“Effect of Integrated Nutrient Management on Growth and Yield of Barley (*Hordeum vulgare* L.)”

ABSTRACT

A field experiment was conducted at Research Farm, Vivekananda Global University, Jaipur during Rabi season of 2018-19, to study the “Effect of Integrated Nutrient Management on Growth and Yield of Barley (*Hordeum vulgare* L.)”. The experiment was laid out according to randomized block design with three replications. The treatments consisting of nine treatment combinations *viz*., 100% RDF (T1), 100% RDF + vermicompost 2.5 t ha^{-1} (T2), 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3), 75% RDF (T4), 75% RDF + vermicompost 2.5 t ha^{-1} (T5), 75% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T6), 50% RDF (T7), 50% RDF + vermicompost 2.5 t ha^{-1} (T8) and 50% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T9) were applied to the barley var. RD-2035. The experimental results showed that the growth, yield attributes and yield, quality and economics of barley was significantly increased due to different integrated nutrient treatments. The maximum plant height at 60 DAS and 90 DAS, total number of tillers at 60 DAS and 90 DAS, effective number of tillers, ear length, number of grains ear^{-1}, grain yield, straw yield, biological yield and nitrogen content in grain and straw of barley was obtained with the application of application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3). However the significantly highest net returns and B: C ratio of barley was obtained with the application of application of 100% RDF (T_1).

KEYWORDS: Biofertilizers, Integrated Nutrient Management, Nitrogen, vermicompost.

INTRODUCTION

Barley, the world's fourth most important cereal crop, is cultivated in alkali soils and areas with frost or drought. It is used in brewing industries for malt production, and its straw is used as fodder for cattle. Barley grains and straw are highly digestible compared to wheat, with 12.5% moisture, 11.5% albuminoids, 74.0% carbohydrate, 1.3% fat, 3.9% crude fiber, and 1.5% ash. Barley is cultivated in countries like China, Russia, Germany, USA, Canada, India, Turkey, and Australia. In India, barley is grown in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, West Bengal, and Bihar. However, lower productivity in arid and semiarid regions is due to climate erraticity, poor irrigation water quality, inadequate fertilization, poor soil physical conditions, nutrient imbalances, and soil permeability.

Nitrogen is a universally deficient plant nutrient in most Indian soils, and phosphorus is an essential constituent of nucleic acid, ADP, and ATP. Nitrogen is an essential constituent of many compounds such as nucleotides, phospholipids, enzymes, hormones and vitamin etc. It governs to a considerable degree to the utilization of carbohydrates, potassium and other elements. Nitrogen being an essential constituent of protein nucleic acid and chlorophyll plays a major role in photosynthesis and chlorophyll synthesis (Kanwar, 1976). The response of nitrogen is universal in the world.

The availability and form of phosphorus in the soil depend on native and/or added sources of phosphate fertilizer and organic matter content from external sources. At present 49.3% of the Indian soils are under low category, 48.8% under medium and 1.9% under high category of phosphorus. The phosphorus input in Indian agriculture comes from fertilizers, organic manures and to a very small extent from crop residues. It is an indispensable constituent of nucleic acid, ADP and ATP. It has beneficial effects on root development, growth and also hastens maturity as well as improves quality of crop produce. The availability and form of phosphorus in the soil depends upon the native and/or added sources of phosphate fertilizer and organic matter content from external sources.

Over use of chemical fertilizers harms the biological power of soil, which must be prevented as all nutrient transformation are negotiated by soil micro flora. Organic matter is the source of energy to the soil micro flora and organic carbon content and it is considered to be index of the soil health. Organic materials are intrinsic and essential component of all soils and make the soil a living dynamic system. Organic matter serves as a reservoir of nutrients that are essential for plant growth. It produces organic acids and CO_2 on decomposition which helps to dissolve minerals and make them more available to growing plants. Organic manures are potential sources of micro nutrient, improves soil structure by providing binding action to soil aggregates, increases water holding and buffering capacity of soils. It also increases nutrient use efficiency by chelating the chemical fertilizer. The organic supplementation not only a potential sources of NPK and micronutrient but have also been found to be a good substrate for flourishment of microbes resulting into sustained soil productivity. Now a days vermicompost has been advocated as good manure for use in integrated nutrient management practices adopted in the field (Shroff and Devasthali, 1992).

