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Effect of integrated nutrient management on growth, yield and yield attribute in wheat crop (*Triticum aestivum* L.)

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Abstract
An experiment was conducted at Uttar Pradesh in rural district Mandhana 10 km from Kanpur during *Rabi*, season of 2022-23 on sandy loam soil, having pH 7.89, EC 0.14 dSm^{-1}, organic carbon 0.34%, available N, P and K 189.0, 15.0 and 178.0 kg ha^{-1} respectively. The experiment was laid out in randomized block design with three replication and 9 treatments *viz*. T_1. RDF 100% (150:60:40 N:P: K), T_2. RDF 75% + *Azotobacter* + *PSB*, T_3. RDF 50% + *Azotobacter* + *PSB* + VC 5 t/ha, T_4. RDF 75% + *Azotobacter* + *PSB* + FYM 15 t/ha, T_5. RDF 50% + *Azotobacter* + *PSB* + FYM 25 t/ha, T_6. RDF 75% + *Azotobacter* + *PSB* + Zn 10 kg/ha + Vermicompost (2.5 t ha^{-1}) + Bentonite S 10 kg/ha, T_7. RDF 50% + *Azotobacter* + *PSB* + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg/ha, T_8. RDF 50% + *Azotobacter* + *PSB* + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg/ha and T_9 (Control). The highest yield attributes and yield of wheat were produced with application of RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg ha^{-1} was resulted from experiment, but it did not differ significantly with RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg ha^{-1} while it was significantly performed over RDF 100%, 150:60:40 N:P: K. On the basis of data, T_6 produced 43.54% higher number of effective tillers, 44.26% taller spike length, 31.65% more test weight, 85.24% higher grain yield and 10.71% higher straw yield of wheat over control.

Keywords: Vermicompost, *Azotobacter*, *PSB* and bentonite sulphur

Introduction
Wheat (*Triticum aestivum* L.) is the superior food grain crop produced in world. Important wheat-producing countries of the world; like China, India, USA, Russia, Canada and European Union, Australia. The whole cultivated area in India under wheat crop is 30.6 million hectares and production of 107.6 million tonnes. Whereas the average productivity of 3216 Kg ha^{-1} (Khan *et al*, 2023) [7]. In all republics, the important wheat producer states are Utter Pradesh, Punjab, and Haryana. Among all states, Uttar Pradesh occupied the leading state in area (9.85 million hectares) and production (35.5 million tonnes) of wheat crop but the productivity of wheat crop also (2.7 tonnes ha^{-1}) is still less than the national average. (DAC&FW). Balanced use of nutrient is a key point for higher land profitability and a healthy environment. The accurate decision on the optimum and balanced use of chemical fertilizer required knowledge of crop response to applied fertilizer, inherent nutrients by soil and its short or long-term fate effects on soil or crops (Dobermann *et al.*, 2003) [5] Due to extensive agriculture the Indian soils are deficient in nutrients particularly in nitrogen and the, soil is degrading day by day with respect to soil fertility and productivity. Application of organic manures may improve availability of native nutrients in soil as well as the efficiency of applied fertilizers (Sawrup, 2010) [17]. Judicious use of FYM with chemical fertilizers improves soil physical, chemical and biological properties and improves the crop productivity (Sharma *et al.* 2005) [18].

The inoculation of soil or crop with phosphate solubilizing/mineralizing microorganisms is therefore a promising strategy for the improvement of plant absorption of phosphorus and thereby reducing the use of chemical fertilizers that have a negative impact on the environment (Alori *et al.*, 2012) [1]. The seed and soil treatments with PSB culture, mainly belonging to the genera *Pseudomonas* and *Bacillus*, which have been known to increase uptake of nutrients to plant and in that way increase the nutrient use efficiency of applied chemical fertilizers (Panhwar *et al.*, 2014) [10, 15]. Vermicomposting is process, the earthworms leave behind their castings that are exceptionally a rich source of bio-fertilizer.

Physio-chemical analysis had shown that vermicomposting decreases total organic carbon (TOC) and carbon-nitrogen (C/N) ratio but increases nitrogen-phosphorus-potassium (N:P:K) content when compared to compost and other agricultural wastes. All these factors will ultimately lead to improved crop growth and yield, and better soil physical, chemical and biological properties (Gupta *et al.,* 2019) [4].

To build ecologically sound and economically viable farming systems integrated nutrient management (INM) is a viable option for wheat production as it utilizes available organic and inorganic nutrients. Keeping this in view of above facts, an attempt was made to study the effect of integrated nutrient management on growth, yield attributes and yield of wheat.

