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The effect of nutrient management and bio-inoculants on the growth parameters, yield attributes and yield of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted in Split Plot Design with three replications during Rabi seasons of 2018-19 and 2019-20 in the Research Farm, College of Agriculture, JNKVV, Jabalpur to study the effect of nutrient management and bio-inoculants on the growth parameters, yield attributes, and yield of Wheat (*Triticum aestivum* L.). Different treatments of recommended dose of fertilizers and bio-inoculums with their interactions viz., F_0=control, F_1=50% RDF, F_2=75% RDF, F_3= 100% RDF; Bio-inoculums; B_0=without bio-inoculums, B_1=VAM 10 kg ha^{-1}, B_2=Pseudomonas 5 kg ha^{-1}, B_3= VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1}. Results revealed that application of F3 and B3 and their combinations recorded significantly more days to physiological maturity as well as highest LAI (at 30, 60 & 90 DAS), CCI, and yield attributes i.e. Number of tillers m^{-2}, Number of spike m^{-2}, spike length, Number of grain $spike^{-1}$, Test weight (1000 seed wt.), Grain yield, Straw yield, and Harvest index.

Keywords: Nutrient management, bio-inoculums, Lai, chlorophyll content index, and yield attributes of wheat

Introduction

Wheat (*Triticum aestivum* L.) is one of the most extensively grown cereal crops worldwide that has known as the "king of cereals," emanating as the keystone of India's food security and depicts the primary food for about one-third of the world population (Thakur and Agrawal 2020) [1]. India is the top major producer and consumer of wheat globally. In the global context, India is the second-largest wheat producer, with approximately 12% of the world's wheat production. It is also the second-largest consumer of wheat after China and has a huge growing demand. Wheat has occupied an area of 222.0 million hectares, with a total production of 753.3 million hectares and productivity 3.4 tonnes ha^{-1} (USDA, 2017) in the world. In India, wheat has covered an area of 30.8 million hectares, with a total production of 98.51 million tonnes and productivity 3.2 tonnes ha^{-1}. Nutrient management involves the use of mineral fertilizers and bio-inoculums where VAM and Pseudomonas improve physical properties, soil fertility, and crop yields.

When applied in combination with bio-inoculums, RDF supplies energy to beneficial micro-organisms, including Mycorrhiza and Pseudomonas, and is also used to mitigate the multiple nutrient insufficiency. Principal structural nutrients of the cell, i.e., nitrogen, phosphorus, and potassium, help build up vegetative plant growth. In contrast, the requirement of phosphorus and potassium for better crop production, photosynthesis, and translocation of nutrients from leaves to the seed. Therefore, applying an adequate amount of nutrients is a required key to obtaining a better wheat yield. In this venture, a proper blend of bio-inoculums and inorganic fertilizer is a good substitute for increasing yield and sustaining soil physicochemical and biological properties. It considered the recommended dose of fertilizer its use in the proper amount with bio-inoculums, hampering crop production. VAM and Pseudomonas as an agent to uptake plant nutrients are attaining importance. Pseudomonas and VAM recover the soil health and increase the availability of N, P, K, and other mineral nutrients, as well as help in improving crop productivity by increasing biological activity with better root growth. Efficient nutrient management and bio-inoculums helped us accomplish the goal of increasing grain yield. The present investigation was carried out in finding the effect of RDF and bio-inoculants on the growth and yield of wheat.