Earthworm processed organic west often referred to as vermicompost, which is finally divided peat like material with high porosity, aeration, drain ability and water holding capacity. The vermicomposting is a rich source of macro and micronutrients, vitamins, enzymes, antibiotics and growth hormones. Apart from the balanced supply of nutrient it improves the fertilizer and water use efficiency even better than FYM (Dayal and Agarwal, 1998).

Bio-fertilizers supplement chemical fertilizers, addressing integrated nutrient demands through biological nitrogen fixation (BNF), solubilization of insoluble nutrients, and decomposition of plant residues. Bio-fertilizers result in increased mineral and water uptake, root development, vegetative growth, and nitrogen fixation. Azotobacter, a free-living bacteria in non-leguminous crops, promotes seed germination and initial plant vigour by producing growth-promoting substances. The gap between nitrogen fertilizer production and consumption requires a focus on combining chemical fertilizers with renewable, cheaper sources like biofertilizers and organics. An integrated approach is promising for increased productivity and crop stability. A judicious combination of organic and inorganic fertilizers can sustain long-term fertility and crop productivity. Standardized nutrient management approaches are essential.

MATERIALS AND METHODS

The experiment was conducted during Rabi 2018-19 at Research Farm, Vivekananda Global University, Jaipur. Geographically, the study area is located at 075^{o} 88’99” E longitude and 26^{o} 81’17” N latitude and this region falls under agro-climatic zone III A of Rajasthan (Semi-arid Eastern Plain Zone). The climate of this zone is typically semi-arid characterized by aridity of the atmosphere and extremity of temperature both in summer (45.5°C) and winter (4°C) with annual rainfall of 500-700 mm. The soil of experiment site was loamy sand in texture with soil pH of 8.2. Available nitrogen, phosphorus and potassium of experimental site were 139.66, 14.43 and 241.12 kg/ha respectively. The experiment was laid out according to randomized block design with three replications. The treatments consisting of nine treatment combinations viz., 100% RDF (T1), 100% RDF + vermicompost 2.5 t ha^{-1} (T2), 100% RDF + vermicompost 2.5 t ha^{-1}+ Azotobacter (T3), 75% RDF (T4), 75% RDF + vermicompost 2.5 t ha^{-1} (T5), 75% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T6), 50% RDF (T7), 50% RDF + vermicompost 2.5 t ha^{-1} (T8) and 50% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T9) were applied to the barley var. RD-2035. The crop was sown on November 10, 2018 with a seed rate of 100 kg/ha. Full dose of phosphorus and half dose of nitrogen was applied as a basal dose through urea and DAP prior to sowing. The remaining half dose of nitrogen was top dressed through urea in two equal splits at 25 and 40 DAS. Nitrogen containing in DAP was adjusted with urea. Potassium was applied through MOP as per treatments. Vermicompost (1.67% N, 1.20% P and 0.89% K) was applied in the field as per treatments and was thoroughly mixed at the time of sowing. Biofertilizer inoculation: 30 g of jaggery was boiled in one half liter water and then cooled; 50 g of culture was mixed in jaggery solution. The required quantity of seed was thoroughly mixed with the paste of culture to inoculate them with Azotobacter, and then the seeds were allowed to dry in shade. Four irrigations were applied as per the requirement of crop using sprinkler irrigation method and the crop was harvested on March 25, 2019. After drying of barley, the harvested produce of each plot was weighed to record biological yield plot^{-1}. Threshing was done by beating with wooden sticks and winnowed traditionally. The straw yield was computed by deducting the weight of seed yield from total biological yield. All the values recorded in plot^{-1} were later converted in kg ha^{-1}.

The plant height was taken from five randomly selected plants of each plot and was measured from the base of the plant to the top of the main shoot by metre scale. The number of ear bearing tillers were counted by placing a metre scale in each plot along the crop row at three randomly selected spots and their average was taken as the number of effective tillers per plant. Five ears were selected randomly from each plot and their length was measured with the help of a metre scale and the mean was recorded and expressed in cm. Five ears from each plot were taken and threshed, the grains were counted and average number of grains ear^{-1} was worked out. To find out the most profitable treatment, economics of different treatments were worked out in terms of net returns (₹ ha^{-1}) on the basis of the prevailing market rates so that the most remunerative treatment could be recommended. Benefit: cost ratio for each treatment was calculated to ascertain economic viability of the treatment using the following formula:

$$\text{B:C ratio} = \frac{\text{Gross returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

Data Analysis

Various observations were statistically analysed with the help of Fisher's analysis of variance technique (Fisher, 1950). The critical difference (CD) for the treatment comparisons were worked out wherever the variance ratio (F test) was found significant at 5% level of significance.

