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Research Paper

Tillage and integrated nutrient management in rainy-season grain sorghum (*Sorghum bicolor*)

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ABSTRACT

A field experiments was conducted under All India Coordinated Sorghum Improvement Project (AICSIP) at 6 locations during the rainy seasons of 2009 and 2010 in a split-plot design having 3 tillage systems in main plots and 4 nutrient-management practices in subplots with 3 replications, to find out their effects on productivity, profitability and energetics of sorghum [*Sorghum bicolor* (L.) Moench]. Conventional tillage resulted in higher grain yield (3.12 t/ha), N, P and K uptake, net returns (₹23.5 × 10^3/ha) and output energy (251 × 10^3 MJ/ha) than reduced and minimum tillage systems. Application of recommended dose of nutrients (80: 40: 40 N: P_2O_5, K_2O kg/ha) through inorganic fertilizers proved significantly superior in terms of grain yield (3.32 t/ha), net returns (₹26.6 × 10^3/ha) and output energy (267 × 10^3 MJ/ha) over rest of the treatments.

Key words: Economics, Energy, Integrated nutrient management, Nutrient uptake, Sorghum, Tillage, Yield

Sorghum is one of the leading traditional food crops of millions of rural poor in arid and semi-arid regions of the world. In India, sorghum production is mainly constrained by soil, water and nutrient deficits. Erratic climatic conditions with frequent droughts, poor fertility, and crust-prone soils are the major factors that influence sorghum cultivation in semi-arid tropical India. This situation is particularly worsened by continuous cultivation with low or no nutrient application. The formation of soil surface crusts increases runoff, leading to severe soil, associated nutrient and water losses (Gebreyesus, 2012). The profitable crop response to applied nutrients is reduced due to soil water deficit (Tewodros Mesfin *et al*., 2009). In order to reduce runoff, soil erosion and nutrient losses, and to increase water-infiltration rate and nutrient availability for crop production, an integrated soil and crop-management practices need to be addressed simultaneously (Breman *et al.*, 2001).

Conservation tillage system is gaining importance in many crops, as this technology has resulted in reduced soil erosion, improved soil health, crop productivity and profitability. Deep ploughing disturbs soil aggregation and promotes increased oxygen diffusion aggravating organic matter loss (Bauer and Black, 1981). However, there are conflicting reports on the effects of tillage practices in sorghum. Doran (1980) showed that zero-till management has resulted in the lowest loss of soil organic carbon (SOC) and nitrogen in the top soil over time as compared to tilled soil. However, Patil and Sheelavantar (2006) observed that deep tillage with integrated nutrient management conserved higher amount of soil water and resulted in increased sorghum yields. Chemical fertilizers are the main source of nutrients to the crops. Considering the higher cost of fertilizers and their harmful effects, it is necessary to integrate inorganic and organic sources of plant nutrients to supply balanced nutrients to the crop. Bio-fertilizers like *Azotobacter* and phosphorus-solubilizing bacteria (PSB) play a major role in supplementing the crop nutrients through nitrogen fixation and solubilisation of fixed forms of phosphorus in soil. Integrating organic resources and mineral fertilizers increases soil organic matter (Bationo and Burkert, 2001).

Despite the above facts, the role of tillage practices with integrated nutrient management has been less understood in sorghum-growing regions of India. With increasing costs of inputs such as fuel and fertilizers, it is logical to develop tillage and nutrient-management practices that can reduce the cost of production and increase the yield potential and profitability for sorghum growers. Thus, the

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objective of the present investigation was to evaluate the effect of tillage practices and integrated nutrient management on the productivity of rainy season (*kharif*) grain sorghum.

MATERIALS AND METHODS

A field experiment was conducted under All India Coordinated Sorghum Improvement Project (AICSIP) at 6 locations, viz. Coimbatore [11°01'N, 76°97'E, 411 m above mean sea-level (msl)] in Tamil Nadu, Akola (22°42'N, 77°02'E, 307.42 m above msl) and Parbhani (19°16'N; 76°47'E, 357 m above msl) in Maharashtra, Dharwad (15°26'N, 75°07'E, 678 m above msl) in Karnataka, Indore (22°20'N, 75°25'E, 553 m above msl) in Madhya Pradesh and Udaipur (23°34'N, 73°42'E, 582.17 m above msl) in Rajasthan during the rainy seasons of 2009 and 2010. Soils of different locations ranged from sandy clay loam to clay loam in texture with 75–100 cm depth, pH 7.3–8.04, low to medium in organic carbon (0.32–0.54%) and nitrogen (101–276 kg/ha), low to medium in available phosphorus (15.4–32.0 kg/ha) and high in available potassium (305–702 kg/ha) content. Details of the physico-chemical properties of soils at various locations are given in Table 1. The total rainfall during crop season (June–October) varied from 464.7 mm at Coimbatore to 902.5 mm at Indore during 2009 and 629 mm at Coimbatore to 1,400 mm at Akola during 2010.

