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Review/Overview

Effect of fertility levels and weed-management practices on yield potential, nutrient uptake and economics of spring-planted sugarcane (*Saccharum officinarum*)

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ABSTRACT

A field experiment was carried out during the spring seasons of 2007–08 and 2008–09 at Muzaffarnagar, Uttar Pradesh to study the effect of NPK levels and weed-management practices on yield potential, nutrient uptake and economics of sugarcane (*Saccharum officinarum* L.). The crop was fertilized with 75% recommended dose of fertilizer (RDF), 100% RDF (150:60:60 kg/ha of N: P_2O_5: K_2O) and 125% RDF in combination with 7 weed management practices, viz. weedy check; weed free; three hoeing at 30, 60 and 90 days after planting; one hoeing at 30 days after planting followed by atrazine @ 2.0 kg a.i./ha; atrazine @ 2.0 kg a.i./ha as pre-emergence (PE) + 2,4-D @ 1.0 kg a.i./ha at 60 days after planting; glyphosate @ 1.0 kg a.i./ha at 25 days after planting + one hoeing at 60 days after planting and *Sesbania* sowing in inter-row space followed by 2,4-D @ 1.0 kg a.i./ha at 45 days after planting. The crop fertilized with 125% RDF being at par with RDF resulted in the highest cane yield and number of millable canes, being 15.5 and 22.3% higher respectively, than lower fertility level mainly because of remarkable improvement in individual cane weight, cane girth, cane length, tillering and lower mortality. The dose of 125% RDF was found economically more sound, as it generated the highest return of ₹86,740/ha with benefit: cost ratio of 2.35. The highest nutrient uptake by sugarcane and total nutrient removal by sugarcane + weeds was recorded with 125% RDF which was significantly higher over RDF. The total uptake of nutrients followed the trend similar to that of nutrient removal by sugarcane. Among the weed-management practices, 3 manual hoeings at 30, 60 and 90 days after planting being at par with the treatment post-emergence application of glyphosate @ 1.0 kg a.i. at 25 days after planting + one hoeing at 60 days after planting proved efficient in controlling the weed population and dry-matter production all the growth stages, as evident by the highest weed control efficiency. The cane yield, millable canes and nutrient removal were witnessed higher under glyphosate @ 1.0 kg a.i. at 25 days after planting + one hoeing at 60 days after planting, followed by 3 manual hoeing at 30, 60 and 90 days after planting. Under weedy check plots, weeds removed the maximum nutrients, whereas lower uptake was observed under weed free conditions. Glyphosate @ 1.0 kg a.i./ha at 25 days after planting + 1 hoeing at 60 days after planting was the best weed-management practices for higher net return (₹91,067/ha) and benefit: cost ratio (3.60) when it was compared to other treatments.

Key words : Cane yield, Economics, NPK levels, Nutrient uptake, Sugarcane, Weed management

Sugarcane is an important commercial crop in subtropical India, cultivated on 5.08 m ha with an average productivity of 68.4 t/ha (Pandey *et al.,* 2012). In Uttar Pradesh, intensive cultivation is confined to the western part of Uttar Pradesh, covering 75% of the total area of sugarcane in the state (about 1.5 m ha). Profitability of sugarcane cultivation has drastically declined due to increased cost of cultivation and declining factor productivity of monetary inputs, such as plant chemicals and fertilizers. Heavy infestation of weeds comprising grasses, broad-leaf weeds and sedges poses a big challenge for sugarcane production. Initial slow growth and wider row spacing in sugarcane provides ample opportu-nity for weeds to easily occupy vacant space between rows and offer serious competition to crop. Good sunshine and intermittent rains during early monsoon provides congenial environment for excessive growth of weeds. Besides nutrient removal, weeds inflict greater re-duction in sugarcane yield when compared with other pests. Negligent attitude of farmers towards weed management is the most important among them as the losses due to weeds ranges

