MORPHOLOGICAL RESPONSE OF ROW SPACING ON SUGAR BEET (BETA VULGARIS) WITH SUGARCANE (SACCHARUM OFFICINARUM L.) INTERCROPPING

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ABSTRACT

Keeping in view the stirpcane and beet root yield in Pakistan, a research project was initiated at research area of Agricultural Research Institute Ratta Kulachi Dera Ismail Khan Pakistan during 2009-10 and 2010-11 to provide a practicable package of resource conservation technology to sugarcane and sugar beet growers under arid environment. The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement replicated four times. The sub plot size was 4.5m x 5m (22.5 m^2). Approved sugarcane and sugar beet varieties "HSF-240" and "Antak" were used respectively in experiment. In this experiment three planting geometries 75 cm spaced single row strips, 30/90 cm spaced paired row strips, 30/120 cm spaced paired row strips and sugar beet was intercrop in sugarcane. Data were recorded on various growth and yield parameters like germination %, millable cane (m^{-2}); sugar recovery %, stirpcane yield t ha^{-1}, and sugar yield of sugarcane whereas beet germination %, number of beets (m^2), beet sugar recovery %, and beet sugar yield t ha^{-1} were recorded in case of sugar beet. The pooled analysis of two years data (2009-2010 and 2010-2011) showed significant results regarding no of millable cane (m^2), stirpcane yield t ha^{-1}, cane sugar yield t ha^{-1}. The maximum and economically feasible cane parameters were recorded at G_2 (30/90 cm spaced paired row strips).

Keywords: *Saccharum officinarum L., planting geometry, yield components*

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is an old energy source for human beings and, more recently, a replacement of fossil fuel for motor vehicles. It provides sugar, besides biofuel, fiber, fertilizer, rum, soda, and myriads of by- products with ecological sustainability. Sugarcane juice is used for making white sugar, brown sugar (Gur) and ethanol. The main by-products of sugar industry are bagasse and molasses. Molasses, the chief by-product, is the main raw material for alcohol and thus for alcohol-based industries. Excess bagasse is now being used as raw material in the paper industry. Besides, co-generation of power using bagasse as fuel is considered feasible in most sugar mills. Sugarcane can convert up to 2% of incident solar energy into biomass (Bassham, 1978). Pakistan has a broad natural resource base with various agro- climatic zones having great potential for producing all types of agricultural crops. Sugarcane and sugar beet are two sources for manufacturing sugar in Pakistan. In Pakistan more than 99% sugar is extracted from sugarcane and only less than 1% from sugar beet.

Khyber Pakhtunkhwa has been enjoying a unique position in the Indo Pak-sub continent, where both sugarcane and sugar beet are grown side by side in the same field, and are compatible with each other. Sugar yield in Pakistan is 50 t ha^{-1} which is very much lower than average yield of other countries, for example world average yield is 60 t ha^{-1}, while India and Egypt are setting around 67 t ha^{-1} and 105 t ha^{-1} respectively (Nadeem, 2001). Inter crop is the crop which are raised in an orchard or other widely spaced crops for increasing the income from the same piece of land by short duration crop. Due to increasing population, land holding are reducing, therefore farmers want maximum return from a limited area using there scare resources, and they want to protect themselves against a possible crop failure.

It is also noted that in intercropping the interception of solar radiation is improved and utilization of nutrient and water is more effective and risk of failure of crops is minimized. With the rapid increase in population and reduction in cultivable soil, intercropping is the best strategy for intensifying land use and absorbing surplus land labour. Intercropping is a unique asset for small farmer of tropical and sub tropical areas. Increasing sugarcane crises in Pakistan urges that sugarcane and sugar beet intercropping system must be promoted to provide raw material and prolong crushing seasons of sugar mills. The research studies on various aspects of sugarcane and sugar beet have been evaluated as sole crops under different ecological zones of Pakistan. The present research project was initiated to evaluate the performance of sugarcane, sugar beet as a sole and as intercropping of both and to evaluate the compatibility of both the crops for maximum economic return under the agro ecological condition of Dera Ismail Khan.