Materials and Methods

A field experiment was conducted at a central region of Uttar Pradesh in rural district Mandhana 10 km from Kanpur during *Rabi*, season of 2022-23 situated at 25° 56' to 28° 58' North and longitude 79° 31' to 80° 34' East and is located on an elevation of about 125.9 meters above mean sea level in Gangatic plain. To study the effect of integrated nutrient management on yield attributes and yield of wheat. The experiment was laid out in randomized block design with three replication and nine treatments *viz*. T_1. RDF 100% (150:60:40 N:P: K), T_2. RDF 75% + *Azotobacter* + *PSB*, T_3. RDF 50% + *Azotobacter* + *PSB* + VC 5 t/ha, T_4. RDF 75% + *Azotobacter* + *PSB* + FYM 15 t/ha, T_5. RDF 50% + *Azotobacter* + *PSB* + FYM 25 t/ha, T_6. RDF 75% + *Azotobacter* + *PSB* + Zn 10 kg/ha + Vermicompost (2.5 t ha^{-1}) + Bentonite S 10 kg/ha, T_7. RDF 50% + *Azotobacter* + *PSB* + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg/ha, T_8. RDF 50% + *Azotobacter* + *PSB* + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg/ha and T_9. Control. Fertilizer and organic manure: RDF (N:P: K) @ 150:60:40 kg ha^{-1}, *Azotobacter*, *PSB*, FYM 15 and 25 t ha^{-1} was applied as per treatment. Vermicompost and FYM applied 20 days before sowing for getting a good result in required plot. It was applied in FYM 15 and 25 t/ha respectively. The initial status of soil fertility was 189:15:178 kg NPK ha^{-1} with 0.34 per cent organic carbon. A full dose of phosphorus and half of nitrogen, as per treatments, were applied at the time of sowing and remaining half of the nitrogen was top-dressed. Data on plant height, dry matter accumulation and leaf area index were recorded, number of effective tillers, spike length, number of grains/spike, 1000 grain weight, grain yield and straw yield were recorded by using standard procedure for wheat crops.

Results and Discussion

1. Growth Characters

Among the growth characters *viz*; plant height and dry matter production at 30, 60, 90 DAS and harvest stage were studied. The maximum plant height and dry matter production at 60, 90 DAS and harvest stage of wheat crop was documented from T_8 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg ha^{-1}) which were statistically at par with T_7 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg ha^{-1}) but significantly superior than T_6 (RDF 75% + *Azotobacter* culture + PSB culture + Zn 10 kg/ha + VC (2.5 t ha-1) + Bentonite S 10 kg ha^{-1}) T_4 (RDF 75% + *Azotobacter* culture + PSB culture + FYM 15 t ha^{-1}), T_5 (RDF 50% + *Azotobacter* culture + PSB culture + FYM 25 t ha^{-1}). However, the minimum plant height and dry matter production of wheat crop was recorded with T_9 [control plot]. Significantly increase in plant height and dry matter production due to use of vermicompost and seed inoculation with *Azotobacter* and PSB culture in combination with inorganic fertilizers RDF (150:60:40 N:P: K). These integrated sources of nutrient help rapid mineralization of chemical fertilizer which might have supplied the nitrogen in the early stages of the crop and presence of relatively readily available essential nutrient along with micronutrient, growth-promoting substances and other beneficial micro-organisms in vermicompost, which are involved in nutrient recycling, glucose decomposition and other beneficial activities for nutrient availability in later stages of the wheat crop which in turn helps in vigorous both root and shoot of plant growth and subsequently increase the plant through cell elongation, cell division, photosynthesis and turbidity of a plant cell. (Fazily and Thakral, 2020) [7] Some scientists also reported that vermicompost is the source of different essential plant nutrients as well as micronutrients and hormones in low amount, and its application with inorganic fertilizer increases the growth attributes and yield of wheat. Hadis *et al*. (2018) [8] and Kumar *et al*. (2017) [12]. It is also reported that adequate amount of nutrient supply especially nitrogen translocate more photosynthesis from source to sink and increases the dry matter accumulation of wheat crop. (Patel *et al*. (2018) [11], Mohan *et al*. (2018) [14], and Singh *et al*. (2017) [12].

The maximum numbers of tillers of wheat crop were recorded in T_8 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg ha^{-1}) which statistically at par with T_7 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg ha^{-1}) but statistically excellent than T_6 (RDF 75% + *Azotobacter* culture + PSB culture + Zn 10 kg/ha + VC (2.5 t ha-1) + Bentonite S 10 kg ha^{-1}) T_4 (RDF 75% + *Azotobacter* culture + PSB culture + FYM 15 t ha^{-1}), T_5 (RDF 50% + *Azotobacter* culture + PSB culture + FYM 25 t ha^{-1}) and the minimum numbers of tillers of wheat crop were recorded in T_9 [control plot] at 60, 90 and harvest stage, respectively. It is also concluded from data that the tiller mortality at 60 DAS to 90 DAS was 3.6% and at 90 DAS to harvest stage was 2.16% compare to the treatment T_1 {RDF 100% (150:60:40 N:P: K)} where tiller mortality 9.03% also. This could be happened due to continuous sources of nutrients also decrease the competition among them and ultimately decrease tiller mortality also. Findings were reported by Yadav *et al.,* (2018), Mohan *et al.,* (2018) [14], Singh *et al.,* (2018), Singh *et al.* (2016) [21].

