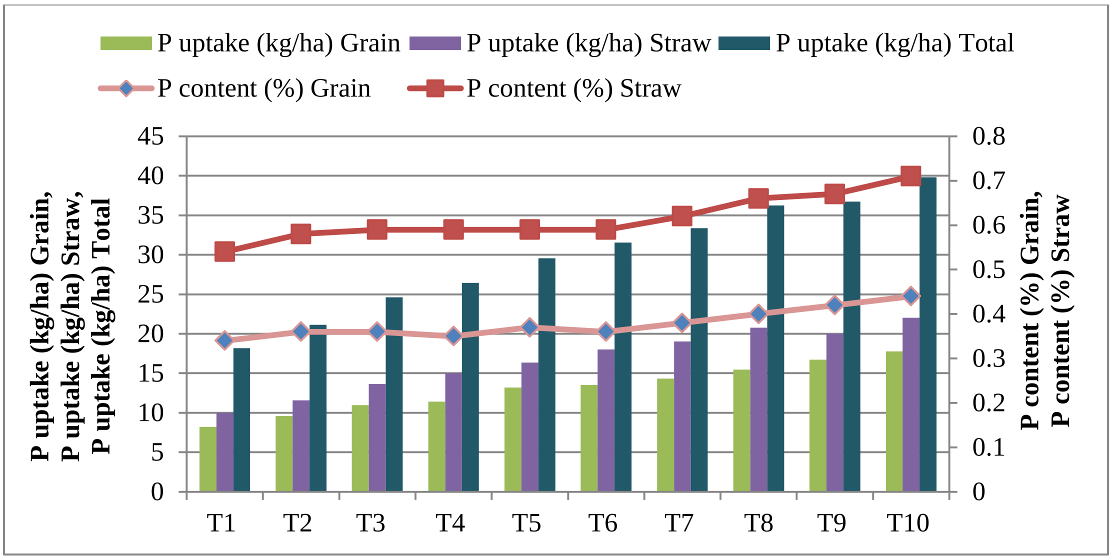

Fig. 12: Effect of integrated nutrient management practices on P content (%) and its uptake (kg ha^{-1}) by barley

4.5.3 Potassium content and uptake by grain and straw

The data pertaining K content and uptake by grain and straw of barley are presented in Table 15. A perusal data showed that treatment T_{10} (0.48 %) being at par with T_4 to T_9 resulted in significantly higher K content in grain over rest of the treatments. There was no significant effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on straw K content of barley. Straw K content was highest in treatment T_8 and T_{10} (1.57 %), but the difference was not significant with other treatments.

Table 15: Effect of integrated nutrient management practices on K content (%) and its uptake (kg ha^{-1}) by barley

Treatments	K content (%)		K uptake (kg ha^{-1})		Total K uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
T_1 : Control	0.36	1.53	8.69	76.36	85.05
T_2 : *Biomix*	0.39	1.54	10.39	80.93	91.32
T_3 : Vermicompost @ 5 t ha^{-1}	0.41	1.55	12.5	91.96	104.46
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	0.43	1.54	14.03	96.45	110.48
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	0.44	1.55	15.69	115.23	130.92
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	0.45	1.54	16.92	120.54	137.46
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	0.43	1.56	16.22	123.79	140.01
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	0.45	1.57	17.38	125.52	142.9
T_9 : RDN (60 kg N ha^{-1})	0.47	1.56	18.7	124.88	143.58
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	0.48	1.57	19.4	128.06	147.46
SEm ±	0.02	0.07	0.68	4.88	5.56
CD at 5 %	0.06	NS	2.03	14.5	16.55

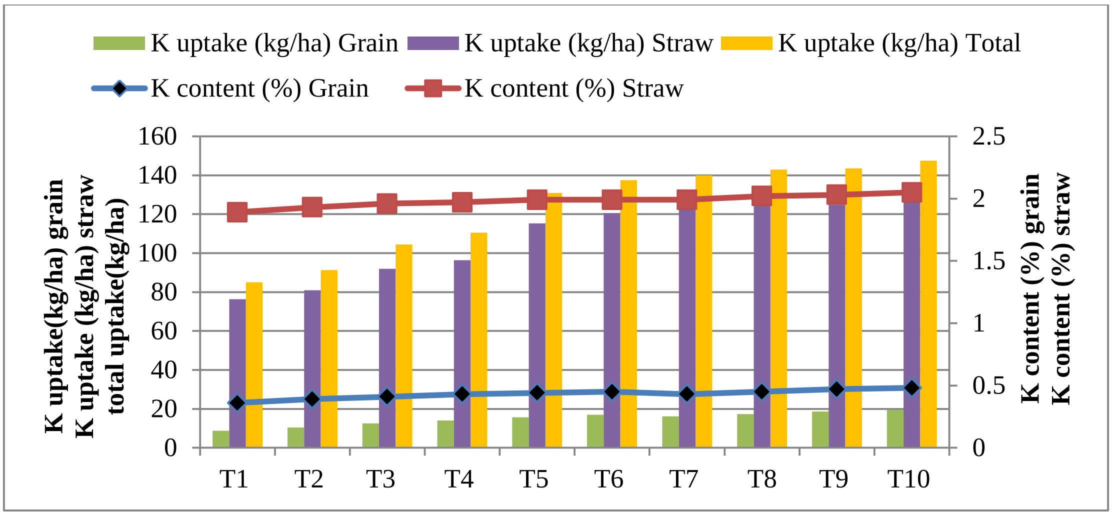

Fig. 13: Effect of integrated nutrient management practices on K content (%) and its uptake (kg ha^{-1}) by barley

Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_{10} being at par with T_8 and T_9 recorded significantly higher K uptake by grain. K uptake by straw and total K uptake was significantly higher in treatment $T_{10.}$ However in treatment T_5 to T_{10} the difference in K uptake by straw and total K uptake was not significant.

