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

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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 percent 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 100 percent RDF, application of vermicompost @ 5 t/ha and dual inoculations of *Azotobacter* + PSB significantly increased nutrient content and uptake by grain and straw as well as total uptake by crop increased significantly up to 100 percent 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*, PSB, nutrient content, Uptake

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) [7]. 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 percent 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

Nutrient content and uptake

Successive increase in fertilizer levels significantly increased the content and uptake of nutrients by grain and straw. Application of 75% recommended fertilizer dose significantly increased the nutrient content in grain and straw however nutrient uptake was increased significantly up to 100% RDF. The significant increase in nutrient content is due to greater availability of nutrients in the soil applied through fertilizer addition. The uptake of nutrients is a function of biomass and nutrient content. This might be due to the improved nutritional environment in rhizosphere and in plant system, leading to the enhanced translocation of nutrients in plant parts. Goyal (2002) [8] reported that recommended dose of fertilizer enhanced efficiency of nutrients, thus maintained synergistic interaction. The uptake of nutrients increased with progressive increase in supply of NPK to crop due to higher availability of these plant nutrients resulting higher biomass yield (Meena *et al*. 2018) [16]. Similar findings have also been reported by (Sharma *et al*., 2013 and Singh and Singh 2017) [20, 21].

Organic manures worked as slow release fertilizer therefore they have more opportunity to uptake the nutrients continuously for longer period. The results showed a significant effect of organic manures on nutrients contents as well as its uptake by grain and straw. Application of 5 t vermicompost ha^{-1} and 10 t FYM ha^{-1} significantly increase the N, P, K, Fe, Mn, Zn and Cu content and uptake by grain and straw during both the years and in pooled analysis (Table 1,2,3 and 4). The positive influence of organic manures on nitrogen, phosphorus, potassium, iron, manganese, zinc and copper content appears to be due to improved nutritional environment both in root zone and plant system. Increased availability of these nutrients in root zone coupled with increased metabolic activities at the cellular level probably increased the nutrient uptake and accumulation in the vegetative parts. Increased accumulation of these nutrients in vegetative parts possibly with improved metabolism led to higher translocation of nutrients to reproductive organs of the crop (Singh and Singh, 2017) [21].

Increased grain and straw yield coupled with higher nutrient content in plant seemed to have increased uptake of these nutrients by the crop due to different treatments. The considerable increase in nutrient content and uptake by grain and straw could also be attributes to fact that the application of organic manures might have been stimulated plant growth, activity of soil micro-organisms resulted in higher fungal, bacterial and actinomycetes population and activity of soil enzymes (Knapp *et al.,* 2010) +. Significant influenced on these nutrient uptake by crop due to the application of organic manures increased the microbial respiration thus resulted in increased carbon content and plant nutrients mineralization rate in the soil (Powon *et al*., 2005) [18]. Higher nutrient uptake by the use of organic manures might have attributing the solubilization of native nutrient status, chelation of complex intermediate organic molecules produced during the decomposition of added organic manures as well as their mobilization and accumulation of different plant nutrients in various plant parts (Sharma *et al.,* 2013) [20]. These results are in closed agreement with findings of (Mitra *et al*., 2010 and Kumar and Pannu, 2012) [17, 12].

Application of biofertilizer to crop improves the absorption availability of many plant nutrients. Results showed that inoculation of biofertilizers significantly influenced the nutrient content and uptake by grain and straw. Abbasi *et al.,* 2012 [3] obtained that the uptake of N and P by shoots of plant was increased by three fold, while K uptake was increased by 58% by the inoculation of biofertilizers. The nutrient content and uptake by crop significantly increased with inoculation of *Azotobactor* and PSB prior to sowing because *Azotobactor* can be ascribed to increased specific activities of iso citric and malic dehydrogenase, the source of electrons for nitrogen fixation creating a better nutritional environment (Kurtz and Larue, 1975) [13] and PSB solubilize the native and applied phosphorus (Singh *et al*, 2012a) [22]. These findings are in confirmation with findings of (Mahmoud, 2006, Marozsan, *et al*. 2009, Suke *et al.*, 2011 and Singh *et al*., 2012a) [14, 15, 23, 22].