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from 40% reduction in cane yield to total crop failure depending on the spec-trum of weeds, planting season, soil type, rainfall, duration and time of weed competition (Srivastava, 2001). Nutrient management is an important factor for increasing yields. However, potential of the fertilizer can be harnessed successfully only if the weeds are managed effectively. Fertilizer use in India is inadequate, imbalanced and is in favour of nitrogen. Escalating prices of fertilizers in the market has become a cause of concern so as to sustain the productivity of sugarcane. The N, P and K fertilizers, being mostly imparted are relatively more costly and not used by the farmers in adequate amount resulting in to stagnation or decline in sugarcane productivity over the years (Shahi, 2002). Considering these facts, the present investigation was conducted to evaluate different fertility levels and weed-management practices in spring-planted sugarcane.

MATERIALS AND METHODS

A field experiment on spring-planted sugarcane was conducted during the spring seasons of 2007–08 and 2008–09 at Research Farm of Chaudhary Chhotu Ram (P.G.) College Muzaffarnagar, to study the effect of NPK levels and weed-management practices on yield potential, nutrient uptake and economics of sugarcane. The soil was sandy loam in texture, low in organic carbon (0.41%) and available N (156 kg/ha), medium in available phosphorus (10.7 kg/ha) and medium in potassium (203 kg/ha) with soil pH 7.5. Twenty one treatments comprising 3 fertility levels, i.e. 75%, 100% [150:60:60 kg/ha of N: P_2O_5: K_2O) and 125% of recommeded dose of fertilizer (RDF) and 7 weed-management practices [weedy check; weed-free, 3 hoeings at 30, 60 and 90 days after planting (DAP); 1 hoeing at 30 DAP followed by atrazine @ 2.0 kg a.i./ha; atrazine @ 2.0 kg a.i./ha as PE + 2.4-D @ 1.0 kg a.i./ha at 60 DAP; glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP; and *Sesbania* sowing in inter-row space followed by 2,4-D @ 1.0 kg a.i./ha at 45 DAP] were tested in factorial randomized block design (RBD) with 3 replications. Sugarcane ¢CoS 97264¢ was planted on 2nd fortnight of March during both the years. Nitrogen, phosphorus and potassium were supplied through urea, single superphosphate and murate of potash respectively. The sugarcane was fertilized as per treatments, full P and K and half of the nitrogen was applied basal and remaining N was top-dressed in 2 equal splits 45 and 75 DAP irrespective of the treatments. Among the weed management practices, all the herbicides were applied as solution in water @ 700 liters/ha. The herbicide solutions were sprayed uniformly in the experimental plots, as per treatments with the help of Knapsack sprayer. Atrazine 50 WP @ 2.0 kg a.i. (4 kg/ha) was applied as pre-and post-emergence as per the requirement of the treatments, whereas 2,4-D 80 WP @ 1.0 kg a.i. (1.25 kg/ha) and glyphosate 41% @ 1.0 kg a.i. (2.439 litres/ha) were applied as post-emergence. Growth, yield and quality parameters were measured as per the standard procedure and the homoginity of error varience was tested using bartlett's c^2 test. As the error varience was homogenous for the years, pooled analysis was done. The economics was work out based on pooled yield data and considering price of input and output of the prevailing market.

RESULTS AND DISCUSSION

Weeds

Weed density and dry-matter: The experimental field was infested with broad-leaf weeds (48.4%) with the majority of *Chenopodium album* L., *Convolvulus arvensis* L., *Melilotus indica* L., *Cleome viscose;* and sedges (20.6%); and among grassy weeds (31.0%), *Cynodoan dactylon* (L.) Pers. was in major proportion during both the years.

The population and dry-matter accumulation of weeds did not varied significantly under different levels of NPK applied to sugarcane (Table 1). However, slightly lower weed density and dry matter accumulation were recorded with 125% RDF at all the stages of sugarcane growth.

