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Root development, water use and water-use efficiency of sorghum (*Sorghum bicolor*) as influenced by vegetative barriers in alley cropping system under rainfed condition

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ABSTRACT

Root development, water use and water-use efficiency of 3 sorghum [*Sorghum bicolor* (L.) Moench] varieties, viz. 'CSV 13', 'CSV 15' and 'Varsha', raised in alleys formed by different vegetative barriers, viz. ***Sesbania sesban, Leucaena leucocephala, Cajanus cajan, Vetiveria zizanoides*** and ***Cenchrus ciliaris***, and unbarriered (control) were studied during the rainy seasons of 1995 and 1996 at Kanpur on light-textured alluvial soil. Best root development of sorghum was observed when raised in alleys of ***Sesbania***, followed by ***Leucaena***, while the poorest root development in alleys of ***Cenchrus ciliaris***. Among the sorghum varieties 'Varsha' resulted in better root development in terms of depth, breadth, number and weight than 'CSV 13' and 'CSV 15'. Better root development of sorghum 'Varsha' raised in alleys of *Sesbania* resulted in higher water use and water-use efficiency and yield attributes like 1,000-grain weight, grains/panicle, grain and fodder yields where 'Varsha' excelled 'CSV 13' and 'CSV 15'. Total water use of sorghum under *Sesbania* was 388.5 mm which was 9.5 mm higher than the control (unbarriered) crop. The water-use efficiency of sorghum in association with *Sesbania* was 5.3 kg/ha-mm as compared with 4.1 kg/ha-mm unbarriered (control).

Key words : Sorghum, Vegetative barriers, Alley cropping, Root development, Water-use efficiency, Rainfed

Sorghum as well known for its drought-enduring capacity. An extensive root system helps it to tide over stress or drought situation. However, in spite of this merit, amount and distribution of rainfall greatly influence productivity of crop, particularly on sloppy lands where a major portion of rainfall finds its way as runoff with which fine silt particles and nutrients are lost, and the moisture scarcity and depleted fertility

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drastically reduce the yield. Intercropping or alley cropping, in which crop is planted between alleys of vegetative barriers or hedgerows of grasses or leguminous shrubs across the slope stabilizes and enhances productivity of rainfed crops of poor fertility Narayan and Nitant, (1996). In such a system however, the intercrop may face differential competition with the vegetative barriers due to differential canopy and root development. A study was conducted to evaluate the potential of different vegetative barriers intercropping under light-textured eroded soils of semi-arid conditions to (i) monitor the effect of various vegetative barriers, (ii) evaluate relative performance of varieties of sorghum under rainfed condition when grown in alleys formed by different vegetative barriers, (iii) compare crop performance in vegetative barriered cropping and unbarriered (sole) cropping system and (iv) evaluate the effect of hedge rows prunings return to the alleys on growth, development and yield of sorghum as well as changes in fertility status of soil. In this paper root development, moisture use any yield of sorghum as affected by different vegetative barriers are presented.

MATERIALS AND METHODS

The field experiment was conducted during the rainy season of 1995 and 1996 at Kanpur. Six vegetative barriers, viz control (unbarriered), *Sesbania sesban, Leucaena leucocephala, Cajanus cajan, Vetiveria Zizanoides* and *Cenchrus ciliaris,* and 3 sorghum varieties ('CSV 13', 'CSV 15' and 'Varsha') were compared in 3 time replicated split-plot design of layout, keeping vegetative barriers in main plots and varieties in subplots. The gross plot size was 7 m × 5.9 m. Vegetative barriers were planted across the slope (2.4 %) in paired rows at 0.5 m apart at distance of 5.4 m during 1993 in north-south direction. The legume barriers were pruned at height of 60 cm while grass barriers at 30 cm height and when they were properly established during 2 years to serve as good barriers. Sorghum varieties were planted between the alleys formed by different vegetative barriers. The pruned material of vegetative barriers was used as mulch (3 tonnes/ha/season, green biomass) between the crop rows to reduce erosion, conserve moisture and organic matter to the soil. Planting of sorghum varieties was done of 1 July in 1995 and 5 July in 1996 with the help of country plough in rows at 45 cm apart using 15 kg seed rate/ha. The crop was fertilized with 80 kg N and 60 kg P_2O_5/ha. Half of nitrogen and whole of phosphorus were applied basal, while remaining half of N was top-dressed 15 days after planting. As the varieties under the study were of different durations, the harvesting was done as per maturity of the variety, 'CSV 13' and 'CSV 15' were harvested in October and 'Varsha' in November each year.