4.6 Soil studies

Data pertaining to NPK status of soil after harvesting are presented in table 16. A close perusal of the data indicated that there was no significant difference due to application of various combinations of nitrogen fertilizer, *biomix* and vermicompost on N, P and K status of soil after harvesting of barley. The range of soil N status varies from 101.45 (T_1) to 136.05 (T_3). Similarly the range of soil P status varies from 13.81 (T_1) to 15.33 (T_3) and soil K status from 285.13 (T_1) to 338.92 (T_{10}).

Table 16: Effect of integrated nutrient management practices on soil NPK status

Treatments	**N (kg ha^{-1})**	**P_2O_5 (kg ha^{-1})**	**K_2O (kg ha^{-1})**
T_1 : Control	101.45	13.81	285.13
T_2 : *Biomix*	123.69	13.95	288.31
T_3 : Vermicompost @ 5 t ha^{-1}	136.05	15.33	320.04
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	131.72	14.87	319.18
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	127.34	13.98	288.31
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	128.17	15.18	299.45
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	130.94	12.58	318.31
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	125.12	14.33	297.18
T_9 : RDN (60 kg N ha^{-1})	129.89	14.08	288.31
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	130.02	14.11	338.92
SEm ±	5.67	0.63	14.74

4.7 Economics

The data pertaining to gross returns, net returns and B: C ratio of barley as influenced by various combinations of nitrogen fertilizer, *biomix* and vermicompost is presented in table 14. A critical examination of data in Table 17 revealed that gross returns were highest in treatment T_{10} (Rs 85542 ha^{-1}) followed by treatment T_9 and T_8. The gross return of barley varied from Rs 51520 ha^{-1} (T_1) to Rs 85542 Rs ha^{-1} (T_{10}).

Among various combinations of nitrogen fertilizer, *biomix* and vermicompost highest net returns was recorded in treatment T_9 (57566 Rs ha^{-1}) followed by treatment T_{10} and T_8. The net return of barley varied from 26052 Rs ha^{-1} to 57566 Rs ha^{-1}.The benefit cost ratio was also higher (3.17) in treatment T_9 followed by treatment T_{10} and T_8. In general benefit: cost ratio of barley varied from 2.02 (T_1) to 3.17 (T_9).

Table 17. Effect of integrated nutrient management practices on economics of *barley*

Treatments	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B : C
T_1 : Control	51520	26052	2.02
T_2 : *Biomix*	55969	30461	2.19
T_3 : Vermicompost @ 5 t ha^{-1}	63756	34288	2.16
T_4 : *Biomix* + Vermicompost @ 5 t ha^{-1}	67915	38407	2.30
T_5 : 50 % RDN + Vermicompost @ 5 t ha^{-1}	76314	46302	2.54
T_6 : 75 % RDN + Vermicompost @ 5 t ha^{-1}	80425	50141	2.66
T_7 : 50 % RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	80958	50906	2.69
T_8 : 75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}	82437	52113	2.72
T_9 : RDN (60 kg N ha^{-1})	84121	57566	3.17
T_{10} : RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}	85542	54947	2.80
SEm ±	1073	705	0.16
CD at 5 %	3238	2123	0.48

