Indian J. Weed Sci. **43** (1 & 2) : 97-100 (2011) Short Communication

Effect of Planting Density and Weed Management Options on Weed Dry Weight and Cane Yield of Spaced Transplanted Sugarcane (*Saccharum officinarum* L.) after Wheat Harvest in Sub-tropical India

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Sugarcane is grown in both tropical and sub-tropical areas of India with an area of over 4.41 million hectare with total production of 294.6 million tonnes and productivity of 66.8 t/ha. In sub-tropical zone, Uttar Pradesh, Haryana and Punjab have 2.058, 0.115 and 0.105 million hectare area with productivity of 58.4, 70.0 and 60.0 t/ha, respectively. Sugarcane-ratoon-wheat is the most prevalent sugarcane-based cropping system in sub-tropical zone. A drastic reduction in the yield of late planted sugarcane after wheat harvest is observed under this system. In spite of low yield of plant cane, farmers prefer to delay the planting of cane till wheat harvest as wheat meets the immediate need of both food and fodder for their families and the animals they keep. Sugarcane spaced transplanting (STP) wherein sugarcane is planted after wheat harvest using sugarcane setts involves transplanting of single bud pre-germinated shoots raised in soil which help in improvement in cane yield of late planted crops after wheat harvest. This technique leads to a significant reduction in the cost of seed cane which compensates for the additional cost in nursery raising and transplanting. Nearly 7.5-8.0 t/ha cane seed is utilized as planting material in conventional method, whereas 1.6-2.0 t/ha seed cane is sufficient to transplant one hectare in STP. Sugarcane, being slow growing crop at initial stage, faces tough competition with the weeds between 60 to 120 days of its planting which often results in heavy reduction in cane yield to the extent of 10-70% as has been reported by Srinivasan *et al*. (1981), Srivastava *et al*. (1985) and Suyal and Saini (1987). Earlier attempts made to control the weed through the use of herbicides or mechanical means showed varying degree of success which generally failed to reach adequate levels for STP method of planting. Therefore, it was felt necessary that besides screening the effective herbicides, there is a need to integrate them along with manual weeding for effective and economic weed control for the STP. The present study was, therefore, attempted in this direction with the objectives to find out the effect of planting density and weed management options on weed population, growth and yield of sugarcane planted by STP method.

The field experiment was conducted after wheat harvest under STP method in summer season of 2009-10 at The Karnal Co-operative Sugar Mills Ltd., Karnal, Haryana, India (longitude 76°58' East and latitude 29°43' North with 245 m above the mean sea level). The soil of the experimental plot was slightly alkaline in nature (pH 7.74), light sandy loam in texture, low in available organic carbon (0.35%), available nitrogen (116 kg/ha), available phosphorus (5.33 kg/ha) and medium in available potassium (170 kg/ha). The trial was laid out in a split plot design with planting density in main plots and weed management options in sub-plots with three replications. The treatments comprised three levels of plant to plant spacing i. e. 30, 45 and 60 cm in main plots to create different plant densities and five levels of integrated weed control options i. e. weed free (W_1), weedy check (W_2), manual hoeing at 30 days after transplanting (DAT) followed by atrazine 2.0 kg/ha at 35 DAT followed by glyphosate 1.0% at 90 DAT (W_3), manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha 35 DAT followed by paraquat 0.3% at 90 DAT (W_4) and manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by 2, 4-D ester (1.0 kg/ha)+metribuzin 0.88 kg/ha at 60 DAT (W_5) in sub-plots. The sugarcane variety Co 0238 was transplanted at 60 cm row spacing on 20 April 2009 from the plantlets raised by planting single bud setts in nursery on 10 March 2009. The gross plot size was 21.6 m^2 (6 x 3.6 m). Single buds seed nursery was raised 40 days before transplanting. The plants' setts were raised in nursery having small area about 50 m^2 (5 x 10 m). The area was well prepared to a depth of about 15 cm and small plots of about 1 m^2 areas were made. Chloropyriphos 20% EC was applied to the soil. In each small plot nearly 700-800 single budded setts were accommodated depending on the thickness of the setts. Setts were dipped in the dithane M-45 (250 g in 100 l water solution) for 10 min. About 20 q seed was used to raise the nursery for one hectare sugarcane planting. Single buds were drawn from upper half of the cane stalk by cutting just above the growth ring and having 5-6 cm of the internodes below the bud. The nursery was irrigated adequately and the setts are dibbled horizontally keeping the buds and roots just below the soil surface. Nursery was irrigated frequently to maintain optimum moisture level. Eighty-five to ninety-five per cent of the buds sprouted within 2-3 weeks' time. After six weeks, the setts were ready for transplanting in the field. Setts were carefully removed from the nursery and de-topped with a sharp knife before transplanting. The de-topped setts were dropped in Aretan solution @ 0.1% and taken out immediately. The cane rows were opened at 60 cm row spacing by ridger and setts were transplanted in furrow keeping plant to plant distance of 30, 45 and 60 cm as per treatment to create different plant density (55555, 37037 and 27777 plants/ha). The setts were covered with soil, leaving about 5 cm portion of the shoot above the ground. Before transplanting the setts, the field was lightly irrigated (2/3 portion of the furrow) with irrigation water. After 10 days of transplantation, setts the gaps, if any, due to mortality of transplants were replaced by the setts from the nursery kept in reserve and irrigated immediately. The crop was fertilized with 150 kg N and 50 kg P_2O_5/ha through DAP. Full dose of P and 20 kg N/ha were applied as basal in the furrows at the time of transplanting of seedlings. Remaining dose of N was applied in two equal splits through urea at tillering (50 DAT) and grand growth stage (100 DAT) of the crop. A quadrant of size 0.5 m x 0.5 m was used at random at two places in every plot and weed population was counted within area by quadrant at 25, 50, 75 and 100 days after transplanting. Major weed species were counted separately and remaining were kept in other weeds. The samples were air-dried and then kept in oven at 65°C and were weighted on electrical digital weighing machine.