RESULT AND DISCUSSION

Plant height, Total number of tillers plant^{-1}, Effective number of tillers plant^{-1}, Ear length (cm)

The plant height of barley increased significantly by application of different integrated nutrient management treatments at 60 and 90 DAS. Application of 100% RDF + vermicompost @ 2.5 t ha^{-1}+ Azotobacter (T3) recorded the highest plant height and proved superior to 75% RDF (T4), 50% RDF (T7), 50% RDF + vermicompost @ 2.5 t ha^{-1} (T8) and 50% RDF + vermicompost @ 2.5 t ha^{-1}+ Azotobacter (T9) at 60 and 90 DAS. Application of 100% RDF + vermicompost @ 2.5 t ha^{-1}+ Azotobacter (T3) registered a significant increase in plant height of barley in the tune of 19.82, 54.98, 24.88 and 21.42% at 60 DAS and 18.91, 50.14, 21.18 and 19.78% at 90 DAS, respectively over T4, T7, T8 and T9 and remaining treatment were statistically similar with the treatment T3.

The experimental findings revealed that different integrated nutrient treatments had significant difference on total number of tillers plant-1 at 60 and 90 DAS of barley. Application of 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3) exhibited significantly highest total number of tillers plant^{-1} at 60 and 90 DAS of barley which was closely followed by T1, T2, T5, and T6 but found superior to T4, T7, T8 and T9.

Effective number of tillers plant^{-1} at harvest of barley increased significantly with the application of different integrated nutrient treatments. Significantly highest effective number of tillers plant^{-1} at harvest of barley was recorded with the application of 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3) which was closely followed by T1, T2, T5, and T6 but found superior to T4, T7, T8 and T9. The application of 100% RDF + vermicompost 2.5 t ha^{-1}+ Azotobacter (T3) recorded significantly maximum effective number of tillers plant^{-1} which were 20.16, 51.96, 22.33 and 21.44% higher over treatment T4, T7, T8 and T9, respectively while, remaining treatment were at par with the treatment T3.

It is oblivious from the data that the ear length of barley influenced significantly with the application of different integrated nutrient treatments. Significantly highest ear length of barley was recorded with the application of 100% RDF + vermicompost 2.5 t ha^{-1} +

Azotobacter (T3) which was found superior to 75% RDF (T4), 50% RDF (T7), 50% RDF + vermicompost @ 2.5 t ha^{-1} (T8) and 50% RDF + vermicompost @ 2.5 t ha^{-1} + Azotobacter (T9). The application of 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3) significantly increased the ear length and registered an increase of 17.10, 19.82, 18.82 and 18.12%, respectively over treatment T4, T7, T8 and T9.

Nitrogen accelerates photosynthetic rate and thereby increases the supply of carbohydrates to plant, which might have in turned into increased dry matter production in plant of barley. Similarly, increased supply of available phosphorus has long been considered as an essential constituent of all living organisms and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformations. Phosphorus is the second most indispensable nutrient required for growth and development of plant and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformation. It is the main constituent of co-enzyme of ATP and ADP, which acts as energy currency within the plants. Thus, phosphorus application affects photosynthesis, biosynthesis of proteins, phospholipids and nucleic acids, membrane transport and 39 cytoplasmic streaming. Increased availability of phosphorus owing to its application in low phosphorus soils might have improved the availability of phosphate and resulted in more uptakes and in turned into increased all the growth attributes of the plants. It is known fact that that exchangeable potassium helps in the protein synthesis, chlorophyll formation and increasing resistance against stress which might have improved growth and development of the plant. The increase in plant height and number of tillers with the application of vermicompost might be due to improved photo synthetically active leaf area for longer period during vegetative and reproductive phases, led to more absorption and utilization of radiant energy which ultimately resulted in higher dry matter accumulation and significant increase in plant height. It is an established fact that organic manures improves the physical, chemical and biological properties of soil and supplies almost all the essential plant nutrients for growth and development of plants along with growth hormones and beneficial microbes (Lee, 1985) which might have developed more favorable nutritional environment in soil for longer period resulted in increased plant height, new shoots and increased dry matter accumulation. Organic matter acts as a chelate for nutrients and soluble chelates probably increase their availability and uptake to plants and mobility in soils. Thus, increased availability of macro and micro nutrients might also be the reason of improved growth parameters of the crop.

