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Ramandeep Kaur
M.Sc. Student, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India

Santosh Kumar
Assistant Professor, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India

Ramandeep Kaur
M.Sc. Student, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India

Jaspreet Kaur
M.Sc. Student, Department of Agriculture, G.S.S.D.G.S. Khalsa College, Patiala, Punjab, India

Correspondence
Ramandeep Kaur
M.Sc. Student, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India

Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) under irrigated conditions

Ramandeep Kaur, Santosh Kumar, Ramandeep Kaur and Jaspreet Kaur

Abstract
An experiment was conducted during *Rabi* season of 2017 at Research Farm of the Department of Agriculture, Mata Gujri College, Fatehgarh Sahib to study the effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) under irrigated conditions. The experiment was laid out in randomized block design with eight integrated nutrient management treatments *viz.* T_1 - control, T_2 - 100% recommended of NPK, T_3 - 75% NPK + FYM @ 5 t ha^{-1}, T_4 - 75% NPK + vermicompost @ 5 t ha^{-1}, T_5 - 75% NPK + *azotobacter*, T_6 - 75% NPK + PSB, T_7 - 75% NPK + *azotobacter* + PSB and T_8 - 75% NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* were applied. On the basis of results summarized at 30 DAS the maximum growth parameters *viz.* plant height (cm), numbers of tillers in running meter, dry matter accumulation (g per running row length) and leaf area index were recorded with the application of T_2- 100 % RDF which was at par with application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter.* However at 60, 90 DAS and at harvest stage, the application of T_8 -75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* gave best result in term of growth characters and yield attributes which was statistically at par with application of T_2 - 100 % RDF. It was significantly superior over all treatments. Application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* gave the maximum net returns of Rs. 277684.1 ha^{-1} and maximum benefit: cost ratio is also observed in T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* is 1.65.

Keywords: INM, plant height, yield attributes, yield

Introduction
Wheat (*Triticum aestivum* L.) being a major cereal crop has been cultivated in India and belong to family Poaceae. It is the first important and strategic cereal crop for majority of world's population. It is the most staple food of about two billion people (36% of the world's population). Wheat is world's most widely cultivated food crop after rice and it is utilized in various forms by more than billion people in the world. Wheat and rice serve as life sustaining crops for our population and thus, considered to be the cornerstone of nation's food security system. The rice-wheat cropping system of Indian agriculture is the cornerstone of the nation's food security. Adoption of intensive cropping system will meet the food demands of increasing population, requires high input energy, which are not only responsible for environment degradation but also increased the cost of cultivation. After the green revolution, production of crops has increased to a great extent due to the use of chemical fertilizers but their indiscriminate use has led to soil sickness, ecological hazards and depletion of other sources of energy (Bisen *et al.* 2011) [3]. The recent energy crisis, high fertilizer cost and low purchasing power of the farming community have made it necessary to rethink alternatives.
Under these situations, INM is a good option in food grain security as well as to maintain soil health. Integrated plant nutrient management (INM) is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, composts, green manures and bio-fertilizers (Antil, 2012) [2]. It contributes in attaining agronomical feasible, economically viable, environmentally sound and sustainable high crop yields in cropping systems by enhancing nutrient use efficiency and soil fertility, reducing nitrogen losses due to nitrate leaching and emission of greenhouse gases (Milkha and Aulakh, 2013) [8]. Application of 75% RDF + 10 t FYM ha^{-1} helps to increase the yield and nutrient uptake in wheat (Patel *et al.* 2017) [11].

Biofertilizer have also emerged promising components of nutrient supply system. Application of biofertilizer which is environment friendly and low cost input, with organic and inorganic fertilizers as part of an integrated nutrient management strategy and play significant role in plant nutrition (Patel *et al.* 2011) [11]. The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation collectively leading to much higher response on various growth and yield attributing characters (Saiyad, 2014) [13]. Seed inoculation with *azotobacter* significantly increased the number of effective tillers m^{-1} row length, number of grains ear^{-1}, ear head length, test weight as well as grain and stover yields over without inoculation (Togas *et al*. 2017) [16]. Addition of organic manures along with chemical fertilizers sustained the yield through increased nutrients availability and nutrient use efficiency. Application of organic manures, *i.e*. FYM @ 10 t ha^{-1} and vermicompost 5 t ha^{-1} with 60 kg P_2O_5 ha^{-1} or 40 kg P_2O_5 ha^{-1} + PSB and 40 kg S ha^{-1} produced maximum wheat grain and straw yield (Patel *et al*. 2014). Thus the integration of organic and inorganic sources of nutrient helps in enhances the crop productivity as well as improves the soil fertility.

