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Research Paper

Effect of conservation practices and fertilizer on sorghum (*Sorghum bicolor*) yield under rainfed conditions of northern India

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ABSTRACT

A field experiment was carried during the rainy seasons of 2011 and 2012 in split-plot design at New Delhi, to study the impact of conservation practices and fertilizer levels on yield of sorghum [*Sorghum bicolor* (L.) Monech] under rainfed conditions. Sorghum variety 'CSH 14' hybrid was planted using 2 types of tillage (minimum and conventional) and 2 methods of planting (ridges and furrows, and flat bed). For each type of tillage and method of planting three levels of fertilizer were applied. No significant effects of the treatments and interaction was observed at 5% level of significance on the leaves/plant, plant height, stem girth, panicle weight, harvest index and benefit: cost ratio. However, it affected the panicle length, panicle girth, 1,000-seed weight, total cost of production, gross returns and net returns significantly. The plant-moisture content was affected by sowing method and tillage type regardless of fertilizer levels. The highest average grain yield (2.03 tonnes/ha), fodder yield (9.42 tonnes/ha), maximum cost of production (₹ 7.7×10^3/ha), gross returns (₹ 16.0×10^3/ha), net returns (₹ 8.3×10^3/ha) and benefit: cost ratio (2.08) were found under sowing on ridges and furrows in conventional tillage with 100% recommended dose of fertilizer (RDF). Yield attributes were affected by rainfall quantity between the 2 crop growing years. The system of ridges and furrows planting method in conventional tillage with 100% RDF for sorghum production, although it consumes higher expenditure (32.7%), but it provides higher return of money (139.1%) as compared to the flat bed planting in minimum tillage with 100% RDF.

Key words : Economics, Fertilizer, Fodder, Rainfed, Ridges and furrows, Sorghum, Tillage

Sorghum is the world's fifth most important cereal in terms of production and area planted. It is very important cereal in the semi-arid areas of the tropics and subtropics in Africa. It is also one of the major cereal crops consumed in India after rice and wheat (DES, 2007). The grain constitutes the main food for over 750 million people who live in the semi-arid tropics of Africa, Asia, and Latin America, and globally over half of all sorghum is used for human consumption (NSP, 2006). Improved rainwater conservation measures increases infiltration of rainwater into the soil enhances water availability to plants (Lipiec *et al*., 2005). Conservation tillage systems often increase surface residue and limit incorporation and mixing of organic matter and nutrients, resulting in reduced soil erosion, accumulation of organic matter near the soil surface, lower soil temperatures, increased infiltration, decreased water runoff, higher soil moisture, stratification of nutrients and soil pH, and changes in the rooting pattern of crops (Douglas 2011). Conservation and availability of water and nutrients during different stages of crop growth were increased by deeper tillage resulting in increased grain yield of winter sorghum. A compartmental bunding and ridges and furrows increases the sorghum grain yield by 22.8 and 25.6%, respectively, over flatbed sowing (Patil and Sheelavantar, 2005). Better-nutrient management strategies should aim both to attain higher productivity and sustain them in the a long run (Singh and Singh, 2002). Kumar *et al.* (2010) concluded that the increase in productivity could be brought both by genetic improvement as well as associated nutrient-management intervention in a rainfed environment.

There is a need to explore and evaluate the interactions of tillage, methods of planting, and fertilizer application in rainfed sorghum. The present study was planned to quantify the response and interaction of conventional and minimum tillage, methods of planting and fertilizer levels on

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sorghum crop to develop best management practices under rainfed conditions to achieve higher yield and reduce energy consumption and cost of production.