The experiment was laid out in a split-plot design with 3 replications on a net plot of 3.6 m × 4.4 m. The main plot consisted of 3 tillage systems, viz. conventional tillage-CT (1 summer ploughing, 2 harrowing + atrazine at 0.50 kg/ha + hoeing and hand-weeding), reduced tillage-RT (2 harrowing + atrazine +1 hoeing + hand-weeding) and minimum tillage-MT (1 harrowing + atrazine + hand-weeding), while different combinations of nutrient sources, viz. recommended dose of nutrients (80, 40 and 40 kg/ha of N, P_2O_5 and K_2O) through fertilizers (RDF), 75% RDF + 5 t FYM /ha, 50% RDF +2.5 t FYM /ha + *Azotobacter* + phosphorus-solubilizing bacteria and control constituted the subplot. Sorghum hybrid 'CSH 16' was sown in rows 45 cm × 15 cm apart during fourth week of June – first week of July at different locations. Half dose of nitrogen and full dose of other fertilizers and manures were applied basal, while remaining nitrogen was applied at 30 days after sowing. To control the weeds, atrazine at 0.50 kg/ha was applied as pre-emergence with 500 litres/ha of water with the help of knapsack sprayer fitted with flat-fan nozzle. Hand hoeing was done with hand hoe at 25 days and intra-row weeds were removed by hand weeding. Treatment of sorghum seed with *Azotobacter* and phosphorus-solubilizing bacteria were done by mixing the seed with 10% jaggery-biofertilizers solution before to sowing. Observations on growth and yield parameters were recorded. Data of both the years and all the 6 locations were pooled and relative economics was computed considering the local price of input and output. Net income was calculated as the difference between gross income and total cost. Benefit: cost ratio was worked out by dividing gross returns with total cost of cultivation. To calculate the input energy, all inputs in the form of labor, machinery, fuel, fertilizer, seed, pesticide, irrigation, harvesting and threshing were taken into consideration with use of energy conversion factors. The farm produce (grain and stover yields) was also converted into energy in terms of energy output (MJ). Energy equivalent of each parameter was calculated by using the energy conversion factors suggested by Devasenapathy *et al*. (2009). All the data were subjected to analysis of variance (ANOVA) by using a split-plot design and main effects and interactions were tested for significance. Treatment means obtained by ANOVA were compared using critical difference (CD) at P=0.05 level of significance.

RESULTS AND DISCUSSION

Growth and yield attributes and yields

Different tillage practices could not bring significant

Table 1. Physico-chemical properties of soils

Particulars	Coimbatore	Parbhani	Indore	Akola	Dharwad	Udaipur
Soil texture	Clay loam	Clay loam	Clay loam	Clay	Clay	Sandy clay loam
Soil depth (cm)	>75 cm	>75 cm	>100 cm	>100 cm	>100 cm	>75 cm
Soil pH value (1 : 2.5 soils : water)	8.04	7.84	7.62	7.82	7.3	7.9
EC (1 : 2.5 soils : water) (dS/m)	0.47	0.25	0.38	0.36	0.60	0.40
Soil organic carbon (%)	0.45	0.36	0.34	0.43	0.54	0.32
Available nitrogen (kg/ha)	216	101	162	174	220	276
Available P_2O_5 (kg/ha)	31	17.2	25.6	15.4	21.2	32
Available K_2O (kg/ha)	605	702	432	372	305	459
Rainfall (mm)						
2009	464.7	609	902.5	515	874.8	526.2
2010	629	1260	975	1400	1003	798

variation in plant height, days to 50% flowering, days to maturity, panicle number and 100-seed weight of the crop (Table 2). Grains/panicle were significantly influenced by tillage methods. Conventional tillage (CT) being on a par with reduced tillage (RT) produced significantly more grains/panicle than the minimum tillage (MT). Better soil conditions in CT made easy availability of nutrients from deeper layers (Ramesh *et al*., 2014), that might have attributed to the formation of more grains/panicle. The highest mean grain yield was recorded with conventional tillage which was on a par with reduced tillage, but significantly higher (> 18%) than the minimum tillage. Significant increase in seed number and relatively higher seed weight in CT are responsible for higher grain yield. Similar trend was also observed for stover yield. Different tillage practices did not influence the harvest index, however, it was maximum with conventional tillage. A better harvest index in conventional tillage is indicative of a shift in conversion of complex carbohydrate into a simpler form and its mobilization towards increased sink capacity.

