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Effect of integrated management of farmyard manure, phosphocompost, poultry manure and inorganic fertilizers for rainfed sorghum (*Sorghum bicolor*) in Vertisols of central India

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ABSTRACT

A field experiment was conducted during the rainy reason of 2000–2001 on deep Vertisols of Bhopal, to study the effect of different nutrient combinations, viz. 0, 75, 100% recommended dose of nitrogen, phosphorus and potassium (NPK), 75% NPK + farmyard manure (FYM) @ 5 tonnes/ha, 75% NPK + poultry manure (PM) @ 1.5 tonnes/ha and 75% NPK + phosphocompost (PC) @ 5 tonnes/ha on growth, water-use efficiency, productivity and economics of sorghum [*Sorghum bicolor* (L.) Moench] cultivation. The results showed that with the increase in NPK dose from 0 to 100% there was significant improvement in both below (root) and above-ground (shoot) dry matter 60 days after sowing (DAS) and at harvest. Integrated use of organics and inorganics not only recorded significantly more root shoot dry matter but also accelerated their growth compared to inorganic fertilizer application. The shoot growth was more between 60 DAS and harvest (26.6, 24.8 and 26.7 g/m^2/day with NPK + FYM, NPK + PC and NPK + PM, respectively, compared with 21.1g/m^2/day with 100% NPK) and root growth between 30 and 60 DAS (5.2, 5.0 and 5.2 g/m^2/day with NPK + FYM, NPK + PC and NPK + PM, respectively, compared with 4.4 g/m^2/day with 100% NPK). All organics in combinations with inorganic fertilizer were superior to sole inorganic fertilizer for water-use efficiency (WUE), grain and straw yields, and harvest index (HI). Overall, application of 75% NPK and PM @ 1.5 tonnes/ha recorded highest WUE, grain and straw yields, yield attributes (ear length, ear weight/plant and 1,000-grain weight of sorghum), net return and benefit : cost ratio in both the years. The performance of nutrient combination followed the order of 75% NPK+PM>75% NPK+FYM>75% NKP + PC > 100% NPK.

Key words : Integrated nutrient management, Dry-matter production, Vertisols, Sorghum, Water-use efficiency, Farmyard manure, Poultry manure, Phosphocompost

In India, sorghum is popularly grown as main source of food and fodder by poor people and forms an important component of dryland agriculture. Yield potentiality of rainfed sorghum in Madhya Pradesh is very low (975.3 kg/ha). Low organic matter content in Vertisols coupled with low and imbalance application of macro- and micronutrient to this crop limits the full potential of yield and is the main yield barrier for this crop. Though its energy need is less than other crops, it is very exhaustive crop and requires high quantities of nutrient particularly nitrogen. Therefore, for sustainable production of sorghum judicious use of fertilizers is extremely important (Bellakki *et al.,* 1999; Kalane, 1998). High price of fertilizers and low availability of nitrogen fertilizer necessitate integrated use of organics and inorganics for highly fertilizer responsive crop like sorghum to maintain soil health and to augment the efficiency of nutrients. Besides, such integration plays an important role in better penetration and establishment of sorghum roots, which helps the plant to take up water from deeper players and to maintain high relative plant water content under soil-moisture deficit condition. Hence the present investigation was undertaken to study the effects of judicious and combined use of inorganics (NPK) and 3 organic manures (FYM, PM and PC) on growth, water-use efficiency, yield and economics of sorghum.

MATERIALS AND METHODS

The experiment was conducted during rainy (*kharif*) season of 2000 and 2001 at the research farm of the Indian Institute of Soil Science, Bhopal, on a deep Vertisols. The soil (Typic Haplustert) was clayey, having pH 7.8, organic carbon 0.52% and EC 0.52 dS/m. The available soil N, P and K were 145, 10.7 and 325 kg/ha respectively. The water holding capacity, bulk density and porosity of the surface (0–15 cm) soil were 62%, 1.45 Mg/m^3 and 45% respectively. The experiment was laid out in randomized block design (RBD) with 6 nutrient treatments replicated 4 times.

The treatment consisted of no fertilizer manure (F_1), 75% NPK through fertilizers (F_2), 100% of NPK through fertilizers (F_3) , 75% NPK through fertilizers + 25% through (FYM) (F_4), 75% of NPK through fertilizers +25% through phosphocompost (F_5) and 75% of NPK through fertilizers + 25% through poultry manure (PM)(F_6). The N content in 3 organic manures was analysed (0.63, 1.81 and 0.66% N in FYM, PM and PC respectively) and their quantities required to substitute a specified amount of N as per treatment was calculated. All organics were applied on dry weight basis 2 weeks before sowing. The recommended dose of N: P_2O_5 : K_2O (100% NPK) used for sorghum were 90:60:30 kg/ha. Full dose of phosphorus and potassium and half of nitrogen were applied at sowing through urea, single superphosphate and muriate of potash, respectively, and remaining N was top-dressed at 30 DAS. Phosphocompost was prepared using fresh cowdung, soil and wheat straw in ratio of 1:0.5:1 (dry-weight basis). Pyrite (S-22.2%) @ 10%, 2.2 % P through Mussoorie rock phosphate (100 mesh) and N @ 0.5% thought urea were added to the mixture on dry-weight basis. The materials were allowed to decompose for 90 days. Sorghum ('CSH 9') was sown at 45 cm × 15 cm spacing in the first week of July during the rainy season.