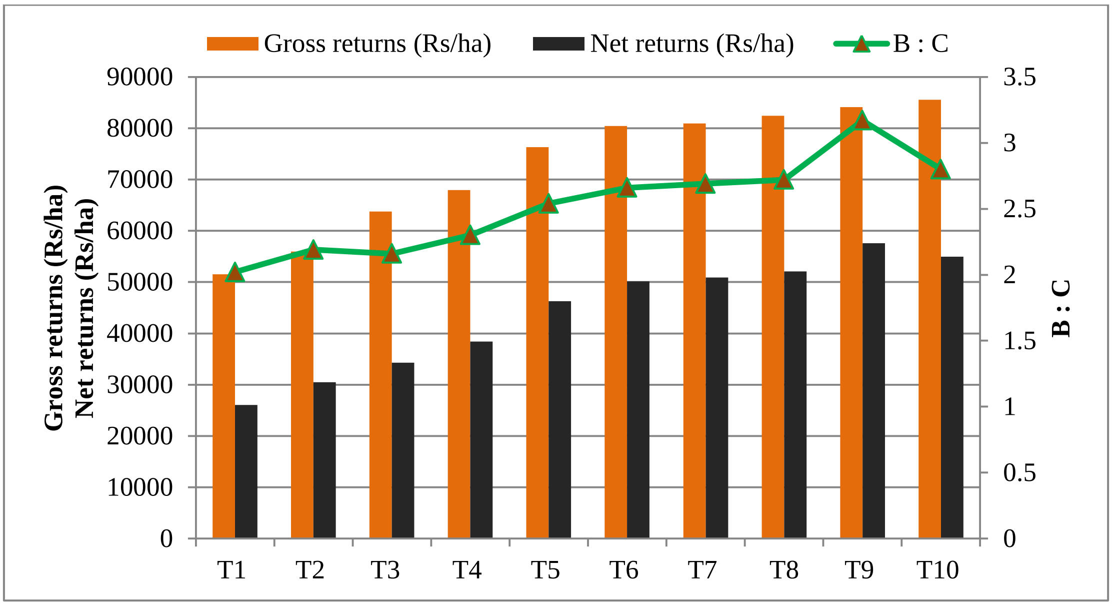

Figure 14. Effect of integrated nutrient management practices on economics of *barley*

CHAPTER-V

DISCUSSION

The potential yield of a crop could be achieved only with the combined effect of variety and agronomic management practices to which it is exposed during the growing period. Crop yield is the combined effect of its genetic constitution which it inherits and of the environment to which it is exposed during the life period and a considerable increase in it is possible due to significant amelioration of these complementary factors. Although, it is not possible to entirely modify the crop environment under field conditions to suit the need of a particular plant type, favorable environment by judicious organization of controllable factors like choice of variety, sowing time, irrigation and nutrient supply to various genotypes, can be provided which may to a considerable extent, help to harness the maximum/full genetic potential of crop plants. A plant may express its yield potential under most optimum environmental conditions. Through scientific research during the recent century, the man has made significant strides in increasing the agricultural production to feed the ever increasing human and animal population. The results of the experiment entitled “Integrated Nutrient Management in barley” mentioned in Chapter-IV have been discussed in the present chapter. Results revealed that various crop parameters were influenced significantly by different treatments. In this chapter, an attempt has been made to discuss these results using cause and effect analysis and explained in the light of available information /results of earlier researchers. To support the findings of these investigations, results obtained by other researchers have also been cited.

5.1 Influence of weather conditions on crop growth

The success or failure of the crop intimately related to the weather during the crop periods. Therefore, it would be appropriate to bring out salient features of weather condition which prevailed during the *rabi* season of 2017-2018. The weather details of temperature, sunshine hours, humidity and rainfall pertaining to crop seasons are presented in Table 1 and depicted through Fig. 1. Yield of any crop is the result of complex interaction between its genetic potential and environmental affect. Potential yield may be obtained when the yield deciding processes operating during life cycle of crop growth *viz.* early vegetative growth, grand growth period, spike initiation and development stage and final maturation phase are fully balanced. Evans and Wardlaw (1976) emphasized that seasonal environmental conditions under which the crop was grown played a significant role in determining the optimum balance of yield components. In general, the weather conditions, which prevailed during *rabi* 2017-2018 were favorable for growth and development of the barley crop. The topography of experimental field was uniform. Fertility status of experimental site was homogenous. Variation in the growth and yield of crop was mainly due to effect of the treatment tested. The value of maximum and minimum temperatures and relative humidity presented in Table 1, indicate variation in weather parameters. There was average production of cereals during 2017-18 due to less winter season. The grain filling period of the crop increased due to prolongation of winter period to the tune of nearly 9-10 days. During 2017-18 the amount of rainfall received during crop season was only 2.3 mm. The mean weekly maximum and minimum temperature ranged between 16 to 34.7 ºC and 3 ºC to 19.4 ºC, respectively .The mean weekly values for morning and evening relative humidity ranged between 61.3 to 100% and 24.7 to 75.3%, respectively. While sunshine hours ranged between 2.9 to 7.8 hours during the crop season.

5.2 Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on phenology of barley

In the present study there were no significant differences in the days taken to emergence and tillering in barley due to various combinations of nitrogen fertilizer, *biomix* and vermicompost because at the time of emergence, seedling derived nutrients from the storage organs and hence nitrogen levels had no significant influence on the seedling to emergence. This might also be due to the basic nature of the crop that phenology of a crop (genotype trait) might not be influenced markedly by some factors of crop growth and development. Neelam and Nanwal (2013) also observed that different inorganic and organic sources of nutrients had no significant effect on phenological development of wheat. A critical examination of data revealed that 2-3 days more were taken in the higher doses of fertilizer treatments as compared to control because of better root development or more prominent growth of vegetative phase of the crop. Days taken to tillering were between 30.12-33.28 DAS and anthesis between 79.09-89.35 DAS. Perusals of data also indicated that days taken to flag leaf emergence; booting, anthesis and maturity of barley were significantly affected due to various combinations of nitrogen fertilizer, *biomix* and vermicompost. Treatment T_{10} (RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}) took highest number days to flag leaf emergence, booting, anthesis and maturity as compared to other treatments. Nitrogen application increased the vegetative growth as nitrogen application increase the photosynthetic activity and the leaves remain functional for a longer period which improved plant height and dry matter accumulation which ultimately delayed the ear heading in barley. Similar response of delayed heading was also reported by Malik (2017) in barley. Minimum number of days to flag leaf emergence, booting, anthesis and maturity were recorded in treatment T_1 (Control). No fertilizer application in treatment T_1 had induced early flowering and early maturity as compared to higher fertility treatments (T_{10}, T_9 and T_8) which on the other hand has prolonged the growth, flowering and maturity duration. It might be due to release of growth hormones by *biomix* which results in more vegetative growth stage and hence delay in phenological stages of crop growth. Kumar (2005) also revealed that days taken to 50% anthesis with the application of 125% recommended dose of RDN were highest which differed significantly from other treatments except 100 % RDN + *Biomix.* Days taken to maturity of barley were in treatment T_{10} (RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}) being at par with treatment T_4 to T_9 were significantly higher than other treatments. Increase in nitrogen application resulted in increase in photosynthetic efficiency of the plant which ultimately delayed the maturity of the crop. Rehman *et al.* (2010) also reported influence of fertilizer on days to maturity in wheat. Similar results of delay in days to flowering due to higher doses of fertilizer application in Hisar have also been reported by Malik (2017) and Neelam and Nanwal (2013). Further, days taken to maturity were reduced by five days under treatment T_1 (Control) as compared to T_{10} (RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}). Days taken to maturity of barley were between 136.96-141.09 DAS. Similarly, Malik (2017) in Hisar also concluded that days to flowering and maturity are delayed due to seed inoculation to various combinations of bio fertilizers.