In the experimental field, the pre-dominant weeds were *Cyperus rotundus, Dactylon aegyptium* and *Trianthema portulacastrum* apart from some other weeds. *C. rotundus* and *D. aegyptium* were major weeds during 25 DAT; these two weeds constituted 28 and 56% of the total weeds' population, respectively. At 100 days' stage of observations, the population of *C. rotundus*, *D. aegyptium, T. portulacastrum* and other weeds was 29, 40, 13 and 16%, respectively. The total weed dry weight of *C. rotundus*, *T. portulacastrum*, *D. aegyptium* and other weeds was not influenced significantly at 25, 75 and 100 DAT by different plant densities created by increasing plant to plant spacing (Table 1). At 50 DAT stage, lowest dry weight of weeds (26.4 g/m^2) was recorded at 60 x 30 cm spacing and it was increased by 22.3 and 26.9% with the increase in plant spacing to 45 and 60 cm, respectively. This might be due to closer canopy cover after establishment of seedling in narrow plant spacing compared with wider spacing. The significantly lowest and highest weed dry weight was recorded in weed free (W_1) and weedy check (W_2) plots, respectively, at 25, 50, 75 and 100 DAT. Treatment W_5 (one manual hoeing at 30 DAT along with application of atrazine at 35 DAT followed by 2, 4-D+metribuzin at 60 DAT) proved more effective in

Table 1. Effect of plant spacing and weed management options on weed dry weight and WCE at different growth stages

Treatments	Total weeds dry weight (g/m^2)				Weed control efficiency (%)			
	25 DAT	50 DAT	75 DAT	100 DAT	25 DAT	50 DAT	75 DAT	100 DAT
Spacing (row x plant)								
60 x 30	4.9 (27.5)	4.5 (26.4)	4.6 (29.6)	4.9 (31.9)	22.1	60.1	78.4	91.37
60 x 45	5.4 (34.0)	4.9 (32.3)	6.1 (47.2)	5.3 (35.4)	24.9	70.6	83.8	89.29
60 x 60	6.2 (46.2)	5.1 (33.5)	4.9 (33.8)	6.3 (48.2)	26.3	67.8	85.0	88.20
LSD (P=0.05)	NS	0.38	NS	NS				
Weed management methods								
W_1	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	-	-	-	-
W_2	6.9 (48.3)	9.4 (89.0)	7.5 (63.8)	8.1 (68.2)	-	-	-	-
W_3	6.8 (47.3)	4.2 (17.8)	6.3 (46.5)	8.0 (65.7)	17.4	71.8	79.9	88.66
W_4	6.7 (47.0)	5.4 (29.4)	7.2 (55.1)	5.0 (26.2)	27.2	58.7	80.5	88.95
W_5	6.1 (37.0)	4.2 (17.6)	3.9 (19.0)	5.3 (33.9)	28.7	67.6	86.7	91.25
LSD (P=0.05)	1.12	1.10	2.39	1.49				

Data were transformed $\sqrt{x+1}$. Original values are given in parentheses.
NS–Not Significant.