Plant samples were collected from 0.5 m^2 land areas at different stages of crop growth and oven-dried at 65°C till constant weight. Dry matter was determined based on the fresh weight of sample plants and the moisture content of the sub-samples. The plant height was measured at 3 stages from base of the plant to the tip of the top-most leaves. The crop was harvested at 110 days and grain yield was reported at 14% moisture. The gross and net plot size was 9 m × 6 m and 7.75 m × 4 m respectively. Five plants were randomly selected for yield attributes and ear length, ear girth, number of ears, grain weight/ear and 1,000-grain weight were determined. Water-use efficiency was calculated by dividing grain yield with the respective value of seasonal evapotranspiration of the crop using water balance equation as $ET=P + I+ C_p-D_p-R_f-S$, where P, precipitation; I, irrigation; Cp, contribution through capillary rice from ground water; deep percolation measured by tensiometer installed at 75 cm and 90 cm soil depth; Rf, runoff measured through multislot divisor; S, change in soil moisture storage in the profile measured by thermo-gravimetric method. The cost of cultivation was calculated using expenditure involved in all field operations and inputs and it was deducted from gross return to obtain net return. The benefit : cost ratio was calculated as net return/cost of cultivation. The total rainfall received during first and second year (June–October) was 693.3 and 766.6 mm respectively. Statistical analysis of data was carried out using standard analysis of variance (Gomez and Gomez, 1984). The significance of the treatment effect was determined using the F-test and to determine the significance of the difference between the means of the 2 treatments, least significance differences (LSD) were computed at the 5% probability level.

RESULTS AND DISCUSSION

Plant growth

Effect of nutrient on plant height was significant at 60 days after sowing and at harvest but significant effect of application of inorganic fertilizer-NPK was observed only up to 75% NPK (Table 1). The plots, where PM was applied in combination with 75% NPK, exhibited significantly higher plant height at 60 days and at harvest over other nutrient treatments. Effect of 75% NPK +FYM and 75% NPK +PC were comparable to 100% NPK, but these were significantly higher than 75% NPK and the control.

Data pooled over 2 years showed that with the increase in NPK dose from 0 to 100% there was a significant increase in both below (root) and above-ground (shoot) dry-matter at 60 days and at harvest. The beneficial effect of applied NPK on dry matter and plant height of sorghum was attributed to increased crop growth and relative growth rate (Hasnabade *et al.,* 1990). However, integrated use of organics and inorganics recorded significantly more dry matter compared to inorganics (Table 1). Shoot and root growth with the combined use of organics and inorganic were much faster than only inorganic fertilizer application. In general, irrespective of nutrient treatments, shoot growth was more between 60 days and harvest and root growth between 30 and 60 days. The shoot growth rate was 14.5, 11.4 and 16.1 g/m^2 days between and 30 and 60 days and 26.6, 24.8 and 26.7 g/m^2/day between 60 days and harvest with NPK + FYM, NPK + PC and NPK + PM, respectively, compared with 7.4 and 21.1 g/m^2/day with 100% NPK. Similarly, root growth rate was 5.2, 5.0, and 5.2 g/m^2/days between 30 and 60 DAS and 4.7, 3.4 and 4.7 g/m^2/days between 60 days and harvest with NPK + FYM, NPK+ PC and NPK + PM, respectively, compared with 4.4 and 3.6 g/m^2/day with 100% NPK. Application of 75% NPK in combination with poultry manure @ 1.5 tonnes/ha showed significantly higher above and below-ground dry matter at 60 days and at harvest over other nutrient treatment except 75% NPK + FYM where effect on above-ground dry matter was statistically at par with NPK + PM (Table 1).