Further biofertilizers had beneficial effect on growth attributes because of certain growth promoting substances secreted by microbial inoculants and thus increased the availability of nutrients. Addition of biofertilizers in relation to N and P fertilization is instrumental in increasing the growth attributes in every level of plant growth. The favorable effect of bacterial inoculation could be attributed to increase in N supply in inoculated plots due to N-fixation ability of these bacteria. Inoculation of seed with Azotobacter give host plant drought tolerance and disease resistance benefits apart from nitrogen fixation. The faster availability of nutrients from adequate supply of inorganic fertilizers with organic manure and biofertilizers through-out the cropping period enhances the nutrient requirement of the crop and production of greater number of photo-synthetically 40 active leaves which might have lead to higher production of carbohydrates and phytohormones which resulted in increased dry matter accumulation and number of tillers. The results of the present investigation are in close conformity with those of Choudhary (2013), Kumawat (2015) Dhiman and Dubey (2017), Limanpure *et al*. (2017), Singh (2017), Jat *et al*. (2018) and Singh *et al*. (2018) in barley crop.

Table 1 Effect of integrated nutrient management on plant height of barley

Treatments	**Plant height (cm)**			**Total number of tillers m^{-1} row length**		**Ear length (cm)**
	At 30 DAS	**At 60 DAS**	**At 90 DAS**	**At 60 DAS**	**At 90 DAS**	
100% RDF	21.28	70.86	126.10	94.25	95.41	9.78
100% RDF + VC 2.5 t ha^{-1}	21.76	71.42	127.30	95.13	96.46	9.91
100% RDF + VC 2.5 t ha^{-1} + *Azotobacter*	21.98	71.59	128.11	95.40	96.97	9.95
75% RDF	20.81	59.75	107.74	79.62	81.21	8.50
75% RDF + VC 2.5 t ha^{-1}	21.07	70.47	125.52	93.74	94.67	9.74

75% RDF + VC 2.5 t ha^{-1} + *Azotobacter*	21.50	71.20	126.80	94.70	96.02	9.86
50% RDF	20.17	46.19	85.33	63.91	65.28	8.31
50% RDF + VC 2.5 t ha^{-1}	20.30	57.32	105.72	78.37	79.73	8.38
50% RDF + VC 2.5 t ha^{-1} + *Azotobacter*	20.66	58.96	106.95	78.84	80.48	8.43
SEm$\pm$	1.10	3.02	5.25	4.05	4.20	0.38
CD (P = 0.05)	NS	9.05	15.73	12.16	12.58	1.13
CV	9.02	8.14	7.87	8.17	8.32	7.12