Application of recommended dose of nutrients (80 : 40 : 40 N, P_2O_5 and K_2O kg/ha) through inorganic fertilizers being on a par with 75% recommended dose of fertilizer (RDF) + 5 t/ha FYM and 50% RDF + 2.5 t/ha FYM + *Azotobacter* + PSB produced significantly the tallest plants, but significantly reduced the duration of flowering and maturity compared to the control. Yield attributes, viz. number of grains/panicle, 100-seed weight, and grain and stover yields were also significantly higher with recommended dose of fertilizer. These results clearly indicated that application of 5 t/ha FYM or 2.5 t/ha FYM +*Azotobacter* + phosphorus solubilizing bacteria could not substitute the 25% NPK requirement supplied through inorganic fertilizers in recommended dose of fertilizer treatment. Hence there is a need to increase the dose of organic sources while integrating with inorganic fertilizers.Interaction effect of tillage and nutrient management for grain yield was not significant during both the years. However, conventional tillage and application of recommended dose of nutrients (80 : 40 : 40 N, P_2O_5 and K_2O kg/ha) through inorganic fertilizers resulted in the highest grain yield during both the years.

Irrespective of the treatments, grain yield of sorghum varied greatly with locations (Table 3). The highest grain yield (4.13 t/ha) was recorded at Udaipur, followed by at Indore (3.83 t/ha). The grain yields at Dharwad and Akola were almost the same (2.81 and 2.98 t/ha). The lowest grain yield was obtained at Coimbatore (1.61 t/ha), followed by at Parbhani (1.99 t/ha). Variation in grain yields over locations was primarily due to difference in soil physico-chemical properties and rainfall patterns (Table 1). Besides, variation in other weather parameters, viz. number of rainy days, temperature, humidity, and sun shine hours might also have affected the grain yield at different locations. The poor grain yield at Coimbatore was due to lower rainfall resulting in moisture stress at repro-

Table 2. Effect of tillage and integrated nutrient management on growth, yield attributes and yield of sorghum (mean of 2 years and 6 locations)

Treatment	Plant height (cm)	Days to 50% flowering	Days to maturity	Panicles/ m^2	Grains/ panicle	100-seed weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Tillage									
Conventional	193	64	99	14.08	2,227	3.06	3.12	11.03	22.1
Reduced	193	64	101	14.38	2,202	2.97	2.91	10.53	21.7
Minimum	190	64	100	14.00	2,102	2.90	2.64	9.98	20.9
SEm±	1.2	0.10	0.8	0.20	30	0.06	0.08	0.22	0.7
CD (P=0.05)	NS	NS	NS	NS	89	NS	0.22	0.69	NS
Nutrient management									
RDF (80 : 40 : 40 N, P, K kg/ha) through inorganic	198	63	99	14.22	2,235	3.14	3.32	12.47	21.0
75% RDF through inorganic + 5t/ha FYM	195	63	100	14.17	2,196	3.06	3.14	11.68	21.2
50% RDF through inorganic + 2.5 t/ha FYM + *Azotobacter*+ PSB	192	65	100	14.22	2,153	2.98	2.81	10.66	20.9
Control	183	66	101	14.00	2,124	2.74	2.31	9.33	19.8
SEm±	2.40	0.35	0.30	0.15	13	0.03	0.10	0.22	0.6
CD (P=0.05)	7	1	1	NS	38	0.08	0.24	0.68	NS

RDF, Recommended dose of fertilizer; PSB, Phosphorus solubilizing bacteria ductive stage, whereas at Parbhani poor soil fertility, especially low nitrogen content was the major reason for the lower grain yield.