All weed management practices significantly decreased the weed population and dry-matter production compared to weedy check (Table 1) at 60, 90 and 120 days after planting (DAP). Manual hoeing at 30, 60 and 90 DAP proved to be best weed-management practice in reducing weed population and drymatter production at all the stages. The next best treatment being at par with 3 manual hoeings for reducing density of weeds was the post-emergence application of glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP followed by one hoeing at 30 DAP + atrazine @ 2.0 kg a.i./ha at all the stages of crop growth. The treatment of pre-emergence application of atrazine @ 2.0 kg a.i./ha + application of 2,4-D @ 1.0 kg a.i./ha at 60 DAP failed to suppress the growth of weeds and thereby recorded the highest weed population and dry-matter production. Three hoeings at 30, 60 and 90 days after planting and glyphosate + 1 hoeing at 60 DAP treatment led to continuous decline in population of total weeds and individual populations of *Cyperus rotundus, Cynodon dactylon* and *Sorghum halepense*(L.) Pers. with advancement in crop age up to 120 days. It might be attributed to germination of other weeds controlled by hoeing performed at 60 DAP. The results confirm the findings of Raskar (2004). Reduction in weed dry matter, attributed to repeated weeding and such observations with 3 hoeings was also reported by Singh and Lal (2008).

Weed-control efficiency: Weed-control efficiency, as an index to reduction in weed dry matter at different growth

stages, was highest under 3 hoeings done at 30,60 and 90 DAP followed by glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP (Table 1). It might have happened due to improved crop growth under better physical condition of soil created by reduced weed competition, better aeration and root growth. Obviously, lower weed-control efficiency was recorded with weedy check conditions.

Nutrient uptake by weeds: The NPK uptake by weeds was not significantly influenced by fertility levels. However, slightly higher removal of nutrients was observed when lower dose of NPK was applied to sugarcane. Nutrient removal by weeds varied significantly due to weed-control measures (Table 3). The 3 hoeings at 30, 60 and 90 DAP led to removal of 4.3, 1.8 and 6.7 kg/ha of N, P and K respectively, compared with significantly lower by 28.1, 11.8 and 45.2 kg/ha of N, P and K respectively over weedy check conditions. Among the herbicidal treatments, glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP, followed by 1 hoeing at 30 DAP followed by atrazine @ 2.0 kg a.i./ha found most effective in removal of less amount of nutrients. Reduction in nutrient uptake might be due to lower density and dry-matter production of weeds under these weed-control treatments. The results are in accordance with the findings of Singh and Kaur (2003).

Sugarcane

Growth: Growth parameters, i.e. shoot height and dry-matter accumulation, varied significantly owing to fertilizer doses. All the growth characters increased with increasing in doses of fertilizers up to the highest level (Table 2). The highest shoot height and dry-matter accumulation/shoot were recorded with the application of 125% RDF, being significantly higher by 26.4 cm and 10.9 g/shoot respectively, over 75% RDF. However, the response of 125% RDF was at par with RDF. Such higher shoot height and dry-matter accumulation might be due to assured supply of nutrients during grand growth stage, improved nutrient availability in root zone to support the cell elongation and their proper development, which resulted vigorous growth. The results confirm the findings of Rana *et al.* (2003) and Kumar *et al.* (2004).

All the weed-control measures improved the tillering of sugarcane, though the superiority was established by weed-free, glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP and 3 hoeings at 30, 60 and 90 DAP. Accordingly, the highest shoot height was recorded when sugarcane grown with weed-free atmosphere at 120 days stage, though it was closely

Table 1. Effect of fertility levels and weed management practices on density, dry matter production and weed-control efficiency of weed flora at different stages in spring planted sugarcane (pooled data of 2 years)