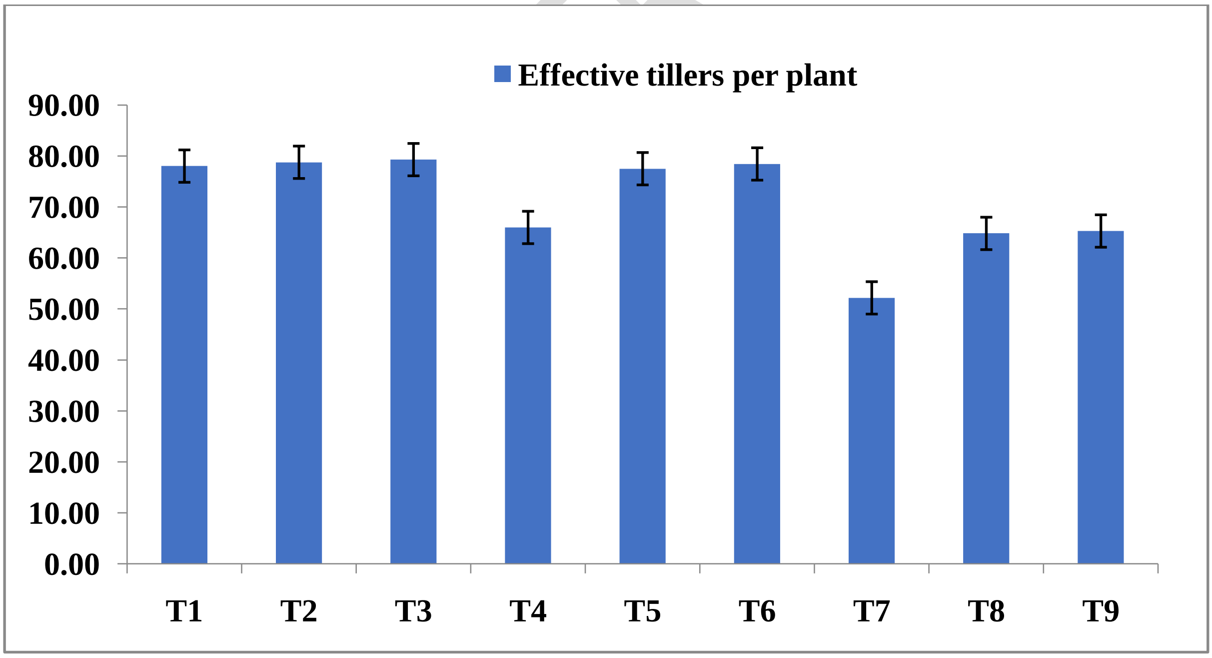

Fig. 1 Effect of integrated nutrient management on effective tillers of barley

Grain yield, Straw yield, Biological yield

It is apparent from data (Table 2) that different integrated nutrient treatments significantly influenced the grain yield of barley. Application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3) exhibited significantly highest grain yield (4073 kg ha^{-1}) of barley which was closely followed by application of 100% RDF (T_1), 100% RDF + vermicompost @ 2.5 t ha^{-1} (T_2), 75% RDF + vermicompost @ 2.5 t ha^{-1} (T_5), and 75% RDF + vermicompost @ 2.5 t ha^{-1} + *Azotobacter* (T_6) but found superior to 75% RDF (T_4), 50% RDF (T_7), 50% RDF + vermicompost @ 2.5 t ha^{-1} (T_8) and 50% RDF + vermicompost @ 2.5 t ha^{-1} + *Azotobacter* (T_9). The corresponding increase in grain yield due to application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3) was in the order of 17.39, 40.07, 20.77 and 18.93%, respectively over treatment T_4, T_7, T_8 and T_9.

A critical analysis of data in table 2 revealed that different integrated nutrient treatments significantly increased the straw yield of barley. The highest straw yield (5727 kg ha^{-1}) was obtained by application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3) which remained at par with application of 100% RDF (T_1), 100% RDF + vermicompost @ 2.5 t ha^{-1} (T_2), 75% RDF + vermicompost @ 2.5 t ha^{-1} (T_5), and 75% RDF + vermicompost @ 2.5 t ha^{-1} + *Azotobacter* (T_6) but found significantly higher than 75% RDF (T_4), 50% RDF (T_7), 50% RDF + vermicompost @ 2.5 t ha^{-1} (T_8) and 50% RDF + vermicompost @ 2.5 t ha^{-1} + *Azotobacter* (T_9). The per cent increase in straw yield due to application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3) was in the line of 18.10, 42.11, 20.53 and 19.48%, respectively over treatment T_4, T_7, T_8 and T_9.

It is clear from the experimental findings (Table 2) that biological yield of barley was significantly improved with the application of different integrated nutrient management treatments. The application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3) gave significantly highest biological yield of barley (9800 kg ha^{-1}) over 75% RDF (T_4), 50% RDF (T_7), 50% RDF + vermicompost @ 2.5 t ha^{-1} (T_8) and 50% RDF + vermicompost @ 2.5 t ha^{-1} + *Azotobacter* (T_9) but remained at par with application of 100% RDF (T_1), 100% RDF + vermicompost @ 2.5 t ha^{-1} (T_2), 75% RDF + vermicompost @ 2.5 t ha^{-1} (T_5), and 75% RDF + vermicompost @ 2.5 t ha^{-1} + *Azotobacter* (T_6). The corresponding increase in biological yield of barley due to application of 100% RDF + vermicompost 2.5 t ha^{-1} + *Azotobacter* (T_3) was 17.80, 41.26, 20.63 and 19.25% as compared to T_4, T_7, T_8 and T_9, respectively.

