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Subhita Kumari
Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Mahendra Sharma
Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Dharmpal Singh Dudi
Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Pankaj Kumar Kaswan
SKRAU, Bikaner, Rajasthan, India

Rekha Kharra
Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

HS Purohit
Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Corresponding Author:
Subhita Kumari
Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Effect of fertility levels, organic sources and bio-inoculants on productivity of wheat (*Triticum aestivum* L.)

Subhita Kumari, Mahendra Sharma, Dharmpal Singh Dudi, Pankaj Kumar Kaswan, Rekha Kharra and HS Purohit

Abstract
A field experiment was conducted at Agronomy Farm, Rajasthan College of Agriculture, Udaipur during *rabi* season in 2015-16 and 2016-17. The experiment consisted of 24 treatment combinations comprising of three levels of fertility (50, 75 and 100 per cent RDF), four organic sources (FYM @ 5 and 10 t ha^{-1}, vermicompost @ 2.5 and 5 t ha^{-1}), and two bio-inoculations (Without inoculation and *Azotobacter* + PSB). Experiment was conducted under factorial randomized block design replicated thrice taking wheat var. Raj- 4037 as test crop. Enrichment of soil with 75 per cent RDF, application of vermicompost @ 5 t/ha and dual inoculations of *Azotobacter* + PSB significantly increased the effective tillers/m row length, number of grains/spike, test weight, grain, straw and biological yield over 50 per cent RDF. However, nitrogen, phosphorus and potassium uptake by grain and straw as well as total uptake by crop increased significantly up to 100 per cent RDF. The maximum monetary return of ₹63688 with benefit cost ratio of 2.28 was obtained with 75% RDF, ₹64661 was found with vermicompost @ 5 t/ha and ₹ 63711 with benefit cost ratio of 2.28 was obtained with dual inoculation of *Azotobacter* + PSB.

Keywords: *Azotobacter*, effective tillers, PSB, nitrogen, yield

Introduction
Wheat (*Triticum aestivum)* is the most important staple food grain crop in India and main source of protein and calories for a large section of population. In India, the wheat production is about 106.21 m t from an area of around 29.9 m ha (Anonymous, 2019-20) [1]. In Rajasthan production of wheat is about 13.8 m t from an area around 3.5 m ha (Anonymous, 2018-2019) [2]. Although, India is well placed in meeting its needs for food grains and the major objective of food and nutritional security for its entire population has not been achieved. The demand for food grains is expected to rise not only as a function of population growth but also as more and more people cross the poverty line with economic and social development. The integrated use of organic materials and chemical nitrogenous fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favorable ecological conditions on long-term basis (Kumar *et al.*, 2007).
The organic sources with fertilizers and bio-inoculants help to restore and sustain fertility and crop productivity. It also helps to check the emerging deficiency of nutrients other than N, P and K. Further, it brings economy and efficiency in fertilizers. The integration of fertilizers and organic sources with biofertilizers favorably affects the physical, chemical and biological environment of soils. Integrated use of mineral fertilizers together with organic manure and biofertilizer in suitable combination compliments and each other to optimize input use and maximize production and sustain the same without impairing the crop quality or soil health. It enables gainful utilization of organic wastes. (Dhaka *et al*., 2012) [8]. The information about different sources and combination of organic manures and inorganic fertilizer on growth and yield of wheat is scantly in Rajasthan. The response of organic sources of nutrients are also vary depending upon soil fertility and is highly location specific. The present study was undertaken with objective to assess the effect of fertility levels, organic sources and bio-inoculants on wheat.

Materials and Methods
A field study was conducted for two years during *rabi* season of 2015-16 and 2016-17 at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur (24º.35' N latitude, 74º.42' E longitude and an altitude of 579.5 m above mean sea level).

