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Effect of Moisture Conservation Practices on Growth, Yield, Root Development, Water Use and Economics of Sorghum Varieties under Rainfed Condition

A. K. Katiyar, Sumit Raj* and P. K. Rajput

Department of Soil Conservation and Water Management, C.S. Azad University of Agriculture and Technology, Kanpur, India

**Corresponding author*

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A B S T R A C T

A field experiment was conducted during two *kharif* seasons of 2015 and 2016 on sandy loam soil to study the performance of moisture conservation practices on growth, yield attributes, yield, water use, water use efficiency, root development and economics of sorghum varieties under rainfed condition. Results revealed that variety 'Ratna-40' proved to be the most promising in growth, yield attributes, yield, root development, net return and B : C ratio as compared to Hi-tech-3201, Virat and Suraj. Crop yield was better with application of organic residue mulch @ 4 t ha^{-1} on soil surface in between the crop rows at 25 DAS as compared to ridging and furrowing in between the crop rows at 25 DAS and farmer's practice (control).

Introduction

Water availability for agriculture is going to be in short supply due to tremendous pressure from the ever increasing demands for domestic and industrial uses. To safeguard food security to the growing population and to maintain the environmental quality, the available water resources have to be efficiently managed. This is important particularly in rainfed areas, which covers 63% of the cultivated area of India. Moisture conservation practices have great potential to conserve moisture, control weeds, moderate soil temperature and nutrient dynamics which enhance the productivity of sorghum in rainfed areas (Patil *et al.*, 2011). Organic residue mulch reduces moisture loss by improving its availability to the plants at later stages of crop growth. Surface mulching of crop residues in line sown crops is employed to reduce soil splash, evaporation and excessive heating of surface soil so that microbiological activities are not adversely

(Rao *et al.,* 2010). The cultivation of sorghum hybrids was found more economical than traditional varieties. It seems to be desirable that local or improved varieties of sorghum may be replaced by sorghum hybrids for higher crop yield and profit even under rainfed condition. It was therefore, considered useful to test the comparative performance of sorghum hybrids under rainfed condition of Central Uttar Pradesh. An attempt has been made to study the influence of moisture conservation practices on yield and WUE of sorghum varieties in water stress condition.

Materials and Methods

A field experiment was conducted during two consecutive *kharif* seasons of 2015 and 2016 at Soil Conservation and Water Management Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The treatments consisted of 4 varieties i.e. (i) Suraj (ii) Virat (iii) Hi-tech-3201(iv) Ratna-40 and 3 moisture conservation practices i.e. (i) farmer's practice (control) (ii) ridging and furrowing in between crop rows at 25 DAS with the help of spade (iii) organic residue mulch @ 4 t ha^{-1} on soil surface in between the crop rows at 25 DAS were tested in the experiment. The treatments were replicated thrice in a factorial randomized block design. The gross plot size was 5.0 m x 3.6 m but the net plot size was 4.0 m x 2.70 m. Sorghum crop was sown spaced at 45 cm apart on flat beds with recommended seed rate of 15 kg ha^{-1} on July 16 and 22 during 2015 and 2016, respectively. An uniform dose of 40 kg N + 40 kg P_2O_5 + 40 kg K_2O ha^{-1} was applied as basal at sowing through funnel attached with country plough. Additional 40 kg N ha^{-1} through Urea top dressed in standing crop at optimum soil moisture condition. Recommended package of cultural operations was found. The crop was harvested on November 20 and 23 during first and second year, respectively. The soil of the experimental field was deep, well drained, sandy loam and calcareous in nature having 0.31% organic carbon, 0.029% total-N, 168.5 kg ha^{-1} available-N, 15.8 kg ha^{-1} available P_2O_5 and 193.0 kg ha^{-1} available K_2O. The soil pH was 7.8 and EC (1: 2.5) was 0.26 dSm^{-1}. The values of field capacity, wilting point, water holding capacity, bulk density and particle density of the surface soil (0-25 cm depth) were 18.3%, 6.0%, 28.3%, 1.38 Mg m^{-3} and 2.60 Mg m^{-3}, respectively. At sowing time, available soil moisture up to 100 cm soil profile was measured which 231.8 and 202.0 mm during 2015 and 2016, respectively. Total rainfall during crop period was 318.2 and 397.3 mm during first and second year, respectively. Root studies were made at harvest by selecting two plants from each treatment at random. The roots freed with a fine jet of water spray so that the delicate rootlets were not broken. Observations were made on depth of root-penetration, roots $plant^{-1}$ and dry weight of roots $plant^{-1}$. The soil moisture was determined thermo-gravimetrically using the samples collected from 0-25, 25-50, 50-75 and 75-100 cm on depths at different growth stages. The amount of moisture use by the crop under different treatments was computed by summing up the values of soil moisture depletion from the profile during the entire crop season. Water use efficiency of the crop was calculated by the method described by Viets (1962). Studies on root development and water use were made in one replication only where the plant stand was uniform.