The beneficial response of inorganic sources of nutrient with organic manure and biofertilizers on yield attributes and yield of barley might be due to the availability of sufficient amount of plant nutrients throughout the growth period of crop resulting in better uptake of nutrients, plant vigour and improved yield. The positive effect of chemical fertilizer application in combination with vermicompost and biofertilizer on yield attributing characters of barley seems to be due to cumulative effect on growth and vigour of plants. By virtue of increased supply of metabolites, there might have been significant improvement in dry matter production with increasing fertilizer application. Increased growth components due to increased fertilizer levels might have provided stability in higher supply of photosynthates towards the sink (seeds ear^{-1}). The increased growth in terms of plant height, dry matter accumulation and number of tillers plant^{-1} might also provided better sites for pod formation and grain development. As a result, almost all yield attributes of crop resulted into significant improvement due to fertilizer application. Organic matter is also a source of energy for soil micro-flora, which brings about the transformation of organic form of nutrients present in soil, into available form. The increase in the yield attributes with the application of vermicompost ascribed to direct addition of plant nutrients and growth regulators and also due to increased microbial population of soil, which accelerated the process of humification, removal of obnoxious smell and detoxification of soil pollutants.

The increase in grain and straw yields with the application of chemical fertilizers might be due to better nutritional environment in low status of nitrogen and phosphorus soil as evidenced by their uptake in the plant and due to the increased supply of N, P and K and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters, resulted in increased grain and straw yield of the crop. Further biofertilizers (*Azotobacter*) might have played an important role in making the unavailable forms of nutrients into available forms resulting in the better uptake of nutrients subsequently yield increases. The increase in yield with inoculation of *Azotobacter* may be an account of its direct role in nitrogen fixation, production of phytohormone like substances and increased uptake of nutrients such as nitrogen. The increase in yield may also be due to better uptake of nutrients from the soil which might have contributed to increased dry matter accumulation and number of tillers plant^{-1} ultimately enhanced grain and straw yield of barley. The plant emerging from biofertilizer inoculated seeds recorded significantly higher grain yield than plant emerging from biofertilizer uninoculated seeds. The results of the present study are in close conformity with findings of Hariram and Dhaliwal (2012), Chavarekar *et al.* (2013), Kumawat (2015), Singh and Chauhan (2016), Dhiman and Dubey (2017), Jat *et al.* (2018) and Singh *et al.* (2018) in barley crop.

Table 2 Effect of integrated nutrient management on yield of barley and nitrogen content in grain and straw

Treatments	Yield (kg ha^{-1})			Nitrogen content (%)	
	Grain	Straw	Biological	Grain	Straw
100% of RDF	3951	5632	9583	1.66	0.457
100% RDF + VC 2.5 t ha^{-1}	4035	5692	9727	1.69	0.468
100% RDF + VC 2.5 t ha^{-1} + *AZB*	4073	5727	9800	1.71	0.472
75% of RDF	3470	4849	8319	1.49	0.408
75% RDF + VC 2.5 t ha^{-1}	3926	5565	9491	1.51	0.415
75% RDF + VC 2.5 t ha^{-1} + *AZB*	3986	5666	9652	1.67	0.462
50% of RDF	2908	4030	6938	1.27	0.349
50% RDF + VC 2.5 t ha^{-1}	3373	4751	8124	1.45	0.396
50% RDF + VC 2.5 t ha^{-1} + *AZB*	3425	4793	8218	1.47	0.401
SEm$\pm$	144	217	267	0.04	0.01
CD (P = 0.05)	433	651	801	0.13	0.03

CV	6.79	7.25	5.21	4.86	4.72

NS = Non-significan

Effect on Nitrogen content in grain and straw

Data pertaining to the nitrogen content in grain and straw of barley revealed different integrated nutrient management treatments brought significant improvement in nitrogen content of seed and straw of barley. The maximum nitrogen content in grain and straw was observed with the application of 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3) which were remained at par with T1, T2 and T6, and found superior to T4, T5, T7, T8 and T9. The per cent increase in nitrogen content in grain and straw due to application of 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3) was 15.02, 13.25, 34.29, 17.93 and 16.06% in grain and 15.77, 13.82, 35.21, 19.28 and 17.69% in straw of barley, respectively as compared to T4, T7, T8 and T9.