The soil was sandy loam with field capacity 18.7%, water-holding capacity 30.0% and bulk density 1.5 g/cc, organic carbon 0.25%, total nitrogen 0.024%, available P_2O_5 11.7 kg/ha, available K_2O 165 kg/ha and pH 8.2. A rainfall of 621.9 mm and 741.8 mm was received during the cropping season of 1995 and 1996 respectively. Soil moisture was determined gravimetrically up to 100 cm depth at an interval 25 cm before and after each shower during rainy day and at fortnightly interval during remaining period. The amount of moisture used by the crop was computed by summing up the values of soil-moisture depletion from the profile during the entire crop season. Water-use efficiency (WUE) of the crop was calculated by the method described by Viets (1962).

Root studies were made at harvest by selecting 3 plants at random from each plot and washing the roots with a fine jet of water spray. Observations were recorded on depth of root, number of roots and dry root weight per plant.

RESULTS AND DISCUSSION

Root development

Root development of sorghum as measured by root breadth, number of roots and root weight was better when grown in alleys of legume barriers than grass barriers; however, best root development was observed with *Sesbania* which gave a difference of 13.8 cm in root breadth, 20.3 in number of primary roots and 6.7 g per plant in root weight over the control (Table 1). Roots are in fact underground space frontiers and developed in search of water and nutrients both horizontly and vertically. The better root development of sorghum in association with legume barriers, may be attributed to lesser competition offered by the legume barriers firstly because legume barriers penetrated their roots deeper leaving entire top soil mass for the development of root system of sorghum and secondly they enriched soil in organic matter and nitrogen due to their nitrogen-fixing ability and addition of organic matter through mulch. Govindrajan *et al.* (1996) reported that combined root density of maize and *Leucaena* on alley cropping was 4-5 times higher than the root density in sole maize throughout the profile.

'Varsha' exhibited better root development in terms of root depth, root breadth, number of primary roots and dry weight/ plant over 'CSV 13' and 'CSV 15', respectively, during both years. Better root development of 'Varsha' may be attributed to its long duration and its genetic make up. Varietal difference in root development in sorghum was reported by Hiremath *et al.* (1944).

Water use and moisture-extraction pattern

Different vegetative barriers influenced both the moisture use and moisture-extraction pattern. However, the differences were not conspicuous, while the total moisture use of sorghum was 379.0 mm in unbarriered plots, it was little higher 388.5 mm in *Sesbania,* 383.5 mm in *Leucaena,* 381.0 mm in *Vetiveria* and 389.0 mm in *Cenchrus*-barriered plot. The water use was lowest in *Cajanus*-barriered plot (Table 1). As regards moisture extraction pattern in general about 38–42 %, 29–31%, 18–21% and 8-11% was contributed by 0–25, 25–50, 50–75, 75–100 cm soil layers respectively. Various vegetative barriers markedly influenced the pattern of moisture extraction by the crop (Table 2).