5.2 Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on growth of barley

The plant is the product of its genetic constitution and environment. The genetic pattern is a fixed quantity for a given plant and determines its potential for maximum growth under favorable environment for its development. The growth and development analysis is a pre-requisite to understand the growth behavior of crop in the field. The growth and development of the plants depends on the initiation of tissues and organ primordial and on the differentiation and expansion of cells. Several metabolic activities/ reactions are associated with this phenomenon which involves the uptake of nutrients from soil, the synthesis of metabolites and the transport of substances within the plant body. Adequate moisture, nutrients, space and light play an important role. Plant growth is a function of cell enlargement, which depends upon availability of nutrients especially nitrogen. Better nutrient management resulted in optimum utilization of carbohydrates in the synthesis of more protoplasm and other cellular materials rather than their deposition resulting in thickening of cell wall. To modify the environment under field conditions so as to suit the need of a particular crop may not be easy. However, it can be manipulated to some extent by judicious use of controllable factors like selection of variety, seed rate, sowing time, nutrient supply, irrigation and plant protection etc. These factors, if managed properly, can be helpful in realization of genetic potential of a crop plant. The growth parameters modify the yield attributing characters and finally the yield of crops. The photosynthetic ability of a plant is determined mainly by the growth parameters *viz.*, plant height and tillers production which ultimately decide the total dry matter production and productivity of crop. In present investigation, growth characteristics such as plant height, leaf area index and dry matter accumulation of barley were studied. The growth parameter of barley was favorably influenced due to various combinations of nitrogen fertilizer, *biomix* and vermicompost on growth of barley.

The positive response of growth characters with higher RDN or seed inoculation with *biomix* or vermicompost application was due to nitrogen concentration in plant resulting in higher photosynthetic activity thereby rapid cell division and cell elongation and consequently better growth of plant. Improved growth and yield attributes increased with increased dose of N, may be due to fact that N being an important constituent of nucleotides, proteins, chlorophyll and enzymes involves in various metabolic process which has a direct impact on vegetative and reproductive phase of plants.

Lowest plant height was recorded in T_1 (Control) treatment at all the stages of crop growth (Table 6). At low level of nitrogen, plant might have not been able to meet nitrogen requirement, ultimately resulted in stunted growth. Significantly taller plants were recorded in treatment T_{10} at all the stages of crop growth. However, the difference in plant height of barley in treatment T_8, T_9 and T_{10} at 30 DAS, T_9 and T_{10} at 60 DAS and T_6 to T_{10} at 90 DAS were not significant. The increase in plant height due to seed inoculation with *biomix* may be due to secretion of various growth hormones by microorganisms. Results reported by Rathore *et al.* (2003), Kumar (2005) and Shirinzadeh *et al.* (2013) were also similar. Taller plants in treatment containing vermicompost may be owing to increased supply of multi-nutrients, plant growth regulators and beneficial microflora released from vermicompost in addition to the most favorable conditions with respect to physico-chemical and biological properties of the soil. At higher level of nitrogen, crop absorbed sufficient amount of N, resulting in better growth parameters such as plant height, dry matter accumulation, number of tillers. The smallest plants were recorded in control and the tallest plants were observed in treatment T_{10}. This might be because of higher nitrogen supply which enhanced the photosynthesis and better translocation of photosynthates by plant at higher nitrogen application. Nitrogen application increased plant height (Moreno *et al.*, 2003; Meena *et al.*, 2012) and tillering, which ultimately led to higher dry matter production.