Treatment	Weed density (no./m^2)			Weed dry-matter (g/ m^2) Days after planting (DAP)			Weed-control efficiency (%)		
	60	90	120	60	90	120	60	90	120
Fertility level (% recommended dose)									
75	12.16	14.50	11.19	8.79	10.20	9.54	-	-	-
100	11.85	14.09	10.97	8.69	10.14	9.49	-	-	-
125	11.80	13.97	10.92	8.58	9.93	9.35	-	-	-
SEm±	0.07	0.15	0.10	0.09	0.08	0.09	-	-	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	-	-	-
Weed-management practices									
Weedy check	19.00	24.38	18.81	13.83	17.64	19.46	0	0	0
Weed-free	0.00	0.00	0.00	0.00	0.00	0.00	100	100	100
3 hoeings at 30, 60 and 90 DAP	11.07	9.05	10.93	6.63	7.86	7.03	52.1	55.4	63.9
1 hoeing at 30 DAP *fb.* Atrazine @ 2.0 kg a.i./ha	13.64	16.60	11.44	10.35	11.72	10.14	25.2	33.6	47.9
Atrazine @ 2.0 kg a.i./ha as PE+2,4-D @ 1.0 kg a.i./ha at 60 DAP	14.29	18.80	12.46	11.28	12.98	11.27	18.4	26.4	42.1
Glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP	11.47	13.37	11.28	7.75	8.45	8.33	44.0	52.1	57.2
Sesbania in inter-row space *fb.* 2,4-D spray at 45 DAP	14.46	17.10	12.26	10.95	11.99	10.00	20.8	32.0	48.6
SEm±	0.21	0.27	0.17	0.17	0.17	0.15	-	-	-
CD (P=0.05)	0.60	0.78	0.49	0.50	0.49	0.43	-	-	-

PE, Pre-emergence; DAP, Days after plainting; FB, Followed by

followed by glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP and 3 hoeings at 30, 60 and 90 DAP (340.0 cm). Singh (2003) and Singh and Lal (2008) did observe tallest shoots in manually hoeing plots. Dry-matter production/shoot were also followed the similar trends as shoot height under different weed-management treatments.

Yield attributes and cane yield: Graded dose of NPK application had significant impact on individual cane weight, number of millable canes, cane and trash yield (Table 2). The individual cane weight increased significantly with each successive enhancement of fertilizer levels and recorded the highest value, being 15.4 and 22.3% higher at RDF and 125% RDF respectively, over the lowest dose of fertilizers. As a result, the treatment 125% RDF being at par with RDF applied to sugarcane produced maximum number of millable canes, individual cane weight cane yield and trash yield. The enhanced fertility status and more tillering which converting into higher number of millable canes also contributed to more cane yield. The results are in agreement with the findings of Nagraju *et al.* (2000) and Virida and Patel (2010).

Undoubtedly, the highest values of number of millable canes, individual cane weight, and cane yield were recorded under the weed-free conditions. Among the weed-management practices, post-emergence application of glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP was found most effective in achieving significantly higher cane and trash yield being at par with 3 hoeings at 30, 60 and 90 DAP. Higher cane yield under glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP and 3 hoeings at 30, 60 and 90 DAP attributed to higher number of millable canes with more weight (Table 2). Profuse tiller production and low shoot mortality might have helped in realizing higher number of millable canes by virtue of reduced competition of weeds for nutrient, moisture and light. Srivastava and Chauhan (2006) also noticed an increase in number of millable cane with application of glyphosate.

Juice quality: Fertility levels had significant impact on juice quality parameters, i.e. sucrose and purity coefficient %, and were improved with each successive increase in fertility levels. Sugarcane fertilized with NPK at 125% of RDF significantly enhanced the sucrose and purity %, but was at par in terms of purity % with the application of 100% RDF. The improvement in purity % might have been attributed to higher phosphorus content in cane that helps in better flocculation of non-sugar colloids during purification process and results in minimum turbidity of clarified juice. Singh *et*

Table 2. Effect of fertility levels and weed management practices on growth, yield and yield attributes of spring planted sugarcane (pooled data of 2 years).