Higher amount of total water use in barriered plots may be attributed to control of runoff from going out of plot and providing more opportunity time for its absorption in the soil. Improved physico-chemical properties of soil due to addition

Table 1. Root development, water use and water-use efficiency of sorghum as influenced by different vegetative barriers and varieties at harvest

Treatment	Root depth cm			Root breadth (cm)			Primary roots/ plant			Dry weight of root (g)			Water use (mm)			Water-use efficiency (kg/ha)		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Vegetative barriers																		
Control	55.6	51.3	53.5	34.0	32.6	33.3	82.2	76.8	79.5	27.6	25.5	26.6	387	371	379	4.2	4.1	4.1
Sesbania	39.6	43.7	41.7	46.6	46.6	47.1	96.8	101.0	98.8	33.2	33.2	33.2	391	386	389	5.2	5.4	5.4
Leucaena	37.2	41.3	39.3	45.9	46.8	46.4	95.0	98.0	96.5	30.7	31.4	31.1	388	379	384	5.1	5.3	5.2
Pigeonpea	48.0	39.6	43.8	43.8	44.6	44.2	92.1	94.1	93.1	30.0	30.6	30.3	380	370	375	5.0	5.3	5.2
Vetiver	49.5	39.0	44.3	42.3	43.6	43.0	91.4	87.8	89.6	29.9	27.4	28.7	391	371	381	4.8	4.8	4.8
Cenchrus	46.8	37.3	42.1	37.9	41.1	39.5	87.1	82.6	84.9	29.7	26.1	27.9	400	378	389	4.4	4.4	4.4
Sorghum variety																		
'CSV 13'	38.9	36.5	37.7	41.3	41.1	41.2	87.4	87.2	87.3	25.6	28.1	26.9	372	360	366	5.0	5.0	5.0
'CSV 15'	35.2	35.4	35.3	39.2	42.8	41.0	89.2	85.9	87.6	27.1	27.2	27.2	390	979	385	4.1	4.3	4.2
'Varsha'	39.6	45.5	40.1	44.8	44.3	44.6	95.6	97.0	96.3	31.4	32.6	32.0	406	405	406	5.2	5.1	5.1

Table 2. Soil-moisture extraction pattern of sorghum as affected by different vegetative barriers and varieties

Treatment	Soil-moisture extraction pattern (%)											
	0–25 cm soil depth			25–50 cm soil depth			50–75 cm soil depth			75–100 cm soil depth		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Vegetative barriers												
Control	38.5	38.4	38.5	30.6	3.9	3.8	20.9	20.8	20.9	10.0	9.9	10.0
Sesbania	41.2	40.8	41.0	29.7	30.6	30.2	19.1	19.1	19.1	10.0	9.5	9.8
Leucaena	41.9	41.5	41.7	30.4	30.9	30.7	18.7	19.7	19.2	9.0	8.0	8.5
Pigeonpea	40.6	40.1	40.4	30.2	31.2	30.7	19.4	19.1	19.3	9.8	9.6	9.7
Vetiver	41.3	40.7	41.0	30.7	30.8	30.8	18.3	19.6	19.0	9.7	8.9	9.3
Cenchrus	42.0	39.9	41.0	29.5	30.6	30.1	17.8	20.0	18.9	10.7	9.5	10.1
Sorghum variety												
'CSV 13'	41.0	40.3	40.7	30.5	30.5	30.5	18.7	20.4	19.6	9.8	8.8	9.3
'CSV 15'	41.0	40.2	40.6	29.9	30.8	30.4	19.0	19.8	19.4	10.1	9.2	9.7
'Varsha'	40.0	40.0	40.0	29.6	30.1	29.9	19.7	20.2	20.0	10.7	9.7	10.2

of organic matter through mulch in barriered plot also helped to hold more water in soil resulting in higher total water use (Patil and Kulkarni, 1998). Since the moisture was maintained at higher level, it was readily available to the crop particularly during the critical stages, hence the total water use by the crop was higher under vegetative barriers over the control.

'CSV 13', 'CSV 15' and 'Varsha' were found distinctly different in water use. 'Varsha' exhibited a higher soil-moisture regime throughout the cropping period than 'CSV 13' and 'CSV 15'. Higher total water use of 'Varsha' may be attributed to extract moisture from deeper layers and its long duration continued to make growth and development for longer period. More availability of water to crop plants and thereby more availability of nutrients ultimately resulted in increase growth and yield attributes of sorghum (Table 3).