Results and Discussion

Plant growth

Among varieties, Ratna-40 produced tallest plants at harvest but stem girth was recorded highest in variety Hi-tech-3201 during both the years (Table-1). It might be due to genetical characters of different varieties and

their moisture utilization ability in improving plant growth. Similar results have also been reported by Chand and Bhan (2002). Plant height and stem girth both recorded highest under organic residue mulching followed by ridging and furrowing, while the lowest in farmer's practice during both the years. It may be associated with increased availability of soil moisture in root zone of crop under moisture conservation practices of mulching and ridging and furrowing. Surface mulching increases the water infiltration in soil (Chandrasekharan and Pandian, 2009).

Days to flowering and maturity

In case of varieties, Ratna-40 and Hi-tech-3201 delayed panicle initiation and maturity as compared to Virat and Suraj during both the years (Table-1). It might be the genetic effect of different varieties and also to their moisture utilization efficiency. These results are in agreement to the findings of Mishra *et al.,* (2015). Days to panicle initiation and maturity of sorghum crop were also influenced by moisture conservation practices. Mulching practice significantly delayed panicle initiation and maturity than ridging and furrowing practice as well as farmer's practice during both the years. Such delay might be due to increased soil moisture in this treatment which was utilized by plants and prolonged the vegetative growth period.

Yield attributes

Among varieties, Ratna-40 and Hi-tech-3201 being at par recorded significantly higher of all yield attributes viz. panicle length, panicle girth, panicle weight, number of grains panicle^{-1} and 1000-grain weight than Suraj and Virat varieties during both the years (Table-2). It might be associated with genetic make -up of various varieties. Besides, better root development of Ratna-40 and Hi-tech-3201 might has been helpful in utilizing comparatively more soil moisture during reproductive crop phase which might has been useful in proper formation and development of various yield attributes of sorghum. The yield attributes were recorded significantly higher under organic residue mulching followed by ridging and furrowing practice and lowest under farmer's practice during both the seasons. It might be attributes to increased availability of soil moisture under organic residue mulching as compared to ridging and furrowing and farmer's practices. Thus, with this practice plants utilized more soil moisture particularly in reproductive phase of crop which facilitated the proper development of panicles and grains. Improvement in panicle length and girth provided more opportunity for setting of more number of grains and their proper development with highest 1000-grain weight. All these attributes seem to be responsible for higher weight panicle^{-1} under mulching practice of moisture conservation. These results may very well supported by the findings of Gabir *et al.,* (2014).

Yield

Among varieties, Ratna-40 and Hi-tech-3201 being at par produced significantly higher grain and stover yields than other two varieties during both the years (Table-3). Grain yield was found associated with various yield attributes, while stover yield might be attributed to growth characters. These results confirm the findings of Mishra *et al.,* (2015). Grain and stover yields of sorghum were produced significantly highest under organic residue mulching followed by ridging and furrowing practice and lowest in farmer's practice during both the years. Grain yield might be attributed to various yield attributes, while stover yield is the combined effect of growth characters and yield attributes. Similar results have also been reported by Singh *et al.,* (2013) and Gabir *et al.,* (2014).

