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Research Paper

Effect of integrated nutrient management on yield and nutrient uptake in sorghum (*Sorghum bicolor*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2010 and 2011 at Rajasthan College of Agriculture, Udaipur, to study the effect of integrated nutrient management on yield and nutrient uptake in sorghum [*Sorghum bicolor* (L.) Moench]. Two levels of farmyard manure (FYM) (0 and 10 tonnes/ha), four fertility levels based on soil test recommendation (0%, 50%, 75% and 100% NPK) and four biofertilizers (No inoculation, *Azotobacter,* phosphate solubilizing bacteria (PSB) and dual inoculation of *Azotobacter* + PSB) were compared. Application of 10 tonnes FYM/ha significantly increased grain (27.7, 28.3%) and stover (11.3, 12.9%) yields during both the years and as well as nutrient content (NPK) and their uptake over the control. Significant enhancement in grain (26.8 and 28.5%) and stover (11.9 and 13.0%) yields were observed with the application *Azotobacter* + PSB over no inoculation. Application of 100 % NPK increased grain (45.3 and 44.6%), stover (12.2 and 12.3%) yields and harvest index (22.9%) over the control. Improvement in N,P and K content and their uptake in grain (61.6, 15.3 and 22.0%) and stover (84.7, 29.9 and 243.2%) were also noticed with 100% NPK over control.

Key words : Biofertilizers, Economics, FYM, Nutrient uptake, Sorghum, Yield

In India, the area under sorghum is approximately 7.38 million ha with an annual production of about 7.0 million tonnes and an average productivity of 949 kg/ha (DAC, 2012). Since the possibility of horizontal expansion or putting more area under cultivation is difficult, future augmentation in yield should have to be harnessed vertically through increase in productivity by judicious management of all input especially nutrients.

There is a need to develop more efficient, economic and integrated system of nutrient management. Although the balanced use of N, P and K fertilizers could maintain productivity, in practices it has shown a declining trend, which has been attributed to the continuous and intensive use of chemical fertilizers. The deteriorating productivity was found to be associated with deterioration of soil physical and biological qualities besides imbalance in micronutrients. In Zone IVA (Sub-humid Southern Plain and Aravali Hills) of Rajasthan, a fertilizer dose of 80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha has been recommended for the cultivation of sorghum but the efficiency and productivity is low. The INM, however, helps in maintaining the productivity of soil and improves fertilizer-use efficiency. Thus, it economizes the use of chemical fertilizers by influencing the yield of *kharif* crop (Bejbaruha *et al.,* 2009). Besides nutrients availability, FYM also improves soil physical characteristics such as structures, porosity and water-holding capacity through increased organic matter content of soil. FYM when applied in conjunction with biofertilizers, supplies energy to beneficial microorganisms including *Azotobacter* and PSB. Integrated plant nutrition involving judicious and integrated use of chemical/synthetic sources of nutrients along with biofertilizers in addition to nutrient recycling through use of organic manures, green manuring and biodegradable wastes, etc. Biofertilizers offer a low cost, low capital intensive and ecofriendly route to boost the farm productivity depending upon their activity of mobilizing different nutrients.

Use of biofertilizer in crop not only fixes the biological nitrogen but also solubilizes the insoluble phosphates in soil and thus improves fertilizers-use efficiency Gogoi

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(2008). These microorganisms play an important role in increasing the availability of N, P and K. Keeping this in view, present investigation was undertaken to find out effect of INM on productivity and nutrient uptake in sorghum.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2010 and 2011 at Rajasthan College of Agriculture, Udaipur. The site was situated at 24°.35' N latitude, 74°.42' E longitude and an altitude of 579.5 m above mean sea-level. The region falls under agro-climatic zone IVA of Rajasthan.