2. Yield and yield attributes

Yield attributing character

Among the yield attributing characters *viz*; number of productive tillers, No. of spikelets/ ear, Length of spike, number of grains/spike and Test weight (g) of wheat crop were studied. Maximum No. of spikelets/ ear, Length of spike, number of grains/spike and Test weight (g) of wheat crop was recorded from T_8 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg ha^{-1}) which were statistically at par with T_7 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg ha^{-1}) and T_5 (RDF 50% + *Azotobacter* culture + PSB culture + FYM 25 t ha^{-1}) but significantly superior over other treatments. However, the minimum No. of spikelets/ ear, Length of spike, number of

grains/spike and Test weight (g) of wheat crop was recorded with T_9 [control plot]. The significant maximum yield attribute of wheat crop was observed with T_8 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg ha^{-1}) is due to continue of quantities and balanced proportions of plant nutrients throughout the growth period of the crop, which were increased the yield attributing characters of wheat. These results were also supported by Patel *et al.* (2018) [11] who reported that an adequate supply of nitrogen at a critical period of crop growth has a stimulatory impact on tillering of wheat through a synthesis of cytokines and rapid conversion of synthesized carbohydrates, which results to rapid multiplication and increase the size and number of growing cells thus results in increase yield attributing characters. Devi *et al.* (2011) [5] conducted a field experiment in two years and reported that the application of 100% RDF + 1 tonnes vermicompost ha^{-1} produced significantly higher but statistically at par numbers of yield attributing characters with an application of 100% RDF. Hadis *et al.* (2018) [8] concluded that vermicompost contains essential plant nutrient with low mount of hormones and when its integration with chemical fertilizers increase the growth and yield characteristics of wheat crop. Patel *et al.* (2018) [11], reported that the increase in test weight of wheat with RDF was the consequence of an adequate amount of nutrient supply which increased the photosynthetic activities and translocated more photosynthates in reproductive stages of the crop, results promoted growth and increased the test weight of wheat. Singh *et al.* (2016) [13] reported similar results that the application of nitrogen at latter stages of plant growth is necessary for the development of grain.

Yield Parameters

Among the yield Parameters *viz*; grain yield (q/ha), straw yield (q /ha), biological yield (q /ha) and harvest index (%) of wheat crops were studied. Maximum grain yield (q/ha), straw yield (q /ha), biological yield (q /ha) and harvest index (%) of wheat crop was recorded from T_8 (RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg ha^{-1}) which were statistically at par with T_7 [RDF 100% + Vermicompost 1.5 t ha^{-1} + *Azotobacter* + *PSB*] and T_5 (RDF 50% + *Azotobacter* culture + PSB culture + FYM 25 t ha^{-1}) but significantly superior over other treatments. However, the minimum grain yield (q/ha), straw yield (q /ha), biological yield (q /ha) and harvest index (%) of wheat crops were recorded with T_9 [control plot].

The experiment gave clear result that use of vermicompost and seed inoculation with *Azotobacter* culture and PSB culture in combination with inorganic fertilizers RDF (150:60:40 N:P:K) produce the highest grain yield (q/ha), straw yield (q /ha), biological yield (q /ha) and harvest index (%)**.** The use of PSB culture which were solubilize phosphorus and made root enables phosphorus availability significantly improve the yield of wheat. Mohan *et al.* (2018) [14] also reported that the significant maximum grain and straw yield of wheat by application of 100% RDF+25% N through vermicompost/FYM followed by application of 100% RDF were due to due continued supply quantities and balanced proportions of plant nutrients throughout the growth stages of the crop, which further increased the yield attributing characters and yield of wheat. Maurya *et al.* (2019) [19] reported significantly higher grain and straw yield of wheat crops with an integrated application of 125% RDF+25% N through vermicompost/ FYM followed by application of 100% RDF+25% through vermicompost/FYM and application of 100% RDF. They concluded that, sufficient availability of photosynthates and nutrients to develop yield-attributing characteristics, which ultimately improved the final yield of wheat. These similar results also reported by other workers Kumar *et al.*, (2017) [12], Kaushik *et al.*, (2012) [10], Jat *et al.*, (2013) [9]

Table 1: Effect of INM on Plant height (cm), Dry matter accumulation (gm^{-1}) and Productive tillers ($No.m^{-1}$) at 30, 60, 90 DAS and harvest stage