Water-use efficiency

The effect of nutrient application on water-use efficiency of sorghum was significant. Effect of all the 3 organically-treated plots on water-use efficiency though was at par and comparable to 100% NPK, these were significantly higher over 75% NPK and the control (Table 3). Kalane *et al.* (1998) also reported increase in water-use efficiency of hybrid sorghum ('CSH 9') with increasing NPK up to 150% in Vertisols. The increase in water-use efficiency in treatments having combined application of fertilizer and manure might be due to relatively rapid root and shoot growth (Table 1) during crop-growing periods with lower vapour pressure deficit which decreased evaporation : transpiration (Es/T) ratio and improved transpiration efficiency (Zhang *et al.*, 1998; Bellakki *et al.*, 1999). The highest water-use efficiency was recorded in 75% NPK+ PM and lowest in control (Table 3).

Yield attributes, harvest index and yields

The yield attributes like ear length, ear weight/plant and 1,000-grain weight were significantly increased by nutrient application up to 75% NPK application. All these yield attributes were greater in poultry manure and farmyard manure combined with 75% NPK.

In general, grain and straw yields of sorghum were higher in 2000 than 2001 because early withdrawal of monsoon during the grain-filling stage of sorghum in 2001 (Fig. 1) affected adversely the yield-attributing character of sorghum (Table 2). Harvest index in 2001 was also comparatively less than in 2000 because of less grain than straw production. However, reverse was the case in 2000. Higher harvest index in 2000 than in 2001 is attributed to

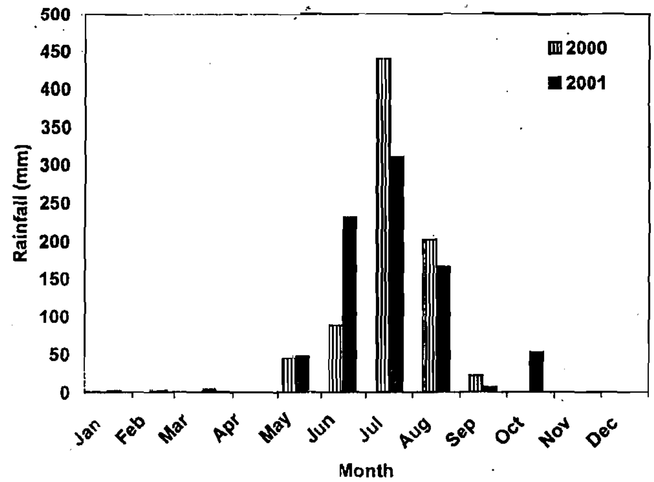

Fig. 1. Rainfall distribution during 2000 and 2001

Table 1. Effect of nutrient management on plant height, shoot and root dry matter of sorghum (pooled over 2 years)

Treatment	Plant height (cm)			Above-ground dry matter (g/m^2)					Below-ground dry matter (g/m^2)				
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	Growth rate (g/m^2/ day) 30–60 DAS	Growth rate 60 DAS–harvest	30 DAS	60 DAS	Harvest	Growth rate (g/m^2/day) 30 DAS	Growth rate 60 DAS–harvest
F_1	32.5	62.1	123.0	11.3	50.8	637.0	1.4	11.7	4.0	31.2	41.7	0.9	0.2
F_2	35.2	73.3	142.0	14.8	189.9	1,029.3	5.8	16.8	4.3	105.5	286.3	3.4	3.6
F_3	37.1	77.6	146.6	16.6	239.1	1,292.3	7.4	21.1	4.5	136.9	315.1	4.4	3.6
F_4	38.6	82.3	159.3	16.6	451.5	1,779.3	14.5	26.6	4.8	161.5	396.1	5.2	4.7
F_5	36.6	77.6	155.3	14.8	355.3	1,593.1	11.4	24.8	4.7	154.0	326.5	5.0	3.4
F_6	40.6	102.6	183.0	16.8	499.9	1,832.5	16.1	26.7	5.1	191.2	427.7	6.2	4.7
CD (P=0.05)	NS	4.9	5.4	NS	15.7	89.2			NS	6.2	27.3		

DAS, Days after sowing
Details of treatments are given in Materials and Methods

Table 2. Effect of nutrient management on yield attributes of sorghum

Treatment	Ear length (cm) 2000	Ear length (cm) 2001	Ear girth/ plant (cm) 2000	Ear girth/ plant (cm) 2001	Ear weight/ plant (g) 2000	Ear weight/ plant (g) 2001	Grain weight/ ear (g) 2000	Grain weight/ ear (g) 2001	1,000-grain weight (g) 2000	1,000-grain weight (g) 2001
F_1	25.0	22.6	12.4	12.2	93.5	78.4	58.1	50.1	25.3	23.2
F_2	29.3	31.0	12.5	12.7	113.4	106.8	67.0	65.2	27.2	25.0
F_3	31.0	32.3	13.9	13.7	120.4	107.3	74.0	72.5	28.4	27.8
F_4	31.3	33.6	15.1	14.5	128.6	125.7	76.1	75.3	31.4	28.2
F_5	29.6	32.0	14.3	14.5	123.9	121.6	78.6	74.0	30.9	25.2
F_6	38.3	34.6	15.9	14.7	134.6	129.7	114.9	85.6	34.1	28.2
CD (P=0.05)	1.8	1.5	NS	NS	7.4	8.1	6.8	5.7	2.3	2.9