Dual inoculation of *Azotobactor* + PSB significantly increased the content and uptake of nutrient under study which may be attributed to fixation of nitrogen and better root growth due to increased availability of phosphorus by PSB besides secretion of growth promoting substances especially by *Azotobactor* and *Azospirillum* (Totawat *et al*., 2000) [24]. These findings have also reported by (Dadarwal *et al.,* 2009 and Balai *et al.,* 2011 and Singh *et al*., 2012a) [6, 4, 22].

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).

Table 1: Effect of fertility levels, organic sources and bio-inoculants on nitrogen content, uptake and protein content of wheat

Treatments	Nitrogen content (%)		Nitrogen Uptake		Protein content in grain (%)
	Grain	Straw	Grain	Straw	
	Pooled	Pooled	Pooled	Pooled	Pooled
Fertility levels					
50% RDF	1.37	0.487	55.09	39.35	8.58
75% RDF	1.53	0.539	69.86	49.63	9.54
100% RDF	1.57	0.555	74.39	52.71	9.80
S.Em ±	0.02	0.007	1.12	0.85	0.11
CD (P = 0.05)	0.05	0.018	3.13	2.38	0.30
Organic sources					
FYM (5 t ha^{-1})	1.41	0.506	56.37	42.28	8.84
FYM (10 t ha^{-1})	1.53	0.536	71.76	49.85	9.54
VC (2.5 t ha^{-1})	1.46	0.518	61.27	43.93	9.14
VC (5 t ha^{-1})	1.55	0.548	76.37	52.86	9.70
S.Em ±	0.02	0.008	1.29	0.98	0.12
CD (P = 0.05)	0.06	0.021	3.62	2.75	0.35
Bio-inoculants					
Without inoculation	1.44	0.511	62.15	45.11	9.01
*Azotobacto*r + PSB	1.54	0.543	70.74	49.35	9.60
S.Em ±	0.01	0.005	0.91	0.69	0.09
CD (P = 0.05)	0.04	0.015	2.56	1.94	0.25

Table 2: Effect of fertility levels, organic sources and bio-inoculants on P and K content and uptake of wheat

Treatments	Phosphorus content (%)		Phosphorus Uptake		Potassium content (%)		Potassium Uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Fertility levels								
50% RDF	0.298	0.149	11.95	12.03	0.518	1.451	20.85	115.66
75% RDF	0.331	0.165	15.14	15.23	0.555	1.555	25.02	142.39
100% RDF	0.335	0.168	15.91	15.91	0.558	1.560	26.02	145.92
S.Em ±	0.004	0.002	0.24	0.24	0.004	0.012	0.36	1.61
CD (P = 0.05)	0.011	0.005	0.66	0.69	0.012	0.033	1.01	4.52
Organic sources								
FYM (5 t ha^{-1})	0.304	0.152	12.10	12.69	0.516	1.444	20.97	118.85
FYM (10 t ha^{-1})	0.328	0.164	15.41	15.24	0.556	1.558	25.58	143.17
VC (2.5 t ha^{-1})	0.315	0.157	13.21	13.34	0.535	1.497	22.46	125.52
VC (5 t ha^{-1})	0.338	0.169	16.60	16.29	0.569	1.591	26.84	151.10
S.Em ±	0.004	0.002	0.27	0.28	0.005	0.014	0.42	1.86
CD (P = 0.05)	0.012	0.006	0.76	0.79	0.014	0.038	1.17	5.22
Bio-inoculants								
Without inoculation	0.310	0.155	13.35	13.68	0.529	1.481	22.50	128.25
*Azotobacto*r + PSB	0.332	0.166	15.31	15.11	0.559	1.563	25.42	141.07
S.Em ±	0.003	0.002	0.19	0.20	0.003	0.010	0.29	1.31
CD (P = 0.05)	0.009	0.004	0.54	0.56	0.010	0.027	0.83	3.69