The soil was clay loam, medium in organic carbon (0.68 and 0.70%), low in available nitrogen (266.80 and 270.20 kg/ha) and medium in phosphorus (19.80 and 22.50 kg/ha) and high in potassium (358.50 and 365.80 kg/ha), with pH 7.98 and 8.10 in 2010 and 2011 respectively. The treatments consisted of two levels of farmyard manure (0 and 10 tonnes FYM/ha), four fertility levels (0%, 50%, 75% and 100% NPK) based on soil test recommendation (STR) and four inoculations (no inoculation, *Azotobacter,* PSB and dual inoculation of *Azotobacter* + PSB). These treatments were evaluated in split-plot design, allocating organic manure and fertilizers in main plots and biofertilizers in subplots and replicated three times. Sorghum variety CSV 23 was sown in furrows at 45 cm row spacing using a seed rate of 10 kg/ha. Application of fertilizers (51.98 kg N, 45.54 kg P_2O_5 and 15.60 kg K_2O/ha) based on soil test recommended doses (STR) was applied as per treatment. Half dose of N and full dose of P and K applied basal at the time of sowing and remaining half dose of N at 30 days after sowing. FYM (N-0.47%, P_2O_5-0.25% and K_2O-0.54%) was mixed in soil at the time of field preparation as per treatment. Seeds were uniformly coated with *Azotobacter* inoculums using 500 g/ha and *Bacillus megatherium* var. *phosphaticum* @ 5 g/kg seed as per the treatments. Total amount of rainfall during the crop growth period was 580 and 630 mm in 2010 and 2011 respectively. Nutrient content in plant sample analyzed as per procedure suggested by Snell and Snell (1959). The results were analyzed using standard statistical procedure given by Panse and Sukhatme (2000).

RESULTS AND DISCUSSION

Farmyard manure

Significant effect of FYM was observed on chlorophyll content, yields and harvest index, whereas plant height and HCN content in sorghum remained unaffected (Table 1). An application of FYM @ 10 tonnes/ha increased grain and stover yield by 28.16 and 12.11%, respectively, over no FYM. Harvest index significantly increased by 11.00% over the control. The increase in yields might be owing to beneficial effect of FYM in improving the soil environment resulting in better absorption of moisture, nutrient and thus resulting in higher yields. Khaswan *et al.* (2012), also reported similar finding in terms of crop yield performance.

Application of FYM resulted in more uptake of N, P and K in grain, stover and total (Table 2). Total uptake of N, P and K increased by 25.82, 7.44 and 35.84 kg/ha, respectively, with FYM treatment over no FYM. The increase in the nutrient uptake with FYM might be because of release of nutrients as a result of decomposition, which caused enhancement in growth characters, increasing rate of N, P and K and micronutrients availability for longer period from FYM, which met the crop demand. Gallani *et al.* (2010) also reported significant improvements in uptake of N, P and K owing to organic manuring.

Fertility level

Successive levels of fertilizers significantly increased the plant height, chlorophyll content, HCN content, yield and harvest index (Table 1). Significantly highest HCN content to the tune of 170.75 and 63.81 ppm at 20 and 40 days after sowing (DAS), respectively, was recorded in treatment receiving 100% NPK based on STR, while the lowest in the control (152.17 and 51.19 ppm at 20 and 40 DAS respectively). Similar results were also reported by Singh *et al.* (2010). Maximum grain (4.18 tonnes/ha) and stover (14.74 tonnes/ha) yield was obtained with application of 100% NPK based on STR, being 45.13 and 12.26% higher over the control respectively.

Total N, P and K uptake by sorghum increased from 103.70 to 146.26, 35.09 to 45.31 and 218.98 to 265.19 kg/ha, respectively, with increase in the level of NPK from 0 to 100% (Table 2). The uptake of N, P and K increased with progressive increase in the supply of NPK to the crops because of higher availability of these nutrients resulting in higher biomass yield. The impact of higher uptake of plant nutrients under these treatments has been reflected in the growth and yield performance of the crop as well (Bejbaruha *et al.* 2009).