Treatment	Shoot height (cm)	Dry matter accumulation (g/shoot)	Cane weight (g)	NMC ($\times 10^3$/ha)	Cane yield (t/ha)	Trash yield (t/ha)	Sucrose (%)	Purity coefficient (%)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
Fertility level (% recommended dose)												
75	315.8	142.6	709.2	90.0	76.2	7.9	13.43	72.43	34,037	1,06,680	72,643	3.13
100	334.5	150.6	798.7	108.0	85.0	8.8	15.33	80.89	35,426	1,19,000	83,574	3.36
125	342.2	153.5	818.4	110.1	88.0	9.0	15.75	81.73	36,644	1,23,200	86,556	3.36
SEm±	3.1	1.4	3.3	1.1	0.8	0.5	0.11	0.06	-	-	-	-
CD(P=0.05)	11.6	2.4	12.1	2.3	3.2	1.4	0.36	1.84	-	-	-	-
Weed-management practices												
Weedy check	301.6	132.2	663.1	74.9	60.1	7.1	14.63	77.81	31,767	84,140	52,373	2.65
Weed-free	353.4	163.4	826.3	125.9	97.5	9.7	15.18	78.40	39,000	1,36,500	97,500	3.50
3 hoeings at 30, 60 and 90 DAP	340.0	154.9	802.8	110.6	89.6	9.2	15.15	79.40	37,124	1,25,440	88,316	3.38
1 hoeing at 30 DAP *fb.* Atrazine @ 2.0 kg a.i./ha	325.9	148.9	778.6	102.1	84.2	8.5	14.61	77.50	35,195	1,17,880	82,685	3.35
Atrazine @ 2.0 kg a.i./ha as PE+2,4-D @ 1.0 kg a.i./ha at 60 DAP	327.2	143.8	757.7	87.3	78.6	8.0	14.43	76.67	33,778	1,10,040	76,262	3.26
Glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP	347.6	159.8	818.7	116.0	90.1	9.3	15.08	79.78	35,073	1,26,140	91,067	3.60
Sesbania in inter-row space *fb.* 2,4-D spray at 45 DAP	320.4	139.4	780.7	91.6	81.4	8.3	14.76	79.22	35,647	1,13,960	78,313	3.20
SEm±	5.7	2.7	14.2	1.8	1.6	0.2	0.28	1.44	-	-	-	-
CD (P=0.05)	16.4	7.8	40.7	5.2	4.7	0.4	NS	NS	-	-	-	-

PE, Pre-emergence; DAP, Days after plainting; FB, Followed by; NMC, number of millable canes

al. (2008) also reported beneficial effect of NPK fertilization on the juice quality. However, weed-management practices did not bring significant variations with respect to sucrose and purity % (Table 2). Nevertheless, performing 3 hoeings at intervals of 30, 60 and 90 DAP numerically improved the sucrose and purity % values.

Nutrient uptake: Nutrient uptake by sugarcane as influenced by levels of fertilizer tended to increase with increasing doses of fertilizers (Table 3). The highest uptake of N, P and K in sugarcane was noticed under 125% RDF. It was being significantly higher by 56.9, 11.2 and 36.8 kg/ha respectively, over sugarcane fertilized with 25% less RDF. Higher nutrients uptake by sugarcane might be due to the assured supply of balanced nutrition that led to increased availability of nutrient, proportionally with production of higher yield which resulted into removal of nutrients in huge quantity. Our results confirm the findings of Rana *et al.* (2003), Kumar *et al. (*2004), Khokar and Nepaliya (2010). Total uptake (weeds + sugarcane) of nutrients also followed the trend similar to uptake by sugarcane.

All the weed-management practices had significant effect on NPK removal by sugarcane over weedy check (Table 3). Significantly higher uptake of N, P and K was recorded when sugarcane was treated with glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP and followed by the treatment of 3 hoeings at 30, 60 and 90 days after planting compared to rest of the treatments although the N removal under these treatments were statistically at par. The higher uptake of nutrients was due to the suppression of weed growth that might have been the driving force behind higher dry matter and nutrient uptake in sugarcane under these treatments. Under different treatments, nutrient uptake was recorded in order of weed-free> glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP > 3 hoeings at 30, 60 and 90 DAP > 1 hoeing at 30 DAP followed by atrazine @ 2.0 kg a.i./ha > atrazine @ 2.0 kg a.i. as PE + 2,4-D @ 1.0 kg a.i./ha > *Sesbania* in inter-row space followed by 2, 4-D at 45 DAP > weedy check. Such higher uptake might be attributed to higher cane yield production under better weed management treatments. The results confirm the findings of Virida and Patel (2010).