Tillering is an important trait for grain production and is thereby an important aspect of barley growth improvement. Effective tillering depends primarily on soil physical conditions that were superior due to addition of vermicompost (Kakraliya *et al*., 2016). Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_{10} at all the stages of crop growth also resulted in highest dry matter accumulation and tillers per metre row length. The difference in dry matter accumulation at 30 DAS in treatment T_7 to T_{10} was significant (Table 7). Treatment T_{10} at all the stages of crop growth resulted in highest number of tillers/mrl. This difference in dry matter accumulation may be due to beneficial effects of combined application of organic manures, inorganic fertilizers along with biofertilizers. This is might be due to the fact that addition of vermicompost, chemical fertilizer and inoculation of *biomix* in conjunction with all necessary macro and micro nutrients and their uptake by the wheat crop and as a resulted effect of higher dry matter accumulation and their translocation in plant parts favored which growth and ultimately value of all yield parameters enhanced. Similar findings have been reported by several research workers (Patel *et al*. 2012 and Kumar *et al.*, 2014**)**. The above findings can also be explained on the basis of the fact that various combinations of nitrogen fertilizer, *biomix* and vermicompost increased the growth of the barley crop resulting in more dry matter accumulation by secreting plant growth hormones. The increase in tillers of barley in INM might be due adequate quantity and balanced proportion of plant nutrient supplied to the crop as per need during the growing period resulting in favorable environment for crop growth. Similar results also observed by Upadhyay and Vishwakarma (2014) and Suthar (2006). Corroborative findings have also been reported by Rathore *et al*. (2003), Rathore and Gautam (2003), Singh and Prasad (2011) and Malik (2017). But various combinations of nitrogen fertilizer, *biomix* and vermicompost fail to influence plant population of barley at 20 DAS.

Leaf area index is an important parameter of photosynthesizing surface of plant and has pronounced effect on crop growth and yield. Among various combinations of nitrogen fertilizer, *biomix* and vermicompost leaf area index at 30 DAS was highest in treatment T_{10}, being significantly higher than other treatments but statically at par with treatment T_8 and T_9. Seed inoculation with *biomix* might also have positive influence on barley growth which may be attributed to the hormone production by these bacteria to increase the nutrient uptake by inoculated roots hence contributing more leaf area. This might be due to combined effect of vermicompost, *biomix* and chemical fertilizers in balanced proportion played a very crucial role in decomposition and easy release of different nutrients and their uptake by the barley crop which led to higher dry matter production and its translocation in different plant parts of growth and yield parameters, which in turn resulted into higher yield. These results are in complete agreement with those of Ram and Mir (2006) and Kakraliya *et al*. (2016). The findings confirmed with the results found by Malik (2017) who reported that among different combination of biofertilizers, seed inoculation with *biomix* recorded highest value for leaf area index and lowest was recorded in uninoculated treatment.

5.3 Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on yield attributes and yields of barley

The ultimate yield of the crop plants depend on sink and source relationship and on different yield component *viz.* spike length, number of spike, number of grains/spike and test weight. Source component may be growth factors *viz.* number of leaves, LAI, CGR and dry matter accumulation. Thus, final grain yield is the function of all these growth and yield components. The yield attributing traits like spike length and number of grains per spike was favorably influenced due to various combinations of nitrogen fertilizer, *biomix* and vermicompost (Table 10). The probable reason for this was due to fact that higher nitrogen application resulted in higher plant height, more dry matter accumulation, more CGR and as a results more photosynthates are produced at higher nitrogen levels, which ultimately resulted in increase in yield attributes of barley crop. Todarmal (2013), Malik (2017), Singh and Singh (2005), and Narolia *et al.* (2012) have also reported improvement in yield attributes of barley due to application of nitrogen and integration of various nutrient source.

Perusal of data revealed that spike length was highest in treatment T_{10} (7.66 cm), being significantly higher than other treatments but statically at par with treatment T_6 (6.81 cm), T_8 (7.23 cm) and T_9 (7.41 cm). Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_1 (5.73 cm) recorded significantly lowest spike length than rest of the treatments. These results were in unison with those obtained by Malik (2017) who reported that seed inoculation with *biomix* recorded significantly higher value for number of spikes/mrl in barley. Similarly number of grains/spike was recorded highest in treatment T_{10} (43.48), being significantly higher than other treatments but statically at par with treatment T_6 to T_9. Difference in number of grains per spike in treatment T_2, T_3 and T_4 were also not significant. The main reason for increased yield attributes of barley might be due to release of growth hormones by various biomix. Similar findings for yield attributes were reported by Yadav *et al*. (2011), Shirinzadeh *et al.* (2013), Yadav *et al*. (2014), Dhiman and Dubey (2017) and Malik (2017).

In the present investigation various combinations of nitrogen fertilizer, *biomix* and vermicompost did not markedly differ with each other in respect of test weight. However, it was numerically higher in treatment T_{10} followed by T_9.