Materials and Methods

A field experiment was conducted at experimental farm of Department of Agriculture, Mata Gujri College, Shri Fatehgarh Sahib Punjab during rabi season of year 2016-17. The experiment was laid out in randomized block design with three replicated. The soil of the experimental field was Gangetic alluvial having clay loam texture with *pH* (8.04). It was moderately fertile, with available nitrogen (371.16 kg ha^{-1}), available phosphorus (13.38 kg ha^{-1}), available potassium (170.12 kg ha^{-1}), organic carbon (0.56%) and electrical conductivity (0.54 dS m^{-1} at 25 ^{0}C). The total treatment combinations were eight. The treatments details are as T_1 - control, T_2 - 100% recommended of NPK, T_3 - 75% NPK + FYM @ 5 t ha^{-1}, T_4 - 75% NPK + vermicompost @ 5 t ha^{-1}, T_5 - 75% NPK + *azotobacter*, T_6 - 75% NPK + PSB, T_7 - 75% NPK + *azotobacter* + PSB and T_8 - 75% NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* were applied. HD-2967 variety was sown by *pora* method with a spacing of 22.5 cm and seed rate was 100 kg ha^{-1}. The recommended dose of fertilizers for wheat are 120, 60, 40 kg of N, P_2O_5 and K_2O ha^{-1} respectively. Full dose of P_2O_5, K_2O and 30% of N were applied at the time of sowing. Remaining doses of nitrogen were applied at 4, 6 & 8 weeks respectively after sowing in equal proportion. The amount of vermicompost, *azotobacter* and PSB was applied at per treatment wise. The major agronomical done as per requirement. Regular biometric observations were recorded at periodic intervals of 30 DAS, 60 DAS, 90 DAS and at harvest stage of selected plants. Yield attributes parameters were recorded just before harvesting of crop. Harvesting was done when the spikes matured and plant was dried up. Thus grain yield of each plot was recorded as kg $plot^{-1}$ and then converted into q ha^{-1}. After that threshing of the crop was done with mini thresher, straw was collected separately. Statistical data were analysed by standard procedure by Gomez & Gomez, 1984) [4].

Result and Discussion

Effect on growth characters

The result of the present study indicated that growth parameters of plant such as plant height, number of tillers in running meter, dry matter accumulation and LAI were significantly influenced by different integrated nutrients management treatments. Among the integrated nutrient management treatments, at 30 DAS the maximum plant height was recorded in application of T_2 - 100 % RDF 100% followed by T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter*. The plant height increased slowly during early stage of crop growth up to 30 DAS. At 60 DAS the maximum plant height was recorded in application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* closely followed by T_2 - 100 % RDF. Plant height sharply increased up to 90 DAS. At 90 DAS and at harvest stage the maximum plant height was recorded in application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter*. However at 30 DAS the maximum no. of tillers in running meter was recorded with application of T_2 - 100 % RDF 100% followed by T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* and T_4- 75% NPK + vermicompost @ 5 t ha^{-1}. At 60 DAS, 90 DAS and at harvest stage the maximum no. of tillers in running meter was recorded with application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* closely followed by T_2 - 100 % RDF and T_4- 75% NPK + vermicompost @ 5 t ha^{-1}. Among the treatments at 30 DAS the maximum dry matter accumulation was recorded with application of T_2 - 100 % RDF 100% followed by T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* and T_4- 75% NPK + vermicompost @ 5 t ha^{-1}. At 60 DAS, 90 DAS and at harvest stage the maximum dry matter accumulation was recorded with application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* closely followed by T_2 - 100 % RDF and T_4- 75% NPK + vermicompost @ 5 t ha^{-1}. Among the integrated nutrient management treatments, at 30 DAS the maximum leaf area index was recorded with application of T_2 - 100 % RDF followed by T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter*. At 60, 90 DAS and at harvest stage the maximum leaf area index was recorded in application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* closely followed by T_2 - 100 % RDF. Minimum growth attributing characters were recorded with the application of T_1- control.