Details of treatments are given in Materials and Methods

Table 3. Water-use efficiency, yields and economics of sorghum at different nutrient combination

Treatment	Water-use efficiency (kg/ha/cm)	Grain yield (kg/ha)		Straw yield (kg/ha)		Harvest index (kg/ha)		Cost of cultivation (Rs/ha)		Net returns (Rs/ha)		Benefit : cost ratio	
		2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
F_1	24.76	1,922	1,230	4,032	3,391	0.32	0.27	5,212	5,495	6,414	3,580	1.2	0.7
F_2	68.69	4,218	3,771	7,654	9,319	0.35	0.27	6,711	6,756	18,206	20,529	2.7	3.0
F_3	80.56	4,558	4,220	8,312	10,984	0.33	0.27	7,492	7,510	19,454	23,302	2.6	3.1
F_4	80.53	5,101	4,350	9,711	11,269	0.34	0.28	7,851	7,986	22,509	23,748	2.9	3.0
F_5	80.54	4,570	4,324	8,477	11,050	0.34	0.29	8,313	8,506	18,775	22,963	2.3	2.7
F_6	80.68	5,345	4,432	10,172	11,563	0.35	0.27	7,205	7,131	24,606	25,242	3.4	3.5
CD (P=0.05)	3.63	467.4	491.3	2,106.6	1,420.7	0.063	0.012			30,68.5	1,452.3	0.46	0.37

Details of treatments are given under Materials and Methods
Price (Rs/q) : Sorghum grain, 500 and 600 in 2000 and 2001; sorghum straw, 50
Price (Rs/q) : FYM, poultry manure and phosphocompost, 275, 280 and 300 in 2000 and 300, 250 and 350 in 2001

better translocation of dry matter into grain as reflected by better yield attributes (Table 2). Effect of inorganic fertilizer NPK on grain and straw yields of sorghum was significant and increased with increasing level of NPK up to 100%. All organics in combination with inorganic fertilizer were superior to sole chemical fertilizer for grain and straw yields, and harvest index. Yadav *et al.* (1998) reported beneficial effect of combined use of organics and inorganics in boosting up crop yields as well as maintaining soil health on long-term basis. Role of organics in increasing yield of sorghum is attributed to supply of essential nutrients by continuous mineralization of organic manures, enhanced inherent nutrient supplying capacity of the soil and its favourable effect on soil physical and biological properties (Hati *et al.* 2001). In 2000, integrated use of 75% NPK and PM @ 1.5 tonnes/ha recorded significantly higher grain and straw yields of sorghum compared to other nutrients except 75% NPK+FYM. However, effects of 3 organic manures on grain an straw yields were at par and comparable to 100% NPK in the second year. Overall, application 75% NPK and poultry manure @ 1.5 tonnes/ha resulted in highest grain and straw yields of sorghum in both the years and the performance of nutrient treatments in terms of grain and straw yields followed the order of 75% NPK +PM>75% NPK+FYM> 75% NPK+PC > 100% NPK. According to Edward and Daniel (1992) if poultry manure is added in combination with chemical fertilizer, it supplements all nutrients to crop, thereby boost up the productivity of crop. Effect of phoshocompost on dry matter, yield attributes and yields of sorghum was not as prominent as FYM and poultry manure. However, yield obtained with 75% NPK and phospho-compost @ 5 tonnes/ha was comparable to 100% NPK.

Higher yields of sorghum obtained in the combined use of manure and fertilized plots are attributed to higher and rapid shoot and root growth, higher water-use efficiency and improved yield attributes (ear number, ear length and 1,000-seed weight) and harvest index. Hybrid sorghum requires application of 100% recommended fertilizer. However, it was possible to reduce the total fertilizer need of sorghum by 25% without any adverse effect on productivity when a part of the NPK was supplied through organics. This finding is in agreement with that of Raghuwanshi and Umat (1994).

Economics

The maximum net return and benefit : cost ratio were obtained with application of 75% NPK and poultry manure @ 1.5 tonnes/ha (Table 3). In terms of economics application FYM was comparable to 100% NPK, though cost of cultivation involved with FYM treatment was comparatively more. Though phosphocompost increased yields of sorghum, it had lower net return and benefit : ratio due to high cost of cultivation.

The present study indicated that the combined use of 75% NPK and poultry manure @ 1.5 tonnes/ha played a significant role in increasing the above and below-ground dry matter, water-use efficiency, yields of sorghum and profits for cultivation of rainfed sorghum in Vertisols.

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