Perusal of data in table 11 revealed that grain, straw and biological yield of barley was significantly affected due to various integrated nutrient management practices. There was significant increase in grain and straw yield of barley with the increasing nitrogen fertilizer, however, treatment T_{10} (RDN + *Biomix* + Vermicompost @ 5t ha^{-1}) being at par with treatment T_6, T_7, T_8 and T_9 resulted in significantly higher grain yield of barley (4042 kg ha^{-1}). Among various combinations of nitrogen fertilizer, *biomix* and vermicompost straw yield was maximum in treatment T_{10}, being significantly higher than treatment T_1, T_2, T_3 and T_4, but statically at par with treatment T_5, T_6, T_7, T_8 and T_9 . Least value for grain, straw and biological yield was recorded in treatment T_1 (Control). However, the difference in grain yield of barley in treatment T_1 (Control) and treatment T_2 (*Biomix*) were not significant. Similarly treatment T_1 (Control) being at par with treatment T_2 produced straw yield significantly lower than rest of the treatments and the difference in biological yield of barley in treatment T_5 to T_{10} were not significant. Treatment T_8 (75% RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}) being at par with T_9 and T_{10} resulted in 60% higher grain yield than treatment T_1 (Control). Integrated nutrient management strategies of barley has synergic and additive effects on yield as they increase the fertilizer use efficiency as well as soil fertility by promoting soil microbial activities, narrow down C: N ratio, decline in bulk density and increase in water holding capacity at low moisture levels. Similar findings were reported by Dhiman and Dubey (2017). An overall increase in grain and straw yields due to combine application of chemical fertilizer and biofertilizers was also observed by Neelam (2009) and Kumar (2005).The main reason for higher yield of barley was mainly due to synergistic effect of different nutrient sources (Chemical fertilizer vermicompost and *biomix* inoculation). Similar were the findings of Raghuvanshi *et al.* (1997), Rathore *et al.* (2003) and Malik (2017). It is further mentioned that the improvement in yield components might have resulted from favorable influence of fertilizers on the growth attributes and efficient and greater partitioning of metabolites and adequate translocation of photosynthates and nutrients to developing reproductive structures. These results confirm the findings of Rehman *et al.* (2010) and Singh and Kumar (2010)**.**

However, various combinations of nitrogen fertilizer, *biomix* and vermicompost did not affect the harvest and attraction index of barley. The range of harvest index was between 32.22 to 34.25% while the range of attraction index was between 47.98 to 52.08%. Abebe and Manchore (2016) revealed that nitrogen fertilizer rate had no significant effect on harvest index. Similar result were obtained by Malik (2017) in barley at Hisar who reported that seed inoculation with various biofertilizers combination did not have any significant effect on harvest index of barley.

5.4 Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on quality of barley

A perusal of data revealed boldness as well as thinness of barley grain is genetic in nature and various combinations of nitrogen fertilizer, *biomix* and vermicompost fail to influence boldness as well as thinness of barley grain. The range of bold grain (%) was between 77.08 (T_1) to 78.83% (T_{10}) while range of thin grain (%) was between 5.06 (T_1) to 5.56% (T_{10}).

Similarly hectoliter weight of barley grain was not affected significantly due to various combinations of nitrogen fertilizer, *biomix* and vermicompost on hectoliter weight of barley. It might be due to the fact that boldness as well as thinness and hectoliter weight are genetic characters of barley and hence not affected by external factors like nutrient management strategies by Malik (2017).

Optimum nitrogen levels were effective in producing better yield and quality of barley grain. A proper supply of nitrogen in barley helped to accumulate protein in seeds and increase in grain weight. Treatment T_{10} (11.74%) being at par with treatment T_3 to T_9 resulted in significantly higher protein content of barley. Least value for protein content was recorded in treatment T_1 (8.50%). However, the difference in protein content of barley in treatment T_1 (Control) and treatment T_2 (*Biomix*) were not significant. This increase in protein content is due to increase in nitrogen levels with increasing fertilizer levels. Similar results were recorded by Singh *et al*. (2013) and Alghabari and Al-Solaimani (2015). Malik (2017) also reported that barley grain protein content increased with increasing rates of N application and seed inoculation with *biomix* produced highest protein content followed by seed inoculation with *Azospirillum + PSB and Azotobacter + PSB* in barley at Hisar. These results were in unison with Mehrvarz and Chaichi (2008) also who reported that *PSB* had a significantly positive influence on increasing the percentage of grain protein. *Biomix* inoculation along with 75% RDF improved both protein content and protein yield (Yamank 2017 and Kumar *et al*. 2007). The increase in protein content in grain under *biomix* inoculation treatment might be due to more availability of nitrogen and solubilization of fixed phosphorous under inoculation treatment (Satyajeet *et al*., 2007).

In the present experimentation perusal of data revealed that among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_1 being at par with treatment T_2 recorded significantly higher value of malt content of barley than treatment T_3 to T_{10}. Lowest value of malt content of barley was recorded in treatment T_{10} (80.18). Dahiya (2014) reported that malt recovery (%) of barley grain decreased significantly with increase in nitrogen levels up to 105 kg N ha^{-1}. Roy *et al*. (2006) also reported that there was a strong negative correlation between protein content and malt extract of barley. These results were in unison with those obtained by Edney *et al*. (2012) and Singh *et al*. (2013). Higher malt extract value is normally associated with low protein content in grain (Singh *et al*., 2013), and this relation has truly been recorded in present study too. Malt extract is a key quality indicator because it reflects the amount of beer that can be produced from a given quantity of malt.