Biofertilizers

Plant height, chlorophyll and HCN content in sorghum remained unaffected due to inoculation of biofertilizers (Table 1). Highest grain and stover yield was recorded in co-inoculation of *Azotobacter* + PSB which were 27.86 and 12.45% higher over no inoculation (3.05 and 13.25 tonnes/ha) respectively. *Azotobacter* found superior to PSB for improving grain and stover yield. The microbial inoculants, bring about improvement in the nutrient availability either by fixation of atmospheric nitrogen in the

rhizosphere (*Azotobacter)* or transformation of native unavailable phosphorus (PSB) into plant utilizable P. Biofertilizers on the other hand transforms fixed and insoluble forms into soluble forms and make them readily available to plant (Arbad *et al.,* 2008).

Inoculation of biofertilizers increased nutrient uptake by grain and stover. Among the biofertilizers, maximum nutrients (NPK) uptake was recorded in *Azotobacter* + PSB treatment followed by *Azotobacter* and PSB. Total uptake of N, P and K in *Azotobacter* + PSB treatment in-

Table 1. Effect of farmyard manure, fertility levels and biofertilizers on plant height, chlorophyll content, yield, harvest index and economics of sorghum (means data of 2 years)

Treatment	Plant height (cm) at harvest	Chlorophyll content (mg/g) 60 DAS	HCN content (ppm)		Yield (tonnes/ha)		Harvest index (%)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
			20 DAS	40 DAS	Grain	Stover			
FYM (tonnes/ha)									
0	254.8	3.03	164.34	59.83	3.16	13.29	19.09	29.9	1.70
10	258.1	3.35	162.13	58.89	4.05	14.90	21.19	37.9	1.93
SEm±	1.64	0.02	0.87	0.489	0.04	0.09	0.21	0.36	0.019
CD (P=0.05)	NS	0.06	NS	NS	0.12	0.25	0.62	1.05	0.055
Fertility level (based on STR)									
0% NPK	241.4	3.05	152.17	51.19	2.88	13.13	17.88	27.25	1.54
50% NPK	254.0	3.15	160.24	60.65	3.36	13.97	19.27	31.75	1.72
75% NPK	263.1	3.22	169.78	61.80	4.00	14.56	21.43	37.59	1.99
100% NPK	267.2	3.34	170.75	63.81	4.18	14.74	21.98	38.92	2.02
SEm±	2.32	0.03	1.24	0.691	0.06	0.12	0.30	0.51	0.027
CD (P=0.05)	6.74	0.08	3.59	2.002	0.17	0.35	0.88	1.48	0.078
Biofertilizers									
No inoculation	251.9	3.14	165.44	58.51	3.05	13.25	18.56	27.96	1.51
Azotobacter	258.4	3.18	165.32	60.62	3.83	14.30	20.95	36.04	1.93
PSB	256.5	3.19	161.29	59.68	3.65	13.94	20.61	34.01	1.83
*Azotobacte*r + PSB	258.9	3.24	160.88	58.64	3.90	14.90	20.44	37.50	2.00
SEm±	1.4	0.02	1.12	0.460	0.06	0.10	0.30	0.48	0.025
CD (P=0.05)	NS	NS	NS	NS	0.16	0.28	0.84	1.34	0.070

Table 2. Effect of farmyard manure, fertility levels and biofertilizers on N, P and K uptake in sorghum (mean data of 2 years)