Table.1 Effect of moisture conservation practices on growth parameters of sorghum varieties

Treatment	Plant height (cm)		Stem girth (cm)		Days to panicle initiation		Days to crop maturity	
	2015	2016	2015	2016	2015	2016	2015	2016
Varieties								
Suraj	191.6	185.6	5.9	6.1	75.2	74.7	125.5	122.3
Virat	198.2	193.0	6.3	6.6	76.3	75.6	126.7	123.4
Hi-tech-3201	193.0	188.2	7.0	8.1	77.5	76.7	127.0	124.1
Ratna-40	205.0	199.1	6.7	7.2	77.7	77.4	127.7	124.8
C.D. (P=0.05)	7.6	7.9	0.6	0.7	1.1	0.9	1.1	0.8
Moisture cons. Practices								
Farmer's practice (control)	189.4	183.9	5.6	5.7	74.6	73.1	123.2	120.8
Ridging and furrowing in between crop rows	197.4	191.5	6.7	7.3	76.7	76.7	127.5	124.2
Organic residue mulch @ 4t ha^{-1}	204.0	199.2	7.2	8.0	78.7	78.5	129.5	126.0
C.D. (P=0.05)	6.6	6.5	0.5	0.6	0.9	0.7	1.0	0.7

Table.2 Effect of moisture conservation practices on yield attributes of sorghum varieties

Treatment	Panicle length (cm)		Panicle girth (cm)		Weight of panicle (g)		Number of grains panicle^{-1}		1000-grain weight (g)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Varieties										
Suraj	18.3	19.7	15.7	16.3	77.6	76.9	2379.8	2396.2	24.00	24.12
Virat	18.8	20.5	16.0	16.9	79.4	80.1	2471.0	2505.4	24.57	24.78
Hi-tech-3201	21.7	22.7	18.6	19.4	91.9	90.8	2859.1	2910.3	28.43	28.73
Ratna-40	22.1	24.6	18.9	19.9	93.4	94.2	2905.3	3006.7	28.89	29.00
C.D. (P=0.05)	1.2	2.1	1.1	2.3	3.7	4.2	106.8	110.4	1.37	1.22
Moisture cons. Practices										
Farmer's practice (control)	17.5	17.9	15.0	16.2	74.2	74.9	2283.7	2267.3	22.96	23.05
Ridging and furrowing in between crop rows	20.6	23.0	17.6	18.2	87.1	88.6	2712.1	2826.2	26.97	27.10
Organic residue mulch @ 4t ha^{-1}	22.6	24.8	19.3	20.0	95.3	96.0	2965.6	3020.5	29.49	29.60
C.D. (P=0.05)	1.1	1.8	1.0	1.7	3.2	3.6	92.5	100.2	1.19	1.01

Table.3 Effect of moisture conservation practices on yield and root development of sorghum varieties

Treatment	Grain yield (q ha^{-1})		Stover yield (q ha^{-1})		Root depth (cm)		Number of roots plant^{-1}				Dry weight of roots plant^{-1}	
							Primary		Secondary			
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Varieties												
Suraj	21.36	21.67	70.63	72.10	14.4	15.3	23.6	22.1	88.4	87.2	5.46	5.86
Virat	21.49	22.35	71.06	72.95	15.3	16.4	24.3	24.9	89.6	88.0	6.01	6.12
Hi-tech-3201	24.87	25.48	82.24	80.12	17.7	18.3	26.9	27.4	92.5	93.7	6.69	6.90
Ratna-40	25.28	27.13	83.59	84.33	19.6	20.6	28.7	28.5	96.3	97.8	7.58	7.62
C.D. (P=0.05)	1.72	2.82	4.20	4.35	-	-	-	-	-	-	-	-
Moisture cons. Practices												
Farmer's practice (control)	20.09	20.79	66.42	68.07	19.3	19.9	22.3	21.0	85.0	82.8	5.68	5.84
Ridging and furrowing in between crop rows	23.59	24.35	78.02	77.70	17.0	17.8	26.9	26.4	92.3	94.2	6.54	6.82
Organic residue mulch @ 4t ha^{-1}	26.07	27.34	86.21	86.37	14.1	15.3	28.5	29.7	97.9	98.1	7.09	7.20
C.D. (P=0.05)	1.49	2.22	3.64	3.85	-	-	-	-	-	-	-	-