S.N.	Treatments	Plant height (cm)				Dry matter accumulation (gm^{-1})				Productive tillers ($No.m^{-1}$)			
		30 DAS	60 DAS	90 DAS	at Harvest	30 DAS	60 DAS	90 DAS	at Harvest	30 DAS	60 DAS	90 DAS	at Harvest
T_1	RDF 100% (150:60:40 N:P: K)	27.14	49.18	95.10	98.36	30.76	98.87	156.47	158.37	46.87	84.10	76.34	75.92
T_2	RDF 75% + *Azotobacter* culture+ PSB culture	27.43	48.17	94.14	96.74	30.66	94.85	151.30	154.23	46.77	82.61	73.71	73.26
T_3	RDF 50% + *Azotobacter* culture + PSB culture + VC 5 t/ha	27.76	46.90	92.70	95.85	30.30	91.69	147.04	150.67	46.12	80.11	68.46	66.16
T_4	RDF 75% + *Azotobacter* culture + PSB culture + FYM 15 t/ha	28.10	50.16	97.15	99.48	30.84	100.76	160.45	163.35	47.20	89.10	83.21	82.86
T_5	RDF 50% + *Azotobacter* culture + PSB culture + FYM 25 t/ha	27.32	52.82	95.15	100.10	31.13	105.29	170.65	174.02	47.75	93.87	90.76	89.42
T_6	RDF 75% + *Azotobacter* culture + PSB culture + Zn 10 kg/ha + Vermicompost (2.5 t ha^{-1}) + Bentonite S 10 kg/ha	27.32	51.16	96.86	99.80	31.01	108.34	166.70	168.70	47.56	90.23	88.11	86.71
T_7	RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg/ha	27.14	54.23	97.89	102.78	31.21	112.14	175.75	179.62	48.25	96.61	94.75	92.65
T_8	RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg/ha	27.34	55.84	98.77	104.17	31.29	116.82	177.68	181.20	48.54	98.78	95.18	93.12
T_9	Control	27.17	42.85	85.59	91.61	30.10	88.80	142.38	145.71	45.28	71.14	51.11	50.86
	SE (m) ±	0.722	1.31	1.72	1.16	0.80	1.83	2.68	3.28	1.23	2.30	2.12	2.11
	C.D. at 5%	NS	3.98	4.24	3.52	NS	5.53	6.11	9.92	N S	6.96	6.42	6.40

Table 2: Effect of INM on Yield attributing characters and yield (q/ha)

S.N.	Treatments	Yield attributing character					Yield (q/ha)			
		Effective Tillers/m^{-1}	No. of spikelet's	Length of spike	Grains/ spike	Test weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvesting index (%)
T_1	RDF 100% (150:60:40 N:P: K)	74.740	19.86	12.65	39.80	38.76	42.22	75.21	118.10	35.74
T_2	RDF 75% + *Azotobacter* culture+ PSB culture	70.920	18.35	12.37	37.61	38.10	38.27	73.46	111.73	34.25
T_3	RDF 50% + *Azotobacter* culture + PSB culture + VC 5 t/ha	64.450	18.16	11.67	35.71	36.71	35.29	71.14	106.43	33.15
T_4	RDF 75% + *Azotobacter* culture + PSB culture + FYM 15 t/ha	80.750	19.90	12.85	41.37	38.65	43.38	75.10	119.48	36.30
T_5	RDF 50% + *Azotobacter* culture + PSB culture + FYM 25 t/ha	86.370	21.10	13.10	43.87	41.87	48.17	76.16	124.33	38.74
T_6	RDF 75% + *Azotobacter* culture + PSB culture + Zn 10 kg/ha + Vermicompost (2.5 t ha^{-1}) + Bentonite S 10 kg/ha	82.820	19.95	13.00	42.14	41.45	45.81	75.30	121.11	37.82
T_7	RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (5 t ha^{-1}) + Bentonite S 15 kg/ha	89.550	21.21	13.13	46.37	42.17	50.23	76.91	127.14	39.50
T_8	RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha^{-1}) + Bentonite S 20 kg/ha	90.100	21.37	13.49	48.16	42.38	52.48	77.26	130.07	40.45
T_9	Control	48.100	16.71	9.90	32.17	32.19	28.33	69.78	98.11	28.87
	SE (m) ±	2.032	0.41	0.12	1.07	0.72	1.13	0.40	2.78	0.95
	C.D. at 5%	6.145	1.30	0.45	3.25	2.10	3.41	1.15	8.42	2.87

Conclusion

In the present scenario to sustain the soil health and to obtain significantly higher wheat yield over control, application of integrated sources of nutrients with RDF 50% + *Azotobacter* culture + PSB culture + Zn 15 kg/ha + Vermicompost (7.5 t ha-1) + Bentonite S 20 kg/ha may be recommended to wheat growers.

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