At 30 DAS application of T_2- 100% RDF gave best results in growth parameters (plant height, no. of tillers in running meter, dry matter accumulation and LAI) because utilization of fertilizer by the plants is usually higher and they are readily available to crop. However at 60, 90 DAS and at harvest stage, the best result in growth parameters is obtained with T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter*). The reason for higher values of growth parameters can be discussed in the light of fact that crop under these treatments had comparatively more availability of nutrients, and thereby more availability of nutrients than other treatments which resulted in better crop growth, dry matter accumulation and more no. of tillers it might due to application of organic matter and bio fertilizer, help in higher nutrient mobility and therefore, plant uptake more nutrients by reducing nutrient losses through leaching, runoff *etc*. Phosphate-solubilizing micro organisms solubilize soil phosphorus through production of organic acid, chelating acid phosphates with net results of an enhanced availability of the nutrient to the plant, which increase the root biomass and then number of tillers, which contributed towards higher values of growth attributes. Increased availability of phosphorus is also known to influence the ratio of photosynthesis, as it is directly related with or involved in energy transfer reactions. These results confirmed the findings of Whitelaw (2000) [17] and Singh *et al*. (2018) [14]. Control plots produced significantly lower plant height, number of tillers in running meter, dry matter accumulation and LAI of wheat. This was due to direct effect of nutrient availability on yield as evident from maximum dry matter resulted from treatment where more nutrient added to soil and in low nutrient available to crop resulted in lower nutrient uptake by wheat and thereby reduction in dry matter of wheat and lower plant growth character. Similar results were reported by Mehra and Singh (2007) [7], Patel *et al.* (2017) [11] and Singh *et al.* (2017) [15].

Effect on yield attributes

Yield attributes, which determine yield, is the resultant of the vegetative development of the plant. All the attributes of yield *viz.* number of effective tillers in running meter, number of grains spike^{-1}, spike length, test weight, grain yield, straw yield, biological yield and harvest index were significantly influenced by different integrated nutrient management methods. The improvement in yield attributes and yield of crop was recorded with the application of T_8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + *azotobacter* closely followed by T_2 - 100 % RDF. However, all other treatments of integrated nutrient management were comparable to each other in respect of yield. This was due to effect of integration of NPK with vermicompost and *azotobacter* on wheat crop. Integrated nutrient management program in which both organic manure and inorganic fertilizer are used has been emphasized as a rational strategy in improving yield attributes and yield of crop. These are helps in higher plant height, tiller and also increase in total dry matter of crop. Higher nutrient availability and subsequent higher production of photosynthates that led to higher yield and biomass production which reflected in higher effective tillers plant^{-1} that ultimately resulted in higher grain yield plant^{-1}. Similar results were reported by Kachroo and Razdan (2006) [5], Ahmad *et al*. (2007) [1], Khan and Singh (2011) [6] and Singh *et al*. (2018) [14].

Effect on Yield

Yield is the result of co-ordinate interplay of various growth characters. Grain (q ha^{-1}) and stubble yield (q ha^{-1}) were significantly influenced by different treatments. The highest grain yield was recorded with the application of T8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + azotobacter which was at par with application of T_2 - 100 % RDF. It was significantly superior over rest of treatments. However, the lowest grain yield was recorded with the application of T1 - Control. The improvement in grain yield is having 49.47 % in T8 - 75 % NPK + vermicompost @ 2.5 t ha^{-1} + azotobacter as compare to T_1 - Control as observed. This was due to adequate availability of nutrients. Further seed and straw yields of wheat enhanced significantly at higher levels of NPK and integrated use of organic and biofertilizers. Application of organic manures increased grain yield of wheat. Reason for increased grain and straw yields might be attributed in account of organic manures supplemented major and micro nutrients in addition to large organic matter content which increase the microbial activity, improved soil physical and chemical properties of the soil resulting better utilization of the nutrients as compared to no application of nutrients. The all growth attributes specially LAI help in plant photosynthesis, which ultimately help in yield attributes. The high yield is due to the availability of more nutrients i.e. the results in nutrient application was better due to additional supply of nutrients through biofertilizer azotobacter which might have increased nutrient uptake and better translocation of nutrients. This result can be attributed due to marked improvement plant height, leaf area index, dry matter accumulation, yield and better nutrient utilization. Adequate availability of nutrients resulted in enhanced growth attributes and yield attributes. Incorporation of biofertilizer not only increased the growth and yield attributing characters but also increased the grain and straw yields of wheat. The increases in yield attributes and yield through bio-fertilizer might be attributed to supply of more plant hormones (auxin, cytokinin, gibberellin etc.) by the micro organisms inoculated or by the root resulting from reaction to microbial population. These results are in confirmation with the results of, Nehra and Hooda (2002), Mehra and Singh (2007) [7], Rasool *et al.* (2015) [12] and Patel *et al.* (2017) [11].