Table.4 Effect of moisture conservation practices on total water use, water use efficiency, net return and benefit: cost ratio of sorghum varieties

Treatment	Total water use (mm)		Water use efficiency (kg grain ha^{-1} mm^{-1} of water)		Net return (Rs ha^{-1})		B : C ratio	
	2015	2016	2015	2016	2015	2016	2015	2016
Varieties								
Suraj	355.7	355.2	6.01	6.10	15882	16235	1.52	1.57
Virat	354.2	364.6	6.07	6.13	16163	20182	1.53	1.70
Hi-tech-3201	368.8	369.3	6.74	6.90	23468	25511	1.78	1.89
Ratna-40	377.7	394.3	6.69	6.88	24348	39786	1.80	2.39
C.D. (P=0.05)								
Moisture cons. practices								
Farmer's practice (control)	388.5	373.6	5.17	5.56	13876	18047	1.47	1.63
Ridging and furrowing in between crop rows	360.6	370.5	6.54	6.57	22531	25790	1.79	2.13
Organic residue mulch @ 4t ha^{-1}	343.2	368.7	7.60	7.42	23489	32451	1.71	1.90

Total water use and water use efficiency

In case of varieties, total water use was maximum in Ratna-40 but WUE was highest in Hi-tech-3201 during both the years (Table-4). Higher water use in Ratna-40 variety might be attributed to their better root development as compared to other varieties. Higher grain yield of Ratna-40 and Hi-tech-3201 might has increased WUE over other varieties. The findings of other research workers like Chand and Bhan (2002) support the results of present experiment very well. Organic residue mulching treatment recorded lower TWU and higher WUE as compared to other moisture conservation practices during both the years. Farmer's practice plot reflected higher TWU due to partial control of weeds as well as open space, which caused higher ET loss but lower moisture utilization by the crop under organic residues mulch may be ascribed to almost all weeds got depressed due to covered space, which are jointly responsible to minimise moisture loss. WUE was higher in mulched plot than other moisture conservation practices as a result of increased yield and lowest TWU in the mulched plot. Beneficial effect of mulch has also been reported by Singh *et al.,* (2012).

Root development

Among varieties, Ratna-40 recorded maximum root depth, number of roots plant^{-1} and dry weight of roots plant^{-1} followed by Hi-tech-3201 and Suraj recorded the lowest values of roots during both the years (Tale-3). It seems to be associated with genetic make-up of different varieties. The higher root depth was found to be connected with farmer's practice treatment (control) probably due to lack of available moisture in soil, where crop tended to develop deeper roots in search of available moisture and nutrients. On the other hand, higher number of roots plant-1 and their dry weight appeared to be associated with mulching plot where crop appeared to develop lateral roots due to considerable amount of moisture conservation in the surface layer. These results corroborate with the findings of Katiyar (2001).

Economics

Among varieties, Ratna-40 earned highest net return and B: C ratio closely followed by Hi-tech-3201 during both the years (Table-4). Organic residue mulching exhibited higher net return as compared to ridging and furrowing as well as farmer's practice during both the years. However, this treatment was failed to exhibit superiority in B: C ratio over ridging and furrowing plot due to additional cost of mulch application.

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