Nutrient uptake

Conventional tillage significantly increased the N, P and K uptake in sorghum grain compared to reduced and minimum tillage systems (Table 4). However, the N and K uptake in sorghum stover under conventional tillage was on a par with reduced tillage. Higher N, P and K uptake in conventional tillage were attributed to better soil conditions in conventional tillage that made easy availability of nutrients from deeper layers (Ramesh *et al*., 2014). Application of recommended dose of nutrients (80 : 40 : 40 N, P and K kg/ha) through inorganic fertilizers significantly increased uptake of N, P and K in grain and stover of sorghum crop. Higher concentration of nutrients in rhizosphere led to higher N, P and K uptake by the plant biomass. The short supply of nutrients in the INM treatments where 75% and 50% RDF were integrated with FYM and *Azotobacter* + PSB was amply reflected by the lower NPK uptake. This is attributed to slow decomposition rate of FYM during the crop season and subsequently less utilization by the crop resulting in lower yields and uptake.

Table 3. Effect of tillage and fertility levels on grain yield (t/ha) of sorghum at different locations (mean of 2 years)

Treatment	Coimbatore	Udaipur	Parbhani	Akola	Dharwad	Indore	Mean
Tillage							
Conventional	1.81	4.35	2.25	3.50	3.04	3.79	3.12
Reduced	1.62	4.25	1.91	2.94	2.78	3.99	2.91
Minimum	1.40	3.79	1.82	2.49	2.62	3.73	2.64
SEm±	0.04	0.10	0.02	0.10	0.06	0.10	0.08
CD (P=0.05)	0.12	0.33	0.04	0.34	0.17	0.30	0.22
Nutrient management							
RDF (80:40:40 N: P: K kg/ha) through inorganic	1.97	4.77	2.33	3.35	3.37	4.12	3.32
75% RDF through inorganic + 5 t/ha FYM	1.75	4.39	2.18	3.23	3.03	4.24	3.14
50% RDF through inorganic + 2.5 t/ha FYM + *Azotobacter* + PSB	1.49	4.11	1.85	2.89	2.86	3.65	2.81
Control	1.23	3.25	1.62	2.44	1.99	3.33	2.31
SEm±	0.05	0.10	0.05	0.10	0.04	0.15	0.10
CD (P=0.05)	0.15	0.31	0.15	0.30	0.13	0.39	0.24
Location mean	1.61	4.13	1.99	2.98	2.81	3.83	2.89

RDF, Recommended dose of fertilizer; PSB, phosphorus solubilizing bacteria

Table 4. Effect of tillage and integrated nutrient management on nutrient uptake (Mean of Indore and Udaipur locations)

Treatment	Nitrogen uptake(kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
Tillage									
Conventional	81.1	72.2	153	18.6	18.0	36.6	56.3	171	228
Reduced	76.4	69.0	145	17.7	16.6	34.3	54.3	163	217
Minimum	73.1	67.6	141	16.3	15.2	31.5	52.0	146	198
SEm±	1.5	1.2	2.4	0.3	0.45	0.60	0.60	4	4
CD (P=0.05)	4.2	3.7	7.0	1.0	1.3	1.7	1.8	12	13
Nutrient management									
RDF (80:40:40 N: P: K kg/ha) through inorganic	85.8	76.4	162	20.3	18.6	38.9	58.2	174	232
75% RDF through inorganic + 5 t/ha FYM	80.5	71.4	152	18.4	17.2	35.6	56.6	163	219
50% RDF through inorganic + 2.5 t/ha FYM + *Azotobacter* + PSB	76.2	68.6	145	17.1	16.6	33.7	54.5	163	217
Control	64.9	62.1	127	14.3	14.1	28.4	47.6	140	188
SEm±	1.5	1.1	2	0.4	0.30	0.50	0.50	3	4
CD (P=0.05)	4.2	3.2	6	1.2	1.1	1.5	1.5	10	11

RDF, Recommended dose of fertilizer; PSB, phosphorus solubilizing bacteria

Table 5. Effect of tillage and integrated nutrient management on economics and energy parameters in sorghum (mean of 2 years and 6 locations)