Treatment	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
FYM (tonnes/ha)									
0	43.7	71.4	115.2	11.32	25.8	37.1	15.8	211.8	227.6
10	59.4	81.6	141.0	14.82	29.7	44.5	20.8	242.5	263.4
SEm±	0.6	0.5	0.8	0.16	0.2	0.27	0.2	1.5	1.5
CD (P=0.05)	1.7	1.6	2.4	0.45	0.5	0.79	0.7	4.4	4.4
Fertility level (based on STR)									
0% NPK	39.3	64.3	103.7	9.9	25.1	35.0	14.3	204.6	218.9
50% NPK	48.0	75.6	123.6	12.3	26.8	39.1	16.4	223.6	240.0
75% NPK	57.3	81.5	138.8	14.6	29.2	43.8	20.6	237.3	257.9
100% NPK	61.6	84.6	146.2	15.3	29.9	45.3	22.0	243.1	265.1
SEm±	0.8	0.8	1.2	0.2	0.2	0.38	0.3	2.1	2.1
CD (P=0.05)	2.4	2.3	3.4	0.6	0.8	1.12	1.0	6.3	6.2
Biofertilizers									
No inoculation	40.8	67.6	108.4	10.7	24.7	35.5	15.0	210.6	225.7
Azotobacter	55.6	78.5	134.2	13.7	28.2	42.0	19.6	230.5	250.1
PSB	52.3	76.2	128.6	13.3	27.9	41.3	18.5	224.4	242.9
Azotobacter + PSB	57.4	83.7	141.2	14.4	30.1	44.5	20.2	243.1	263.3
SEm±	0.8	0.5	0.8	0.2	0.2	0.273	0.3	1.7	1.7
CD (P=0.05)	2.2	1.5	2.4	0.5	0.5	0.767	0.8	4.9	4.8

creased by 37.72, 9.07 and 37.67 kg/ha over the control, respectively. Biofertilizer has been identified as a good supplement to chemical fertilizer to increase soil fertility and crop production in sustainable farming. The use of bio-fertilizer results in the highest biomass and increased the nutrient uptake by plants (Marozsan *et al*., 2009).

Interaction

Application of FYM @ 10 tonnes/ha with 100% NPK resulted in maximum grain yield of sorghum, being at par with FYM and 75% NPK (Table 3). The magnitude of increase in the yield was 86.74% over control. This indicates that use of FYM in combination with fertility levels has beneficial effect in improving the crop yield. The beneficial response of FYM to yield might also be attributed to the better availability of sufficient amounts of plant nutrients throughout the growth period and especially at critical growth period of crops which has resulted in better plant vigour and superior yield attributes (Bayu *et al.,* 2006).

Table 3. Interaction effect of farmyard manure and fertility levels on grain yield (tonnes/ha) of sorghum (mean data of 2 years)

Treatment	NPK (% STR)			
	0	50	75	100
FYM (tonnes/ha)				
0	2.49	2.98	3.48	3.70
10	3.28	3.75	4.52	4.65
SEm±		0.08		
CD (P=0.05)		0.24		

STR, soil test recommendation

Maximum grain yield was recorded in FYM along with *Azotobacter* + PSB, which was 68.95% higher over the control (Table 4). Less grain yield was recorded in all the biofertilizers treatment in the absence of FYM. This shows importance of integrated use of FYM and biofertilizers in increasing crop production. Farmyard manure also provides energy for N-fixation by free living heterotrophic microorganisms. Amount of N fixation by microorganisms is influenced by energy available in the form of organic residues. Combined application of biofertilizers and FYM has been shown to improve crop yields (Hankare *et al.,* 2005).

Economics

The net returns as well as benefit: cost (B:C) ratio were also highest with FYM 10 tonnes/ha (Table 1). Thus this treatment recorded the highest net returns of with B:C ratio of 1.93. Application of 100% NPK was more economical with higher net returns as well as B:C rather than their lower doses. Combined inoculation of *Azotobacter* and PSB recorded the highest net returns and B:C. This trend in economic returns is mainly owing to the treatment effects on the grain and stover yield.

Table 4. Interaction effect of farmyard manure and biofertilizers on grain yield (tonnes/ha) of sorghum (mean data of 2 years)

Treatment	Biofertilizer			
	No inoculation	*Azotobacter*	PSB	*Azotobacter* + PSB
FYM (tonnes/ha)				
0	2.77	3.44	3.33	3.11
10	3.33	4.22	3.97	4.68
SEm±		0.08		
CD (P=0.05)		0.23		

PSB, phosphate solubilizing bacteria

It could be concluded that application of FYM along with 100% NPK based on STR and coinoculation of *Azotobacter* + PSB improved yield and nutrient uptake in sorghum under the prevailing agro-climatic condition.

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