MATERIALS AND METHODS

The field experiment was conducted during rainy seasons of 2011 and 2012 at Water Technology Centre, Indian Agricultural Research Institute, New Delhi, (28° 38' 23" N of 77° 09' 27" E, at an average elevation of 228.61 m above the mean sea-level). The site has semi-arid and subtropical climate with hot dry summer and severe cold winter. Average annual rainfall is about 650 mm, 75% of which is received in 3 months, namely July, August and September during south–west monsoon. July and August are the wettest months. The soil was sandy loam, low in available N (195.5 kg/ha), medium in available P (12.5 kg/ha) and K (285.5 kg/ha) with moderate water-holding capacity and well-leveled topography. The experiment had 12 treatments, laid out in 3 replications in split-plot design combined over 2 years for sorghum variety 'CSH 14' hybrid. The treatments consisted of 2 types of tillage, viz. minimum and conventional, in main plots, 2 methods of planting, viz. ridges and furrows and flatbed, in sub-plots, and 3 levels of fertilizer which were applied at time of sowing, viz. full recommended dose of fertilizer (RDF), 50% RDF and control. The full recommended dose of fertilizer was 50 kg/ha of urea (46% nitrogen), 25 kg/ha single superphosphate (16% P_2O_5) and 25 kg/ha muriate of potash (60% K_2O). Seed rate was 7.4 kg/ha in the spacing of 45 cm between rows and 15 cm between plants. There were 7 rows or ridges per plot depending on planting method. Sowing was done manually by labourers for the 2 seasons on 24 June 2011 and 11 July 2012. The delayed onset of monsoon was the main reason of the delay in seeding process in the second year. The amounts of inputs and outputs per hectare were multiplied with a wage or price of the unit to consolidate all of them in one unit (₹/ha) to find the economic indices (i.e. total cost of production, gross returns, net returns and benefit: cost ratio). The data on crop growth, yield attributes and economic indices were analysed statistically by using analysis of variance according to Gomez and Gomez (1984) procedure for a split-plot design (3 factors) combined over years and the differences of means were identified by least significant differences (L.S.D) at P ≥ 0.05, by using MSTAT-C Package, version 1.47.

RESULTS AND DISCUSSION

In general, the crop yields were higher owing to optimum and well-distributed rainfall of 574 mm without any biotic constraints in the season of 2011; however, the yield of sorghum was low in 2012 due to the lack of rain (483.2 mm) and attack of the shoot-fly and stem-borer on the plant, as the result of the late-sowing date which was caused by the delayed onset of monsoon.

Crop-growth characters

The treatments and interaction between them had no significant effect on the leaves/plant and plant height (Tables 1) mainly due for using one sorghum variety and the plant height is one of the genetic properties as indicated by Jennie *et al.* (2005). The type of tillage and method of planting had no significant effect on girth of plant stem but the levels of fertilizer and interaction between them made significant difference on it. The plant moisture content was significantly affected by sowing method and tillage type regardless of fertilizer levels. The highest girth of plant stem and plant moisture content were obtained in system of ridges and furrows method of planting in conventional tillage with 100% RDF.

Table 1. Effect of tillage, planting and fertilizer on growth characters of sorghum (pooled data of 2 years).

Treatment	Leaves/ plant	Plant height (cm)	Stem girth (cm)	Plant moisture content (%)
Type of tillage				
Minimum	12.22	175.9	8.4	15.8
Conventional	11.39	177.3	8.7	17.3
SEm±	0.38	1.86	0.13	0.23
CD (P=0.05)	NS	NS	NS	0.68
Method of planting				
Ridges and furrows	11.78	177.0	8.9	17.9
Flatbed	11.83	176.2	8.5	15.1
SEm±	0.12	1.05	0.12	0.46
CD (P=0.05)	NS	NS	NS	1.37
Level of fertilizer				
100% RDF	12.17	177.6	9.0	20.9
50% RDF	11.58	176.5	8.7	15.5
Control	11.67	175.8	8.5	13.0
SEm±	0.14	1.31	0.11	0.50
CD (P=0.05)	NS	NS	NS	1.25

The treatments and interaction between them had significant effect on panicle length, panicle girth and 1,000-seed weight, while it failed to affect significantly on panicle weight and harvest index. However, the biggest panicle weight (0.21 kg) was observed in system of ridges and furrows method of planting in conventional tillage with 100% RDF (Tables 2 and 3). The higest values of panicle length, panicle girth and 1,000-seed weight were recorded on system of ridges and furrows method of planting in conventional tillage with 100% RDF. These results emphasized that the influence of the different levels of fertilizer and planting method were more effective than the influence of tillage types on these yield attributes.