The nitrogen content in grain and straw and their uptake were significantly improved due to application of different integrated nutrient management treatments. Application of 100% RDF + vermicompost 2.5 t ha^{-1}+ Azotobacter (T3) registered significantly maximum nitrogen content in grain and straw. The significant increase in nitrogen content in grain and straw of barley in this treatment could be due to improved inherent nutrient supplying capacity of nutrients, complexing of nutrients, flush of available nutrients on autolysis of microbial cells (Shuman and Hargrover 1985) besides, improvement in biochemical parameters of soil. When vermicompost is added to soil, complex nitrogenous compounds slowly breakdown and make steady nitrogen supply throughout growth period of crop which might be attributed to more nitrogen availability. The increase in nitrogen content in grain and 42 straw of barley with the application of fertilizers might be due to improved nutritional environment in the rhizosphere as well as in the plant system leading to enhanced translocation of N, P and K in plant parts. Similar finding have also been reported by Choudhary (2013), Kumawat (2015), Singh (2017) and Jat *et al*. (2018) in barley.

Effect on economics

Net returns and BC ratio Summary of the data on net returns and B: C ratio of barley is presented in table 3. A critical examination of data revealed that all the integrated nutrient management treatments had significant difference on net returns and B: C ratio of barley. The significantly maximum net returns (Rs. 45074 ha^{-1}) was obtained with the application of 100% RDF which were remained at par with application of 100% RDF + vermicompost @

2.5 t ha^{-1} (41404 ha^{-1}), 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (41531 ha^{-1}), 75% RDF + vermicompost @ 2.5 t ha^{-1} (40338 ha^{-1}), and 75% RDF + vermicompost @ 2.5 t ha^{-1}+ Azotobacter (40913 ha^{-1}). Application of 100% RDF provided the additional net returns of 7730, 16704, 13570 and 13232 ha^{-1} in comparison to 75% RDF (T4), 50% RDF (T7), 50% RDF + vermicompost @ 2.5 t ha^{-1} (T8) and 50% RDF + vermicompost @ 2.5 t ha^{-1} + Azotobacter (T9), respectively. While, highest B: C ratio (2.95) was obtained by the application of 100% RDF which was significantly higher than all other treatments.

Now-a-days in agriculture, the feasibility of any treatment can be decided only on the basis of benefit: cost ratio. The gross returns from barley crop varied markedly under the influence of various treatments that ultimately influenced the overall net returns and benefit: cost ratio. The application of 100% RDF (T1) fetched highest gross, net returns and B: C ratio of barley. The cost involved under these treatments was comparatively lower than additional income, which led to more returns under these treatments as compared to other treatments. Similar finding have also been reported by Hariram and Dhaliwal (2012), Choudhary (2013) and Kumawat (2015) in barley.

Table 3: Effect of integrated nutrient management on economics of various treatments

Treatment	COC (Rs.)	Treatment Cost (Rs.)	Total cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
T_1	20050	3029	23079	68154	45074	2.95
T_2	20050	8029	28079	69483	41404	2.47
T_3	20050	8529	28579	70110	41531	2.45
T_4	20050	2272	22322	59667	37345	2.67
T_5	20050	7272	27322	67660	40338	2.48
T_6	20050	7772	27822	68735	40913	2.47
T_7	20050	1515	21565	49935	28370	2.32
T_8	20050	6515	26565	58069	31504	2.19
T_9	20050	7015	27065	58907	31842	2.18

**Barley grain = ₹ 14.4 kg^{-1}, straw = ₹ 2.0 kg^{-1}, Urea = ₹13 kg^{-1}, DAP = ₹ 52 kg^{-1}, MOP = ₹ 18 kg^{-1}, Vermicompost = ₹ 2 kg^{-1} and Biofertilizer = ₹ 250 packet^{-1}.

CONCLUSION

On the basis of result obtained under the study it was concluded that the growth attributes and economics of barley was significantly increased due to different integrated nutrient treatments. The maximum plant height, total number of tillers, effective number of tillers, ear length, nitrogen content in grain and straw of barley was obtained with the application of application of 100% RDF + vermicompost 2.5 t ha^{-1} + Azotobacter (T3). However, the significantly highest net returns and B: C ratio of barley was obtained with the application of application of 100% RDF (T1). These results are only indicative and require further experimentation to derive credible conclusion.

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