Water-use efficiency

The water-use efficiency (WUE) of sorghum was appreciably improved due to different vegetative barriers over the control (Table 1). The WUE was found to depend more on grain yield than total Water use and was recorded maximum under *Sesbania* barriers, followed by *Leucaena* and *Cajanus cajan.* Minimum WUE was observed under the control (unbarriered) crop. The increase in the WUE may be attributed to appreciable increase in grain yield which was in much greater proportion than the water use under different vegetative barriers (Table 3). As regards water-use efficiency for dry-matter production almost similar trend was

Table 3. Plant height, yield attributes and yield of sorghum as affected by various vegetative barriers and varieties

Treatment	Plant height (cm)		Ear length (cm)		Ear girth (cm)		1000-grain weight (g)		Grain yield/ ear (g)		Grains/ear (g)		Seed yield (q/ha)		Stover yield (q/ha)	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Vegetative barriers																
Control	183.0	179.1	17.6	17.0	15.7	15.3	20.4	20.0	26.4	26.0	986.0	975.0	16.2	15.0	64.9	62.0
Sesbania	196.0	197.9	22.7	23.7	19.9	20.6	22.1	21.5	34.0	34.4	1,234.0	1,247.0	20.2	20.9	80.0	84.9
Leucaena	194.0	196.4	21.9	22.7	18.5	19.6	21.7	21.2	33.6	34.0	1,189.0	1,199.0	19.8	20.0	78.2	81.0
Pigeonpea	191.9	193.4	20.6	21.7	17.8	18.5	21.6	21.0	32.8	31.7	1,148.0	1,172.0	19.1	19.5	74.7	76.0
Vetiver	191.1	188.0	19.6	19.5	17.2	16.3	21.2	20.3	28.7	27.0	1,046.0	1,030.0	18.8	17.6	71.9	67.7
Cenchrus	188.9	185.3	19.1	18.3	16.9	15.9	20.5	20.5	26.9	26.6	980.0	949.0	17.6	16.5	68.9	64.3
CD (P = 0.05)	3.9	2.6	1.1	1.6	1.7	0.9	1.0	0.7	2.0	2.1	45.3	54.0	1.0	1.3	2.8	3.2
Sorghum variety																
'CSV 13'	153.0	152.7	22.3	22.1	16.6	16.8	21.5	20.9	29.4	28.5	1,113.0	1,108.0	18.7	18.3	70.9	67.5
'CSV 15'	205.3	203.9	20.5	20.7	15.6	15.9	20.5	20.2	27.3	27.1	1,023.0	1,018.0	16.0	15.9	63.3	65.9
'Varsha'	214.4	213.4	18.2	18.7	20.9	20.5	21.7	21.2	34.4	34.1	1,156.0	1,152.0	21.2	20.6	85.1	84.6
CD (P=0.05)	4.0	1.9	0.6	1.5	0.7	0.6	0.7	0.7	1.3	1.6	27.2	26.8	0.9	1.2	2.5	3.3

observed as was for grain production in relation to various vegetative barriers. Improved WUE due to vegetative barriers or hedgerows was reported by Gupta and Bhan (1993) and Narayan and Nitant (1996)

'Varsha' sorghum was distinctly superior in water-use efficiency in terms of grain production as well as dry-matter production to 'CSV 13' 'CSV 15'. The performance of 'CSV 15' was poorest in this respect, which may be attributed to higher yield of 'Varsha' which was in greater proportion than the water use.

Thus on slopy and light-textured eroded soils of dryland areas of central Uttar Pradesh facing twin problems of moisture scarcity and poor fertility, it is advisable to grow sorghum 'Varhsa' in 5.4 m wide alleys of *Sesbania sesban* or *Leucaena leucocephala* planted in paired rows at 0.5 m apart and pruning them at a height of 60 cm at the time of planting of sorghum and after about 45 days of crop age and using the biomass as mulch between the crop rows for obtaining higher root development, water-use efficiency and grain and stover yields over sole crop of sorghum.

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