Grain and fodder yield of sorghum

The interaction influence of the treatments was more than individually influence of planting method and tillage type treatments which significantly affected the grain and fodder yield (Tables 3 and 4). The ridges and furrows method of planting in conventional tillage with 100% RDF recorded the highest grain yield of 2.03 and fodder yield of 9.42 tonnes/ha.

In addition to use of improved cultivation practices, the amount of rainfall during the crop season, which influenced the amount of moisture stored in the soil profile, was an important factor in the performance of the crop grown on sandy loam during the dry season according to Memon (2007), who reported that the soil-moisture content after tillage operation showed highly significant difference in all the treatments. These results are consistent with Gebreyesus (2012), who reported that the better sorghum yields were observed when moisture harvesting tillage practices integrated with fertilizer. Musambasi *et al,* (2003) reported that maize planting on ridges gave the highest grain yield during the 1995–96 season.

Table 2. Effect of tillage, planting and fertilizer treatments on yield attributes of sorghum (pooled data of 2 years).

Treatment	Panicle length (cm)	Panicle girth (cm)	Panicle weight (g)	1,000-seed weight (g)	Grain yield (t/ha)	Fodder yield (t/ha)	Harvest index
Type of tillage							
Minimum	30.6	20.5	101	25.8	1.2	3.3	0.28
Conventional	31.0	20.0	131	27.7	1.5	6.4	0.19
SEm±	0.04	0.41	5.4	0.24	0.03	0.29	0.03
CD (P=0.05)	0.13	1.23	NS	0.71	0.10	0.88	NS
Method of planting							
Ridges and furrows	31.5	20.7	130	27.3	1.5	5.5	0.23
Flatbed	30.1	19.8	110	26.2	1.2	4.1	0.23
SEm±	0.31	0.45	5.3	0.08	0.04	0.20	0.01
CD (P=0.05)	0.93	1.34	NS	0.23	0.13	0.62	NS
Level of fertilizer							
RDF	32.2	21.5	139	29.0	1.65	6.12	0.22
50% RDF	30.5	20.0	113	26.6	1.28	4.72	0.24
Control	29.7	19.2	104	24.6	1.10	3.68	0.25
SEm±	0.19	0.18	5.6	0.35	0.05	0.17	0.01
CD (P=0.05)	0.77	0.74	NS	1.03	0.38	0.71	NS

RDF, Recommended dose of fertilizer

Table 3. Interaction effect of tillage, planting and fertilizer treatments on yield attributes of sorghum (poled data of 2 years).

Treatment	Panicle length (cm)	Panicle girth (cm)	Panicle weight (g)	1,000-seed weight(g)	Grain yield (tonnes/ha)	Fodder yield (tonnes/ha)	Harvest index
Minimum + ridges and furrows + RDF	32.7	21.8	123	28.2	1.74	4.69	0.27
Minimum + ridges and furrows + 50% RDF	30.9	20.5	103	26.8	1.38	3.48	0.30
Minimum + ridges and furrows + control	30.5	20.3	102	25.5	1.14	2.54	0.32
Minimum + flatbed + RDF	31.2	21.2	99	26.6	1.31	3.54	0.27
Minimum + flatbed + 50% RDF	29.8	20.3	97	24.9	1.02	2.87	0.28
Minimum + flatbed + control	28.4	19.1	95	22.8	0.83	2.63	0.25
Conventional + ridges and furrows + RDF	32.9	22.6	144	31.1	2.03	9.42	0.17
Conventional + ridges and furrows + 50% RDF	31.4	19.9	142	27.1	1.56	7.50	0.17
Conventional + ridges and furrows + control	30.7	19.3	97	25.1	1.35	5.59	0.19
Conventional + flatbed + RDF	31.9	20.5	127	30.3	1.54	6.84	0.18
Conventional + Flatbed + 50% RDF	29.9	19.4	100	27.5	1.17	5.02	0.19
Conventional + flatbed + control	29.3	18.2	99	24.9	1.07	3.97	0.22
SEm±	0.38	0.35	5.3	0.69	0.09	0.33	0.02
CD (P=0.05)	2.17	2.09	NS	2.92	1.08	2.02	NS