Materials and Methods

The field experiment was carried out at Research Farm, College of Agriculture, JNKVV, Jabalpur (M.P.), during the Rabi season of the year 2018-19 and 2019-20, situated at 23' 90" N latitude and 79' 58"E longitude at an altitude 411.78 meters over the mean sea level. The area was rich in sandy clay loam soil, having a pH of 7.1. The experiment was laid out in a split-plot design with three replications and four different nutrient management (F_0=control, F_1=50% RDF, F_2=75% RDF, F_3= 100% RDF, {RDF=120:60:40 N, P_2O_5,K_2O kg ha^{-1}}) as main plot and four application of bio-inoculums (B_0=without bio-inoculums, B_1=VAM 10 kg ha^{-1}, B_2=Pseudomonas 5 kg ha^{-1}, B_3= VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1}) as subplots. The total treatment combinations were sixteen. The crop was grown with all recommended cultural operations as per requirement. The seed was sown in lines at spacing of 20cm with recommended seed rate, i.e., 100 kg ha^{-1}. The recommended dose of fertilizers for wheat is 120:60:40 N:P_2O_5:K_2O ha^{-1}. Application of fertilizer and sowing of seed was made manually. The basal dose of fertilizers was applied as per nutrient management in the plots and mixed in the soil. A full dose of P_2O_5, K_2O, and 50% Nitrogen was applied at the time of sowing as per nutrient management. The remaining nitrogen was top-dressed in two splits as per treatment after first and second irrigation. The amount of VAM and Pseudomonas were applied treatment wise. The field was kept free from weeds by hand weeding. Five irrigations applied at critical stages in the same manner for all the treatments. LAI's regular observations were recorded at intervals of 30 DAS, 60 DAS, 90 DAS, and chlorophyll content index (CCI) (SPAD) at 60 DAS from selected plants. Physiological maturity was noted when the plant attended maximum grain size and moisture content. Yield parameters were recorded just before harvesting the crop. Harvesting was done when the spikes matured and the plant was dried up. Thus grain and straw yield of each plot was recorded in kg $plot^{-1}$ and then converted into kg ha^{-1} after threshing. Statistical data were analyzed by ICAR wasp 2.0.

The following equation was used for the calculation of the leaf area index (LAI) (Watson, 1952).

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}} \qquad LAI = \frac{(LA2+LA1)}{2/p}$$

Where LA_1 and LA_2 represent leaf area during two consecutive intervals and 'P' ground area.

Harvest Index it refers to the ratio of economic yield (seed yield) to the biological yields (seed + straw), and it is expressed under a particular treatment in percentage. It was worked for each plot by using the following formula (Nichiporvich, 1967),

$$HI\ \% = \frac{\text{Economic yield}}{\text{Biological yield}} X100$$

Result and Discussion

Days to Physiological maturity

Physiological maturity is usually defined as when the flag leaf and spikes turn yellow (Hanft and Wych, 1982) [6]. Physiological maturity is when the seeds gain maximum dry weight (Harrington, 1972) [7]. Days to physiological maturity of wheat as influenced by different treatments are presented in Table 1. The result of 2018-19 and 2019-20 revealed significant differences among main treatments and sub-treatment with their interactions. Under nutrient management, application of F_3 (102 and 103 days) leads to increased days to physiological maturity, and in contrast, noted the Lowest value for days to physiological maturity on treatment without fertilizer (94 & 94 days), which was at par with F_2 (97 and 97 days) respectively. Among the bio-inoculants, the application of VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1} (99 and 100 days) took more days to attain physiological maturity, respectively. Treatment with no bio-inoculums (95 and 96 days) observed lesser days to reach physiological maturity with respect to the interaction of both years, the F_3B_3 (106 and 107 days), respectively. Similar Results conform with the findings of Jat *et al*. (2015) [9]; Shaukat *et al*. (2020) [22]. After physiological maturity, the assimilates are not partitioned to sink from the source because the formation breaks the vascular connection to the seed of the abscission layer.

Leaf area index

Leaf area index is important because it represents the plants' canopy density and depth, which determines the extent of solar energy interception and its proper utilization for the conversion into chemical energy. The LAI is related to the biological and economic yields, and an increase in LAI causes higher yield (Singh *et al*., 2009) [20]. The investigations revealed both years' non-significant differences of LAI among nutrient management application (F) and bio-inoculants application (B) at 30 DAS. During the experimentation (2018-19 and 2019-20), At 60 DAS, recorded nutrient management with the application of F_3 (3.31 and 3.46) was a significantly higher leaf area index than other treatments. On the other hand, the lowest leaf area index was recorded significantly without fertilizer (2.91 & 3.01) in both years, respectively. Among the bio-inoculants, treatment VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1} (3.26 & 3.43) was recorded significantly higher and superior leaf area index than other treatments. Without bio-inoculums treatment (2.88 & 3.00), the significantly lowest leaf area index was recorded, respectively. F_3B_3 showed maximum LAI (3.69 & 3.89) in both years, respectively, with respect to the interaction effect. Our findings similarity to Singh and Ghosh (1991) [18], Naveed (2013) [13], Jat et al. (2015) [9]. The present study indicated a progressive increase in leaf area index with the advancement of crop growth. After attaining a peak at 60 days after sowing, it declined at 90 DAS lower LAI observed than 60 DAS, reducing the magnitude of assimilatory surface area and mobilizing photoassimilates from the assimilatory apparatus to the other parts of the plants, particularly grains.