Treatment	Cost of cultivation (× 10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio	Total energy requirement (×10^3 MJ/ha)	Energy productivity (kg/MJ)	Output energy (×10^3 MJ/ha)	Energy output: input ratio
Tillage							
Conventional	27.72	23.51	1.98	8.94	1.717	251	29.66
Reduced	23.22	22.92	2.06	8.28	1.789	238	30.93
Minimum	22.02	20.46	1.99	7.62	1.864	224	32.28
SEm±	1.0	0.95	0.08	-	-	-	-
CD (P=0.05)	2.86	2.78	NS	-	-	-	-
Nutrient management							
RDF (80:40:40 N, P, K kg/ha) through inorganic	24.66	26.63	2.27	10.12	1.527	267	26.38
75% RDF through inorganic+5t/ha FYM	27.64	23.23	1.97	10.29	1.425	253	24.62
50% RDF through inorganic+2.5t/ha FYM + *Azotobacter*+PSB	24.88	21.75	1.91	8.17	1.642	232	28.39
Control	20.10	17.58	1.88	4.54	2.565	200	44.45
SEm±	0.70	0.58	0.05	-	-	-	-
CD (P=0.05)	2.17	1.65	0.16	-	-	-	-

RDF, Recommended dose of fertilizer; PSB, phosphorus solubilizing bacteria

Economic analysis and energy efficiency

The total cost of cultivation and net returns were more in conventional tillage system than the other systems due to higher costs involved in field preparations and higher yields (Table 5). The highest benefit: cost ratio (2.06) was accrued with reduced tillage system. Among the nutrient management treatments, application of recommended dose of nutrients through inorganic fertilizers was more economical. Higher cost of FYM coupled with lower yields resulted in lower profitability in INM treatments.

The conventional tillage system required the maximum energy (8.94 × 10^3 MJ/ha) due to higher energy required for field preparation. However, the higher output energy (251 × 10^3 MJ/ha) in conventional tillage system was due to higher productivity. The energy output: input ratio (32.28) and energy productivity (1.864 kg/MJ) was maximum in the minimum tillage system due to lower energy required for field preparation. The highest output energy (267 × 10^3 MJ/ha) was obtained with application of RDF through inorganic fertilizers. The energy productivity and energy output : input ratio were however higher in the control plot due to the lower energy requirement.

Our results revealed that higher sorghum yields and net returns can be obtained with conventional tillage and application of recommended dose of nutrients (80:40:40 N, P_2O_5, K_2O kg/ha) through inorganic fertilizers. The results also indicated that 5 t/ha FYM and 2.5 t/ha FYM + *Azotobacter* + phosphorus solubilizing bacteria are not sufficient to replace the 25% and 50% dose of NPK applied through inorganic fertilizers.

REFERENCES

Bationo, A. and Burkert, A. 2001. Soil organic carbon management for sustainable land use in Sudano-Sahelian West African. *Nutrient Cycling in Agroecosystems* **61**(1 and 2): 131–42.

Bauer, A. and Black, A.L. 1981. Soil carbon, nitrogen and bulk density comparisons in two cropland tillage systems after 25 years and in virgin grassland. *Soil Science Society of America Journal* **45**(6): 1,166–170.

Breman, H., Groot, J.J.R. and Van Keulen, H. 2001. Resource limitations in Sahelian agriculture. *Global Environmental Changes* **11**(1): 59–68.

Devasenapathy, P., Senthilkumar, G. and Shanmugam, P.M. 2009. Energy management in crop production. *Indian Journal of Agronomy* **54**(1): 80–90.

Doran, J.W. 1980. Soil microbial and biochemical changes associated with reduced tillage. *Soil Science Society of America Journal* **44**(4): 765–71.

Gebreyesus, B.T. 2012. Effect of tillage and fertilizer practices on sorghum production in Abergelle area, northern Ethiopia. *Momona Ethiopian Journal of Science* **4**(2): 52–69.

Patil, S.L. and Sheelavantar, M.N. 2006. Soil water conservation and yield of winter sorghum [*Sorghum bicolor* (L.) Moench] as influenced by tillage, organic materials and nitrogen fertilizer in semi-arid tropical India. *Soil and Tillage Research* **89**(2): 246–57.

Ramesh, Rana, S.S., Negi, S.C., Suresh Kumar and Subehia, S.K. 2014. Effect of resource- conserving and planting techniques on productivity of maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **59**(1): 34–40.

Tewodros Mesfin, Gebreyesus Brhane Tesfahunegn, Wortmann, C.S., Nikus, O. and Mamo, M. 2009. Tied-ridging and fertilizer use for sorghum production in semi-arid Ethiopia. *Nutrient Cycling and Agroecosystems* **85**(1): 87–94.