5.5 Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on NPK content and uptake of barley

Nutrient uptake in crops is largely dependent on the growth and development of plants. However, concentration of various nutrients in the plant system also affects their total uptake. The results of the present investigation indicated that various combinations of nitrogen fertilizer, *biomix* and vermicompost significantly influenced the N, P and K content in grain and straw, N, P and K uptake in grain and straw and total N, P and K uptake except K content in straw. N, P and K content in grain was recorded highest in treatment $T_{10.}$ Due to the combined application of chemical fertilizers, vermicompost and *biomix* inoculation more nutrients availability might have increased the cation exchange capacity of roots thereby increasing the nutrient absorption and nutrient contents in grain and straw (Kumar *et al*., 2002). It may also be due to the fact that nutrient uptake followed the yield pattern which increased due to seed inoculation with biomix and vermicompost application. Because of better root proliferation and growth in INM treatment higher total uptake of N, P and K was observed. Similar results for higher total N, P and K uptake by barley were reported by Malik (2017). Sayed *et al.* (2000) also reported that *Azospirillum* inoculation alone or in combination with *PSB* significantly increased N, P and K uptake. Increase in nutrient concentration with treatment T_{10} seem to be affected by greater mobilization of nutrients from vegetative parts (leaf and stem) to ear head (grain).

5.6 Effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on economics of barley

Among various combinations of nitrogen fertilizer, *biomix* and vermicompost gross returns was highest in treatment T_{10} (85542 Rs ha^{-1}) followed by treatment T_9 (84121 Rs ha^{-1}) and T_8 (82437 Rs ha^{-1}) and highest net returns was recorded in treatment T_9 (57566 Rs ha^{-1}) followed by treatment T_{10} and T_8. The gross return of barley varied from 51520 Rs ha^{-1} (T_1) to 85542 Rs ha^{-1}(T_{10}) while net return varied from 26052 Rs ha^{-1} to 57566 Rs ha^{-1}.The benefit cost ratio was also higher in treatment T_9 (3.17) followed by treatment T_{10} and T_8. In general benefit: cost ratio of barley varied from 2.02 (T_1) to 3.17 (T_9). It might be ascribed to the higher grain and straw yield recorded due to INM treatment where vermicompost application and seed inoculation with *biomix* is done. These results were in unison with those obtained by Malik (2017) and Singh *et al*. (2013). Least value for gross returns was reported in T_1 (Control). Higher B: C ratio in treatment T_2 as compared to T_1 is because of very less increase in cost of cultivation as compared to the control. Similar results were revealed by Malik (2017) and Yadav *et al*. (2014). Overall Integrated Nutrient Management treatment resulted in higher gross returns, net returns and benefit cost ratio.

CHAPTER-VI

SUMMARY AND CONCLUSION

The field investigation entitled, **"Integrated Nutrient Management in barley"** was conducted during the *Rabi* season of 2017-2018 at the Agronomy Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar. The experiment was laid out in Randomized block design with three replications and ten treatments. The findings of the present investigation are summarized here under:

6.1 Effect of integrated nutrient management practices

6.1.1 Various combinations of nitrogen fertilizer, *biomix* and vermicompost failed to produce any significant variation in days taken to emergence and tillering in barley.

6.1.2 Treatment T_{10} took highest number days to flag leaf emergence, booting, anthesis and maturity as compared to other treatments.

6.1.3 Significantly taller plants were recorded in treatment T_{10} at all the stages of crop growth. However, the difference in plant height of barley in treatment T_8, T_9 and T_{10} at 30 DAS, T_9 and T_{10} at 60 DAS and T_6 to T_{10} at 90 DAS were not significant. Similarly, plant height at maturity in treatment T_7, $T_{8,}$ T_9 and T_{10} were recorded at par with each other.

6.1.4 Treatment T_{10} at all the stages of crop growth resulted in highest dry matter accumulation. The difference in dry matter accumulation at 30 DAS in treatment T_7 to T_{10} were not significant. Similarly, the differences in dry matter accumulation at 60 DAS and at maturity in treatment T6 to T_{10} were also not significant. At 90 DAS dry matter accumulation in treatment T_4 to T_{10} were at par with each other.

6.1.5 Among various combinations of nitrogen fertilizer, *biomix* and vermicompost leaf area index at 30 DAS was highest in treatment T_{10}, being significantly higher than other treatments but statically at par with treatment T_8 and $T_{9.}$ Similarly at 60 and 90 DAS the difference in leaf area index value of barley at in treatment $T_{8,}$ T_9 and T_{10} were not significant but higher than other treatments.

6.1.6 Among various combinations of nitrogen fertilizer, *biomix* and vermicompost highest number of tillers per metre row length at all the stages of crop growth was observed in treatment T_{10}.

6.1.7 No variations in plant population of barley at 20 DAS was observed due various combinations of nitrogen fertilizer, *biomix* and vermicompost.

6.1.8 Spike length was highest in treatment $T_{10,}$ being significantly higher than other treatments but statically at par with treatment $T_{6,}$ T_8 and $T_{9.}$

6.1.9 Among various combinations of nitrogen fertilizer, *biomix* and vermicompost number of grains per spike was recorded highest in treatment T_{10}, being significantly higher than other treatments but statically at par with treatment T_6 to T_9.

6.1.10 Various combinations of nitrogen fertilizer, *biomix* and vermicompost fail to influence test weight of barley.

6.1.11 Treatment T_{10} (100% RDN) being at par with treatment T_6, T_7, T_8 and T_9 resulted in significantly higher grain yield of barley (4042 kg ha^{-1}).

6.1.12 Among various combinations of nitrogen fertilizer, *biomix* and vermicompost straw yield was maximum in treatment T_{10}, being significantly higher than treatment T_1, T_2, T_3 and T_4, but statically at par with treatment T_5, T_6, T_7, T_8 and T_9.