Table 1: LAI at 30, 60 and 90 DAS of wheat as affected by nutrient management and bio-inoculums

Treatments	Leaf area index (30 DAS)		Leaf area index (60 DAS)		Leaf area index (90 DAS)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Fertilizer (nutrient management) F						
F_0	1.15	1.12	2.91	3.01	2.01	2.36
F_1	1.31	1.10	2.96	3.07	2.57	2.48
F_2	1.46	1.40	3.15	3.30	2.61	2.71

F_3	1.71	1.50	3.31	3.46	2.76	2.79
Mean	1.41	1.28	3.08	3.21	2.49	2.58
S.Em±	0.11	0.12	0.09	0.07	0.11	0.07
CD(P=0.05)	NS	NS	0.29	0.26	0.39	0.25
Bio inoculants (soil application) B						
B_0	1.22	0.94	2.88	3.00	2.06	2.19
B_1	1.50	1.32	3.14	3.26	2.55	2.64
B_2	1.41	1.35	3.05	3.15	2.67	2.66
B_3	1.49	1.50	3.26	3.43	2.68	2.85
Mean	1.41	1.28	3.08	3.21	2.49	2.58
S.Em±	0.08	0.14	0.05	0.04	0.16	0.08
CD(P=0.05)	NS	NS	0.16	0.13	0.46	0.24

Chlorophyll content index (CCI)

The high chlorophyll contents might also contribute to a higher photosynthetic rate, and a significant positive correlation between chlorophyll content and photosynthesis rate was noted (Thomas *et al*., 2005) [23]. The chlorophyll is one of the major chloroplast components for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. Flag leaf chlorophyll content is an indicator of the photosynthetic activity and its stability for the conjugation of assimilating biosynthesis (Bijanzadeh and Emam, 2010) [3]. The present study showed that 100% nutrient management with VAM+ Pseudomonas F_3B_3 (51.96) registered higher magnitudes for chlorophyll content index than control (45.48).

During the year 2018-19 & 2019-20, the chlorophyll content index varied significantly for nutrient management application. It was found to be maximum in treatment F_3 (50.18 & 50.66), and minimum chlorophyll content index was found in treatment without nutrient management (45.84 & 49.63), respectively. Among the bio-inoculants application, the chlorophyll content index varied significantly. It was maximum in treatment VAM 10 kg ha-1 + Pseudomonas 5 kg ha^{-1} (49.15) in the first year and (49.63) in the second year and minimum in treatment no bio-inoculums (46.80 & 47.28), respectively. Among the application of fertilizer, full dose of nutrient management observed 9.41 percent more chlorophyll content index than control and among bio-inoculums VAM + Pseudomonas (4.9%) recorded the maximum values for this character than the B0, respectively. Prokhorov *et al*. (1998) [16] reported a similar result.

Table 2: Days to maturity and CCI of wheat as affected by nutrient management and bio-inoculums

Treatments	**Days to physiological maturity**		**Chlorophyll content index (CCI)**	
	2018-19	**2019-20**	**2018-19**	**2019-20**
Fertilizer (nutrient management) F				
F_0	94	94	45.84	46.32
F_1	95	95	47.17	47.65
F_2	97	97	48.41	48.89
F_3	102	103	50.18	50.66
Mean	97	97	47.90	48.38
S.Em±	0.4	0.4	0.34	0.34
CD(P=0.05)	1.3	1.3	1.17	1.17
Bio inoculants (soil application) B				
B_0	95	96	46.80	47.28
B_1	96	97	47.79	48.27
B_2	96	97	47.86	48.34
B_3	99	100	49.15	49.63
Mean	97	97	47.90	48.38
S.Em±	0	0	0.22	0.22
CD(P=0.05)	0.7	0.7	0.65	0.65

Number of tillers (m^{-2}) and Number of spikes (m^{-2})