The experiment consisted of 24 treatment combinations comprising of three levels of fertility (50, 75 and 100 per cent RDF), four organic sources (FYM @ 5 and 10 t ha^{-1}, vermicompost @ 2.5 and 5 t ha^{-1}), and two bio-inoculations (Without inoculation and *Azotobacter* + PSB) were evaluated in randomized block design with three replications. The soil of experimental site was clay loam having 0.61% organic carbon, 7.52 pH, 315, 21 and 305 kg/ha available N, P and K, respectively. Wheat 'Raj-4037' was sown on 20 November 2015, and 21 November 2016 at 22.5 cm row-to row spacing and was harvested on 10 April 2016 and 15 April 2017, respectively. Fertilizers were placed beneath the seed, after placing the seed in furrows it was covered with soil for uniform germination and to protect from bird damage. Total rainfall received during the crop season was 0.0 mm during 2015-16 and 12.4 mm in 2016-17, respectively. Besides pre-sowing irrigation, 5 irrigations were applied as per requirement of crop using sprinkler irrigation method.

Results and Discussion

Yield attributes and yield

Application of 75% RDF to wheat significantly increased the number of effective tillers m^{-1} row length, number of grains $spike^{-1}$, test weight as well as grain, straw and biological yield of wheat (Table 1). The positive effect of recommended fertilizer application on yield attributing characters 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 biomass production with increasing fertilizer application (Jat *et al*., 2014 and Chauhan, 2014) [9, 5]. Significant increased in grain, straw and biological yield with increasing levels of fertilizers might be due to improvement in yield attributes. Application of NPK in balanced share at proper time has great impact on wheat yield. The optimum use of fertilizers can be achieved only by maintaining balanced fertilizer management for the crop and thereby better yield. Similarly these results supported by (Chauhan, 2014 and Maurya *et al*., 2019) [5, 13].

The application of vermicompost @ 5 t ha^{-1} and 10 t FYM ha^{-1} recorded significantly higher yield attributes as compare to other organic manures. This might be ascribed to overall improvements in vigour and crop growth as already stated in preceding paragraphs. Since, FYM and vermicompost contains all essential plant nutrients, its incorporation in soil promotes rapid vegetative growth and tillering, thereby, increasing the sink size in terms of flowering, fruiting and seed setting (Patel *et al*., 2014) [15]. The significant increase in grain and straw yield with application of manure might be due to their positive influence on maintaining balanced source–sink relationship which clearly evident from remarkable improvement in dry matter production, growth characters and yield attributes. Since, biological yield is a function of seed and straw yield representing vegetative and reproduction growth of crop. The profound influence of organic manuring on both these components of crop growth led to realization of higher biological yield (Kavinder *et al.* 2019) [11].

Dual inoculation of biofertilizers (*Azotobacter* + PSB) significantly increased the yield attributes and yield of wheat (Table 1). Biofertilizers can play an important role in meeting the nutrient requirement of crops and enhance soil fertility and crop productivity by fixing atmospheric nitrogen, mobilizing sparingly soluble P facilitating the release of nutrients through decomposition of crop residues. The significant increase in straw yield under dual inoculation of *Azotobacter* + PSB seems to be due to their direct effect in improving biomass $plant^{-1}$, while indirect effect might be on account of increase in morphological parameters (Kaushik *et al.*, 2012) [10].

Nutrient uptake

Application of 100% recommended dose of fertilizer significantly increased the nutrient uptake of wheat. The uptake of nutrients as a function of biomass production and nutrient content of that biomass increased with fertilizer application. This might be owing to increased availability of nutrients due to addition of fertilizers (Dhaka and Pathan, 2013) [7]. The uptake of nutrients increased with progressive increase in the supply of NPK to the crops because of higher availability of these nutrients resulting in higher biomass yield (Meena *et al*. 2018) [14]. Similar findings have also been reported by (Sharma *et al*., 2013 and Singh and Singh 2017) [17, 18]. Application of 5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} significantly increase the nutrient uptake by wheat crop. The higher nutrient uptake with organic manure might have attributed to solubilization of native status of nutrients, chelation of complex intermediate organic molecules produced during decomposition of added organic manures, their mobilization and accumulation of different nutrients in various plant parts. (Sharma *et al.*, 2013) [17].

Dual inoculation significantly increased the uptake of nutrient by crop which could be attributed to the fixation of nitrogen, better root growth due to increased availability of phosphorus by PSB besides secretion of growth promoting substances especially by *Azotobacter* and *Azospirillum*. Similar findings have been also reported by Balai *et al.*, 2011 [4].