Table 1: Effect of integrated nutrients management on growth attributes of wheat

Treatments Details	Plant height (cm)				No. of tiller running meter				Dry matter accumulation (g)				Leaf area index		
	30 DAS	60 DAS	90 DAS	Harvest stage	30 DAS	60 DAS	90 DAS	Harvest stage	30 DAS	60 DAS	90 DAS	Harvest stage	30 DAS	60 DAS	90 DAS
T_1- Control	17.77	37.33	58.33	102.33	30.10	61.17	43.83	37.93	3.67	9.47	30.19	43.00	0.72	2.85	3.07
T_2- 100% Recommended dose of NPK	27.42	60.71	97.87	142.39	58.33	98.58	79.27	67.67	9.05	16.00	47.67	63.67	0.94	3.90	4.20
T_3- 75% NPK + FYM @ 5 t ha^{-1}	22.75	56.78	88.33	135.17	46.33	89.00	71.80	58.76	6.67	14.17	42.67	56.00	0.81	3.57	3.87
T_4- 75% NPK + Vermicompost @ 5 t ha^{-1}	23.75	58.33	89.80	136.00	52.60	90.50	74.33	64.43	7.33	15.50	46.00	62.33	0.83	3.59	4.05
T_5- 75% NPK + *Azotobacter*	22.17	54.32	84.15	134.33	45.00	88.92	70.67	58.60	6.17	14.13	42.00	55.00	0.80	3.54	3.76
T_6- 75% NPK + PSB	22.92	54.45	83.47	129.23	41.00	87.30	70.07	56.68	6.00	14.00	40.00	54.17	0.77	3.34	3.62
T_7- 75% NPK + *Azotobacter* + PSB	23.25	57.10	88.66	135.33	47.67	90.00	72.33	60.77	7.17	14.50	44.00	61.17	0.82	3.58	4.06
T_8 - 75% NPK + Vermicompost @ 2.5 t ha^{-1} *Azotobacter*	27.17	64.79	99.13	151.00	55.50	100.13	80.00	68.00	7.93	17.00	51.67	67.67	0.92	3.99	4.50
SEm±	0.96	2.09	3.01	4.77	1.84	3.25	2.45	2.20	0.62	0.54	1.90	2.12	0.03	0.13	0.14
C.D. at 5 %	2.91	6.34	9.13	14.48	5.58	9.85	7.43	6.68	1.87	1.65	5.77	6.44	0.09	0.39	0.41

Table 2: Effect of integrated nutrient management on yield attributes and yield parameters of wheat

Treatments	No. of effective tillers in running meter	No. of grain spike-1	Spike Length (cm)	Test Weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	HI (%)
T_1- Control	45.00	38.67	6.17	27.60	33.35	46.50	79.85	33.33
T_2- 100% Recommended dose of NPK	69.67	62.25	11.03	41.33	62.17	75.37	137.53	44.17
T_3- 75% NPK + FYM @ 5 t ha^{-1}	58.87	56.67	9.90	37.97	55.00	61.06	116.06	39.83
T_4- 75% NPK + Vermicompost @ 5 t ha^{-1}	64.83	58.33	10.60	39.33	60.11	65.15	125.26	41.00
T_5- 75% NPK + *Azotobacter*	58.03	56.42	9.83	37.67	53.74	58.57	112.31	38.57
T_6- 75% NPK + PSB	57.67	56.25	9.53	37.33	47.05	55.51	102.56	38.07
T_7- 75% NPK + *Azotobacter* + PSB	59.57	56.83	10.13	38.83	58.40	64.40	122.80	40.00
T_8 - 75% NPK + Vermicompost @ 2.5 t ha^{-1} *Azotobacter*	71.80	64.33	11.70	43.55	66.00	82.43	148.43	46.00
SEm±	2.15	1.97	0.36	1.33	1.89	3.32	4.16	1.60
C.D. at 5 %	6.53	5.97	1.09	4.03	5.73	10.06	12.62	4.85

Conclusion

On the basis of results summarized above, it can be concluded that application of T8 - 75 % NPK + vermicompost @ 2.5 t ha-1 + azotobacter gave best results in respect to all parameters and second best treatment is T2- 100% RDF. The lowest net income overall was in T1 - control treatment.

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