Cumulative nutrients removal (weeds + sugarcane) also varies significantly owing to different weed-management practices and recorded highest N, P and K with the application of glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP followed by 3 hoeings at 30, 60 and 90 DAP. The minimum nutrient uptake was noticed when sugarcane allowed to grow in weedy check conditions which might be attributed to production of least cane yield.

Table 3. Effect of fertility levels and weed management practices on nutrient uptake by weed, spring-planted sugarcane and total uptake by sugarcane weeds (pooled data of 2 years)

Treatment	Nutrient uptake (kg/ha)								
	Weed			Sugarcane			Total (weed+sugarcane)		
	N	P	K	N	P	K	N	P	K
Fertility level (% recommended dose)									
75	10.7	4.4	16.4	131.2	35.2	239.2	141.9	39.6	255.6
100	10.3	4.2	16.2	181.7	44.8	272.7	192.0	49.0	288.9
125	9.6	4.2	15.9	188.1	46.4	276.0	197.7	50.6	292.0
SEm±	0.1	0.1	0.1	1.2	0.4	2.9	1.4	0.8	4.3
CD (P=0.05)	NS	NS	NS	3.4	1.4	8.5	4.2	2.5	14.4
Weed-management practices									
Weedy check	32.4	13.6	51.9	116.9	30.4	210.9	149.3	44.0	262.8
Weed-free	0.0	0.0	0.0	204.1	53.4	301.0	204.1	53.4	301.0
3 hoeings at 30, 60 and 90 DAP	4.3	1.8	6.7	182.3	45.4	277.8	186.6	47.2	284.5
1 hoeing at 30 DAP *fb.* Atrazine @ 2.0 kg a.i./ha	8.9	3.7	14.1	163.6	41.6	261.8	172.5	45.3	276.0
Atrazine @ 2.0 kg a.i./ha as PE+2,4-D @ 1.0 kg a.i./ha at 60 DAP	11.0	4.5	17.5	147.1	35.6	241.9	158.1	40.1	259.5
Glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP	6.0	2.5	9.5	191.9	48.9	284.8	197.9	51.4	294.3
Sesbania in inter-row space *fb.* 2,4-D spray at 45 DAP	8.8	3.6	13.5	163.0	39.7	253.9	171.8	43.3	267.4
SEm±	0.2	0.1	0.4	2.9	0.7	4.1	2.1	1.2	5.2
CD (P=0.05)	0.6	0.3	1.1	8.4	2.1	11.9	6.4	3.8	14.6

PE, Pre-emergence; DAP, Days after plainting; FB, Followed by

Economics

A dose of 125% RDF recorded the highest net returns and benefit: cost ratio being 19.1 and 7.3% higher over initial dose of fertilizers respectively. It was followed by sugarcane fertilized with RDF which generated a net income being 3.5% lower than the highest income generator treatment. The highest returns under higher doses might be owing to more cane yield production which led to proportionally higher gross return than cost of cultivation.

Among weed-management practices, higher net returns and benefit: cost ratio recorded when the sugarcane was grown under glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP. It was followed by 3 hoeings at 30, 60 and 90 DAP). Minimum net returns and benefit: cost ratio were observed under weedy condition. Lower returns and benefit: cost ratio might be due to lowest cane yield production under weedy check.

Thus, it can be concluded that the application of 125% RDF, being at par with RDF, improved the growth, yield and yield attributes of sugarcane, although 125% RDF was recorded highest returns over lower doses of fertilizers. Among the weed-management treatments, post-emergence application of glyphosate @ 1.0 kg a.i./ha at 25 DAP + 1 hoeing at 60 DAP were superior in controlling weeds and improving growth, yield attributes and yield of sugarcane and economic returns.

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