All fertility levels significantly affected the vegetative and reproductive growth of the plants depending upon the availability of needed nutrition that increases by the bio-inoculums, leading to a proportional increase in tillers. The increase in the number of tillers might be due to nutrient management with VAM and Pseudomonas, which led to greater stimulation of vegetative growth. The number of tillers in wheat affected by nutrient management and bio-inoculums after 60 days after sowing is reported in Table no.3. Application of F_3 (100% RDF) recorded the maximum number of tillers m^{-2} (682 & 696) significantly after 60 days of sowing in both years, respectively. While recorded a minimum number of tillers significantly by applying without fertilizer F_0, it was 536 & 542 respectively in both years. Without bio-inoculums (587.17 & 596.5), a minimum number of tillers m^{-2} were recorded, respectively. Significantly higher numbers of tillers m^{-2} (646.58 and 656.5) were observed for treatment VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1} compared to other treatments, respectively in both years. With respect to interaction F_3B_3 (700), significantly more number tillers were observed compared to different combinations.

In both years, Nutrient management application, a significantly higher and superior number of spikes m^{-2} was observed for treatment F_3 (560.75 and 586.25), followed by F_2 and F_1 treatments, respectively. The number of spikes m-2 was observed to be significantly lowest for treatment without fertilizer (409.42 & 436.3). Among different bio-inoculants, in both years, a markedly higher under a number of spikes m^{-2} was observed for treatment VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1} (523.58 & 551.58), respectively as compared to other bio-inoculums treatments. Without bio-inoculums (467.08 &

487.58) minimum number of spikes m^{-2} was recorded in respective years. Regarding interaction F_3B_3 (700), significantly more number spikes were observed compared to the rest of the combinations. Singh *et al*. (2007) suggest that ineffective tillers died with the time of growth, and only effective tillers have remained. Our findings Similarly to Desai *et al*. (2015) [4], Manino *et al*. (2009) [11], Heidaryan and Feilinezhad (2015) [8].

Table 3: Yield attributing characters of wheat as affected by various nutrient management and bio-inoculums

Treatments	No. of tillers m^{-2}		No. spikes m^{-2}		No. of grain $spike^{-1}$		Test weight		Grain yield (kg ha^{-1})		Straw Yield (kg ha^{-1})		HI (%)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Fertilizer (nutrient management) F														
F_0	536.08	542.42	409.42	436.33	32.13	33.20	35.08	35.36	2329.89	2414.13	3692.61	3828.65	38.68	38.67
F_1	582.17	589.67	459.42	483.42	32.53	33.33	38.43	38.10	2779.43	2867.13	4142.95	4327.41	40.10	39.78
F_2	657.17	668.33	536.67	560.25	33.07	34.13	39.38	38.83	3500.05	3549.51	5034.53	5192.90	40.86	40.45
F_3	682.33	696.00	560.75	586.25	37.33	38.40	40.46	39.74	4426.76	4500.95	6233.86	6417.04	41.53	41.22
Mean	614.44	624.10	491.56	516.56	33.77	34.77	38.34	38.00	3259.03	3332.93	4775.99	4941.50	40.29	40.03
S.Em±	3.64	2.24	3.62	4.65	0.43	0.37	0.35	0.66	86.35	112.93	19.49	20.53	0.57	0.69
CD(P=0.05)	12.60	7.76	12.51	16.08	1.48	1.27	1.23	2.27	298.82	390.80	67.45	71.03	NS	NS
Bio inoculants (soil application) B														
B_0	587.17	596.58	467.08	487.58	30.80	31.87	36.57	36.27	2945.59	3021.01	4346.45	4533.27	40.06	39.69
B_1	609.67	618.50	484.58	508.08	33.33	34.40	38.63	37.54	3122.53	3203.56	4611.19	4801.45	40.13	39.82
B_2	614.33	624.75	491.00	519.00	34.27	35.33	38.71	38.33	3279.62	3351.41	4894.14	5002.19	39.94	39.95
B_3	646.58	656.58	523.58	551.58	36.67	37.47	39.44	39.88	3688.38	3755.75	5252.16	5429.09	41.02	40.65
Mean	614.44	624.10	491.56	516.56	33.77	34.77	38.34	38.00	3259.03	3332.93	4775.99	4941.50	40.29	40.03
S.Em±	2.55	2.51	3.08	3.80	0.14	0.23	0.48	0.45	54.05	48.55	24.16	15.24	0.41	0.30
CD(P=0.05)	7.43	7.31	9.00	11.09	0.41	0.68	1.40	1.30	157.76	141.72	70.51	44.50	NS	NS