6.1.13 Highest biological yield of barley was recorded with treatment T_{10} which was at par with treatment T_5 to T_9 but significantly higher than other treatments.

6.1.14 Various combinations of nitrogen fertilizer, *biomix* and vermicompost did not affect the harvest and attraction index of barley significantly.

6.1.15 Various combinations of nitrogen fertilizer, *biomix* and vermicompost fail to influence hectoliter weight and boldness as well as thinness of barley grain.

6.1.16 Treatment T_{10} (11.74 %) being at par with treatment T_3 to T_9 resulted in significantly higher protein content of barley.

6.1.17 Among various combinations of nitrogen fertilizer, *biomix* and vermicompost treatment T_1 being at par with treatment T_2 recorded significantly higher value of malt content of barley than treatment T_3 to T_{10}.

6.1.18 Treatment T_{10} produced significantly higher N content and uptake in grain and straw and total N uptake of barley followed by treatment T_9 and T_8.

6.1.19 Highest value of P content and uptake in grain and straw and total P uptake was recorded in treatment T_{10}, followed by treatment T_8 and T_9.

6.1.20 Treatment T_{10} recorded highest value of K content in grain and straw, K uptake by grain and straw and total K uptake. There was no significant effect of various combinations of nitrogen fertilizer, *biomix* and vermicompost on straw K content of barley.

6.1.20 There was no significant difference due to application of various combinations of nitrogen fertilizer, *biomix* and vermicompost on N, P and K status of soil after harvesting of barley.

6.1.21 Among various combinations of nitrogen fertilizer, *biomix* and vermicompost highest gross and net returns was recorded in treatment T_9 followed by treatment T_{10} and T_8.The benefit cost ratio was also higher in treatment T_9 followed by treatment T_{10} and T_8.

CONCLUSION

Based on one year study, it can be concluded that performance in terms of yield, quality and economics of barley in treatment T_8 (75% RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}) was at par with treatment T_9 (RDN) and T_{10} (RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}). Hence seed treatment with *Biomix*+ Vermicompost application @ 5 t ha^{-1} can save 25% of RDN in barley crop.

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ABSTRACT

A	Title of Thesis	:	**Integrated Nutrient Management in barley**
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G	Major subject	:	**Agronomy**
H	Total number of pages in thesis	:	**58 +ix**
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Key words: Barley, RDN, Grain and Straw yield, Vermicompost, *Biomix*, quality, economics

The present study entitled, **"**Integrated nutrient management in barley**"** was conducted during the *Rabi* season of 2017-2018 at the Agronomy Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar with the objective to study the effect of different nutrient management practices on growth, yield, quality and economics of barley. The experiment was laid out in Randomized Block Design replicated thrice with ten different treatments viz. T_1(Control) , T_2 (*Biomix*) , T_3 (Vermicompost @ 5 t ha^{-1}), T_4 (*Biomix* + Vermicompost @ 5 t ha^{-1}), T_5 (50 % RDN + *Vermicompost* @ 5 t ha^{-1}), T_6 (75 % RDN + *Vermicompost* @ 5 t ha^{-1}), T_7 (50% RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}), T_8 (75 % RDN + *Biomix*+ Vermicompost @ 5 t ha^{-1}), T_9 (RDN) and T_{10} (RDN + *Biomix* + Vermicompost @ 5 t ha^{-1}). Among nutrient management practices treatments T_{10} recorded significantly higher growth parameters *viz.* [plant height (cm), LAI, number of tillers / m.r.l. and dry matter accumulation/plant (g/plant)], yield attributing characters [Number of grains per spike and spike length (cm)] , grain, straw and biological yield (kg ha^{-1}), protein content, N, P and K content in grain and straw (except K content in straw), gross returns, net returns and benefit: cost ratio of barley. Performance in terms of growth, yield, nutrient studies, quality and economics of barley in treatment T_8 (75 % RDN + *Biomix*+ Vermicompost @ 5t ha^{-1}) was at par with treatment T_9 (RDN) and T_{10} (RDN + *Biomix* + Vermicompost @ 5t ha^{-1}). Treatment T_{10} took highest number of days to flag leaf emergence, booting, anthesis and maturity as compared to other treatments. Treatment T_1 being at par with treatment T_2 recorded significantly higher value of malt content of barley than treatment T_3 to $T_{10.}$ But various combinations of nitrogen fertilizer, *biomix* and vermicompost failed to produce any significant variation in days taken to emergence and tillering, plant population at 20 DAS, test weight, harvest and attraction index, quality parameters like hectoliter weight and boldness as well as thinness of barley grain, K content (%) in straw and available N, P and K status of soil after the harvest of barley.

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I, hereby, declare that all the informations given in the resume are true to the best of my knowledge.

Dated:

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UNDERTAKING OF THE COPY RIGHT

I, **Sandeep Kumar**, Admn. No. **2017A31M**, undertake that I give copy right of my thesis entitled, **"Integrated Nutrient Management in barley"** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar.

I also undertake the patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission of the competent authority of Chaudhary Charan Singh Haryana Agricultural University, Hisar.

[Signature of student]