Economics

The interaction of the treatments significantly affected the total cost of production, gross returns and net returns, but it failed to affect significantly the benefit: cost ratio (Tables 4 and 5). The maximum cost of production gross returns, net returns and benefit: cost ratio were found under sowing on ridges and furrows in conventional tillage with 100% RDF. However, the benefit: cost ratio was the highest in the all levels of fertilizer in the ridges and furrows planting in conventional tillage. This was mainly owing to higher production potential of sorghum under this cultivation system with adequate soil-moisture content accompanied with good monetary return. These net returns were found in congruence with the finding of Mishra *et al* (2011), which reported that the additional net return of ₹6.78×10^3/ha was obtained from the demonstrated cultivars. Results on benefit: cost ratio are in conformity with the findings of Suman *et al.* (2006), which pointed out that the marginal farmers were the maximum gainer, as they get maximum net returns ₹10×10^3/ha, followed by small (₹8.40×10^3/ha), medium (₹6.90×10^3/ha) and large farmers (₹6.20×10^3/ha). The results confirm the findings of Mishra *et al.* (2009).

It was concluded that the application of 100% recommended dose of fertilizer for sorghum production proved optimum for higher yield for all combinations of planting and tillage methods for the two growing seasons. Amongst the different planting systems, ridges and furrows planting in conventional tillage with 100% recommended dose of fertilizers gave the highest yield which constituted 55% more and provides higher return of money (139.1%) as compared to the flatbed planting in minimum tillage with 100% RDF.

Table 4. Effect of tillage, planting and fertilizer treatments on economic indices of sorghum (pooled data of 2 years).

Treatment	Total cost of production (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
Type of tillage				
Minimum	7.37	13.7	6.3	1.86
Conventional	7.42	14.6	7.2	1.98
SEm±	0.01	0.05	0.05	0.01
CD (P=0.05)	NS	0.16	0.15	NS
Method of planting				
Ridges and furrows	7.51	15.1	7.6	2.03
Flatbed	7.29	13.2	5.9	1.81
SEm±	0.04	0.12	0.16	0.01
CD (P=0.05)	NS	0.35	0.49	NS
Level of fertilizer				
RDF	7.55	14.8	7.3	1.94
50% RDF	7.39	14.1	6.8	1.91
Control	7.25	13.5	6.2	1.87
SEm±	0.01	0.09	0.09	0.01
CD (P=0.05)	NS	0.53	0.53	NS

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Table 5. Interactive effect of tillage, planting and fertilizer treatments on economic indices of sorghum (pooled data of 2 years).

Treatment	Total cost of production (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
Minimum + ridges and furrows + RDF	7.6	15.2	7.6	2.02
Minimum + ridges and furrows + 50% RDF	7.4	14.8	7.4	2.01
Minimum + ridges and furrows + control	7.3	14.4	7.2	1.99
Minimum + flatbed + RDF	7.4	13.6	6.2	1.83
Minimum + flatbed + 50% RDF	7.3	12.4	5.1	1.69
Minimum + flatbed + control	7.2	11.5	4.3	1.60
Conventional + ridges and furrows + RDF	7.7	16.0	8.3	2.08
Conventional + ridges and furrows + 50% RDF	7.6	15.5	7.9	2.06
Conventional + ridges and furrows + control	7.4	14.8	7.4	2.03
Conventional + flatbed + RDF	7.4	14.3	6.9	1.94
Conventional + flatbed + 50% RDF	7.3	13.9	6.6	1.91
Conventional + flatbed + control	7.1	13.4	6.3	1.89
SEm±	0.02	0.18	0.18	0.03
CD (P=0.05)	NS	1.51	1.49	NS

RDF, recommended dose of fertilizer

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