Number of grain $spike^{-1}$

The number of grains $spike^{-1}$ has proved to be an important yield component that substantially influences yield. It has been observed in the present study that application of 100% nutrient management with VAM + Pseudomonas recorded more number of grains $spike^{-1}$ as compared to control. The decrease in the number of grains $spike^{-1}$ despite low nutrient management levels treatment was associated with enhancing the other yield components. During both years, nutrient management application, a significantly more grains $spike^{-1}$ was observed for F_3 (37 & 38) than other treatments. A significantly minimum number of grains $spike^{-1}$ was observed in both years for treatment without fertilizer management (32 & 33). Among bio-inoculants, a significantly more number of grains $spike^{-1}$ was observed for treatment VAM 10 kg ha^{-1} + Pseudomonas 5 kg ha^{-1} (37) in both years over the rest of treatment, and no bio-inoculums treatment (31 & 32) was noted a minimum number of grains $spike^{-1}$. The results were in contradictions with the findings of Ashraf (1986) [2], Mondal et al. (2018) [12], and Rani et al. (2018) [17].

Grain yield kg ha^{-1} and Straw yield kg ha^{-1}

Grain (kg ha^{-1}) and straw yield (kg ha^{-1}) were significantly affected by different treatments. The highest grain yield was recorded with the application of 100% RDF (F_3) and B_3 (VAM + Pseudomonas), which was at par with F_2 and B2. In comparison, it was significantly superior to other treatments. Similarly, the straw yield was also substantially greater under F_3 than other treatments except for F_0, F_1, B_0, and B_1. With respect to nutrient management, the improvement in grain yield and straw yield has 89.99% and 68.81% in the first year, 86.44%, and 67.60% in the second year, respectively, compared to control. Bio-inoculums showed a similar effect, i.e., improvement in grain yield, and straw yield has 25.21 % and 20.83% in the first year, 24.31%, and 19.76% in the second year respectively, compared to control. Regarding improvements in grain yield and straw yield of F_3B_3 has 113.54 % and 84% mean of both years, respectively, compared to control (F_0B_0). For these reasons, higher growth attributes contribute to higher yield. Increasing nutrient level (NPK) up to 100% RDF applied alone or combined with Bio-inoculums (VAM & Pseudomonas). Incorporating inorganic sources of nutrients and bio-inoculants might have supplied readily available nutrients, resulting in greater assimilation, production increasing the yield. Similarity results were observed with Devi *et al*. (2011) [5] and Mader *et al*. (2011) [10].

Harvest Index (HI %) and Test weight (1000 seed wt.)

Harvest index had seen minimum (38.20, 38.70, and 39) in F_0B_0, F_0B_1, and F_1B_0. However, found maximum (41.90 and 41.70) F_2B_3 and F_3B_3 combinations of RDF and bio-inoculums and found significantly superior (9.16%) over the control. Harvest index influenced by different nutrient management and bio-inoculums found as maximum for F_3 and B_3 (41.53 and 41.02) in the first year, the similar trend was observed in the second year, i.e., F_3 and B_3 (41.2 and 40.7) it was found significantly superior over control of both the years. Similarly, test weight is also influenced by nutrient management and bio-inoculums, F_3B_3 (16.05%) significantly maximum and superior over the control treatment. With respect to nutrient management, F_3 is maximum, and concerning bio-inoculums, B_3 was recorded maximum. The results are in close association with the findings of Singh and Uttam (1994) [19]; Chopra *et al*. (2016); Rani *et al*. (2018) [17]; Omar *et al*. (1991) [15]; Singh *et al*. (2018) [21].

Conclusions

Based on the results summarized above, it can be concluded that the use of RDF with bio-inoculums to plant along strengthened the nutrient availability and the growth and yield of wheat. Application of 100% RDF (F_3) and (B_3) gave best results in respect to all growth parameters (*viz*., days to physiological maturity, LAI, CCI) yield attributing, and grain & straw yield. F_3B_3 was proved the combined application of nutrient management and bio-inoculums, the most effective wheat production management.

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