Economics

The significantly highest net return (₹ 63688 ha^{-1}) and benefit cost ratio (2.28) were recorded with 75% RDF which was statistically at par with 100% RDF (Table 2). This trend of the net returns for crop depends upon the cost of input and treatment effect on the grain and straw yield. Similar results were reported by (Jat *et al.*, 2014 and Chauhan, 2014) [9, 5].

Application of vermicompost 5 t ha^{-1} obtained significantly higher net returns of ₹ 64661 ha^{-1} and benefit cost ratio (2.14) than other organic manures treatment. This trend in economic return is mainly due to the higher cost and treatment effect on the grain and straw yield of wheat. Similar findings were given by (Choudhary *et al*., 2013 and Baishya *et al*., 2015) [6, 3]. The highest net return (₹ 63711 ha^{-1}) and benefit cost ratio (2.28) was obtained with dual inoculation of *Azotobacter* + PSB as compared to without inoculation (Table 2). Use of efficient strains of bio-fertilizers are environment friendly, low cost agricultural inputs that have an important role in improving nutrient supply to crops but also reducing the cost of production (Kumar, 2013) [12]. These results corroborate the findings of (Ram and Mir, 2006) [16].

Table 1: Effect of fertility levels, organic sources and bio-inoculants on yields attributes, yield and nutrient uptake of wheat (pooled data of 2 years)

Treatments	Effective tillers/m row length	No. of grains/ spike	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Fertility levels								
50% RDF	91.6	36.8	37.7	3.98	7.97	94.44	23.98	136.52
75% RDF	105.0	42.0	39.7	4.56	9.11	119.49	30.37	167.41
100% RDF	108.3	43.3	41.0	4.76	9.38	127.09	31.82	171.94
S.Em ±	1.3	0.5	0.5	0.09	0.09	1.70	0.43	1.77
CD (P = 0.05)	3.5	1.4	1.4	0.26	0.29	4.76	1.20	4.96
Organic sources								
FYM (5 t/ha)	91.1	36.3	37.2	3.96	8.27	98.65	24.79	139.82
FYM (10 t/ha)	108.8	43.9	40.7	4.73	9.19	121.61	30.66	168.75
VC (2.5 t/ha)	95.7	38.3	38.3	4.16	8.37	105.19	26.55	147.98
VC (5 t/ha)	110.9	44.4	41.7	4.89	9.45	129.24	32.89	177.94
S.Em ±	1.4	0.6	0.6	0.07	0.10	1.96	0.49	2.04
CD (P = 0.05)	4.1	1.6	1.7	0.18	0.29	5.50	1.39	5.72
Bio-inoculants								
Without inoculation	98.4	39.5	38.4	4.28	8.64	107.26	27.02	150.75
*Azotobacto*r + PSB	104.8	41.9	40.6	4.59	9.00	120.08	30.42	166.49
S.Em ±	1.0	0.4	0.4	0.05	0.07	1.38	0.35	1.44
CD (P = 0.05)	2.9	1.2	1.2	0.13	0.20	3.89	0.98	4.05

Table 2: Effect of fertility levels, organic sources and bio-inoculants on economics of wheat (pooled data of 2 years)

Treatments	Cost of cultivation (₹ /ha)	Net Returns (₹ /ha)	Benefit cost ratio
Fertility levels			
50% RDF	48580	51000	2.06
75% RDF	50345	63688	2.28
100% RDF	52109	66419	2.29
S.Em ±	-	1107	0.02
CD (P = 0.05)	-	3109	0.06
Organic sources			
FYM (5 t/ha)	44020	56182	2.27
FYM (10 t/ha)	57120	60163	2.05
VC (2.5 t/ha)	43720	60469	2.38
VC (5 t/ha)	56520	64661	2.14
S.Em ±	-	1278	0.02
CD (P = 0.05)	-	3590	0.07
Bio-inoculants			
Without inoculation	50220	57027	2.14
*Azotobacto*r + PSB	50470	63711	2.28
S.Em ±	-	904	0.02
CD (P = 0.05)	-	2539	0.05

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