decreasing weed population and dry weight than W_3 (manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by glyphosate 1.0% at 90 DAT) and W_4 (manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha 35 at DAT followed by paraquat 0.3% at 90 DAT) possibly because of its application as post-emergence when weed population before 90 days in the field had already built up. These findings are in conformity with the observations recorded by Mann and Chakor (1989) and Singh and Tomar (2005). At 100 DAT, highest weed control efficiency (WCE) of 91.37% was found in S_1 (60 x 30) spacing followed by 89.29 and 88.20 at S_2 and S_3 spacings, respectively (Table 1). Among the weed management methods, the highest WCF (91.25%) was found in W_5 (one manual hoeing at 30 DAT followed by atrazine at 35 DAT followed by 2, 4-D ester+metribuzin at 60 DAT) followed by 88.95% at W_4 (manual hoeing at 30 DAT followed by atrazine at 35 DAT followed by paraquat at 90 DAT) and 88.66% at W_3 (one manual hoeing at 30 DAT followed by atrazine at 35 DAT followed by glyphosate at 90 DAT). This indicated that application of herbicides along with one manual hoeing was more effective in increasing the weed control efficiency. This clearly suggests that integrated weed management was found to be best approach which may replace the need of three manual hoeings (Chauhan and Srivastava, 2002).

Increase in the plant population through narrow spacing (60 x 30 cm) significantly increased the number of millable canes (NMC) by 18.8 and 42.8% than 60 x 45 and 60 x 60 cm spacing (Table 2). Increase in plant spacing from 30 to 45 and 60 cm improved the single cane weight (SCW) by 1.8 and 6.0% and cane girth by 0.4 and 1.2%, respectively. Increase in plant x plant spacing from 30 to 45 and 60 cm did not show any significant variation in cane length, cane girth, pol per cent and commercial cane sugar (CCS) per cent than the narrow plant spacing. The cane and CCS yield was significantly better (103.17 and 11.63 t/ha) in S_1 (60 x 30 cm) spacing which was higher by 17.3 and 18.1% as compared with S_2 (60 x 45 cm) and 62.6 and 61.1% as compared to S_3 (60 x 60 cm) spacing, respectively. Significantly higher NMC, cane length, cane girth and SCW were recorded in weed free plots W_2 followed by W_5 (manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by 2, 4-D ester 1.0 kg/ha+metribuzin 0.88 kg/ha at 60 DAT) as compared with W_3 and W_4 (Table 2). As expected, highest cane yield of 111.16 t/ha was obtained under weed free condition (W_1) and minimum of 42.06 t/ha was recorded under weedy condition (W_2). Weedy conditions upto 100 days reduce the cane yield by 62.16% as compared with weed free conditions. Among integrated weed management options, W_5 (one manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by 2, 4-D ester 1.0 kg/ha+metribuzin 0.88 kg/ha at 60 DAT) produced significantly higher (90.98 t/ha) cane yield which was higher by 1.93 % than W_3 (one manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by glyphosate 1.0% at 90 DAT) and 0.17% than W_4 (one manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by paraquat 0.3% at 90 DAT), respectively. The differences in the cane yield among the treatments were attributed to their weed control

Table 2. Effect of spacing and weed control method on yield attributes and yield of STP sugarcane at harvest

Treatments	Single cane weight (g)	Cane length (cm)	Cane girth (cm)	NMC ('000/ha)	Cane yield (t/ha)	Pol (%)	CCS (%)	CCS yield (t/ha)
Spacing (row x plant)								
60 x 30	809.8	186.9	2.52	125.1	103.17	16.46	11.18	11.63
60 x 45	824.1	180.3	2.53	104.7	87.95	16.31	11.04	9.85
60 x 60	858.7	181.3	2.55	72.3	63.45	16.50	11.22	7.22
LSD (P=0.05)	5.5	NS	NS	3.2	2.39	NS	NS	0.55
Weed management methods								
W_1	894.1	236.0	2.89	126.1	111.16	17.38	11.93	13.26
W_2	651.4	131.3	1.90	64.8	42.06	15.50	10.36	4.38
W_3	850.3	154.3	2.50	105.6	89.25	16.26	10.96	9.77
W_4	872.0	187.0	2.67	104.3	90.82	16.16	10.95	9.96
W_5	886.6	205.6	2.72	102.8	90.98	16.83	11.53	10.47
LSD (P=0.05)	5.3	15.9	0.15	2.9	2.49	0.48	0.44	0.49

NS–Not Significant.

efficacy, which was reflected in population of millable canes under different treatments. In case of un-weeded control treatment, cane crop faced severe competition from various weeds throughout its growing period and resulted in reduction of millable canes and ultimately cane yield.

It can be concluded that increase in plant density through narrow spacing (60 x 30 cm) under spaced transplanting (STP) method enhanced NMC, cane and CCS yield significantly. Among integrated weed management options, weed free crop through manual hoeing or weed management by one manual hoeing at 30 DAT followed by atrazine 2.0 kg/ha at 35 DAT followed by 2, 4-D ester 1.0 kg/ha+metribuzin 0.88 kg/ha at 60 DAT or glyphosate/paraquat at 90 DAT produced significantly higher cane yield than weedy check.

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