Table 3: Effect of fertility levels, organic sources and bio-inoculants on Fe and Mn content and uptake of wheat

Treatments	Iron content (mg kg^{-1})		Iron Uptake(g ha^{-1})		Manganese content (mg kg^{-1})		Manganese Uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	rain	Straw
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Fertility levels								
50% RDF	92.27	148.25	369.22	1182.0	14.31	14.31	57.4	162.4
75% RDF	96.20	153.71	441.83	1405.3	15.72	15.72	72.0	205.4
100% RDF	97.61	155.75	464.89	1456.0	16.14	16.14	76.6	213.9
S.Em ±	0.69	0.83	6.37	15.02	0.17	0.17	1.1	3.1
CD (P = 0.05)	1.94	2.34	17.90	42.18	0.47	0.47	3.0	8.7
Organic sources								
FYM (5 t ha^{-1})	91.28	146.04	360.06	1202.6	14.55	14.55	58.0	174.4
FYM (10 t ha^{-1})	97.37	155.52	460.86	1424.6	15.74	15.74	74.0	204.8
VC (2.5 t ha^{-1})	93.39	149.42	392.87	1252.7	15.24	15.24	63.8	179.2
VC (5 t ha^{-1})	99.39	159.30	487.45	1511.1	16.03	16.03	78.7	217.1
S.Em ±	0.80	0.96	7.36	17.34	0.19	0.19	1.3	3.6
CD (P = 0.05)	2.24	2.70	20.67	48.70	0.54	0.54	3.5	10.0
Bio-inoculants								
Without inoculation	93.81	149.83	406.05	1296.8	14.91	14.91	64.3	187.7

*Azotobacto*r + PSB	96.90	155.32	444.57	1398.7	15.87	15.87	73.0	200.1
S.Em ±	0.56	0.68	5.20	12.26	0.14	0.14	0.9	2.5
CD (P = 0.05)	1.58	1.91	14.62	34.44	0.38	0.38	2.5	7.1

Table 4: Effect of fertility levels, organic sources and bio-inoculants on Zn and Cu content and uptake of wheat

Treatments	Zinc content (mg kg^{-1})		Zinc uptake (g ha^{-1})		Copper content (mg kg^{-1})		Copper uptake (g ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Fertility levels								
50% RDF	28.62	16.84	114.8	135.9	7.08	3.21	28.4	25.9
75% RDF	31.44	18.62	144.0	171.4	7.74	3.53	35.4	32.5
100% RDF	32.09	19.06	152.4	180.6	7.92	3.59	37.6	34.1
S.Em ±	0.34	0.20	2.3	2.7	0.08	0.04	0.5	0.5
CD (P = 0.05)	0.95	0.57	6.4	7.5	0.24	0.11	1.5	1.4
Organic sources								
FYM (5 t ha^{-1})	29.11	17.12	116.1	143.1	7.22	3.25	28.8	27.1
FYM (10 t ha^{-1})	31.31	18.63	147.3	173.2	7.75	3.47	36.5	32.2
VC (2.5 t ha^{-1})	30.36	17.90	127.2	151.6	7.48	3.39	31.3	28.7
VC (5 t ha^{-1})	32.10	19.04	157.6	182.6	7.86	3.66	38.6	35.3
S.Em ±	0.39	0.23	2.6	3.1	0.10	0.05	0.6	0.6
CD (P = 0.05)	1.09	0.65	7.4	8.6	0.28	0.13	1.8	1.6
Bio-inoculants								
Without inoculation	29.76	17.57	128.4	155.0	7.34	3.29	31.6	29.0
*Azotobacto*r + PSB	31.68	18.78	145.8	170.2	7.82	3.59	35.9	32.6
S.Em ±	0.28	0.16	1.9	2.2	0.07	0.03	0.4	0.4
CD (P = 0.05)	0.77	0.46	5.3	6.1	0.19	0.09	1.2	1.2

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). These results corroborate the findings of (Ram and Mir, 2006) [19].

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