MATERIALS AND METHODS

Sugarcane (*Saccharum officinarum* L.) is a tropical crop of long duration .The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement having four replications. The objective of this study was to determine the impact of planting geometry and sugarcane-sugar beet intercropping. The two years study was comprised of sugarcane- sugar beet intercropping, in different planting geometries. The sugar beet was also planted as sole as well as intercropped in sugarcane. The sub plot size was 4.5 m x 5 m (22.5 m^2). Each year the crop was planted during the 1^{st} week of September and harvested in first week of December next year. The seed was used at the rate of 70,000 double-budded setts ha^{-1}. All the agronomic practices were kept uniform in all treatments. The experiment was conducted at Agricultural Research Institute Ratta Kulachi Dera Ismail Khan during 2009-10 and 2010-2011. The sugarcane was planted at 75 cm apart rows, 30/90 cm apart rows and 30/120 cm apart rows and then it was irrigated. At a workable condition of soil (20 days after planting sugarcane), the sugar beet was dibbled manually on the ridges, with plant to plant distance of 15 cm.

The chemical fertilizer was applied at the rate of 250-250-250 kg NPK ha^{-1} in the farm of urea, P_2O_5 and K_2O, respectively, The phosphatic and potash fertilizers was applied before the planting of sugarcane and tharouly mixed with the soil to distribute them uniformly in the field. The nitrogen was applied in three different splits. The first split (1/3) was applied at germination completion at the end of February, the second split (1/3) was applied at the start of cane formation stage, (at the end of March) and the 3^{rd} split (1/3) was applied after the uprooting of sugar beet in the month of May. The pre emergence weedicide Dualgold, was used to control weeds. Earthing up was done in the first week of June. The following treatment was studied during experimentation.

Detail of treatments

T1: 75 cm spaced single row strips + *SC sole
T2: 75 cm spaced single row strips + **SB sole
T3: 75 cm spaced single row strips + SC + SB intercropping
T4: 30/90 cm spaced paired row strips + SC sole
T5: 30/90 cm spaced paired row strips + SB sole
T6: 30/90 cm spaced paired row strips + SC + SB intercropping
T7: 30/120 cm spaced paired row strips + SC sole
T8: 30/120 cm spaced paired row strips + SB sole
T9: 30/120 cm spaced paired row strips + SC + SB intercropping
* SC = Sugar cane, **SB = Sugar beet

RESULTS AND DISCUSSION

Germination %

The analysis of two years pooled data of sugar cane germination percentage is presented in Table .1. Data revealed that interactive effect of planting geometries and intercropping was highly significant. The highest sugar cane germination percentage (52.70) was recorded with 30/90 cm spaced paired row strips in sole sugarcane crop, which was statistically similar with all planting pattern in sole crop and 30/90 cm spaced paired row strips in intercrop. The lowest sugar cane germination percentage (50.80) was recorded with 30/120 cm spaced paired row strips in intercropping. It was also noted that 1.99, 1.10 % and 2.14 and 1.08 % higher sugar cane germination % was obtained in sole and intercrop respectively from G_2, G_1 than G_3. Our results are in agreement with the findings of Kanwar, Sharma and Sharma (1989), Malik and Ali (1990), Subasinghe, (2007) who found slightly better germination at closer spacing of 1.0 m than that at wider spacing (1.5 m). They further advocated that this negative effect in wider spacing was due to more seed per unit area. Khan *et al*. (2001) reported that crop planted at interrow spacing of 0.72 m produced maximum cane stand than wider inter row spaces of 0.90 and 1.20 m.

The increase in germination percentage in G_3-30/90 cm spaced paired row strips might be ascribed to complimentary effect of increased nutrient availability and improved air circulation and light interception, which might have resulted in increased germination percentage. Our results are also in agreement with the findings of Yadaw (1981), Verma, Motiwale & Singh, (1985), Tarvedi and Siani (1986), Malik (1993). While in case of sugar beet maximum germination percentage (58.77) was recorded in 30/90 cm spaced paired row strips in sole sugar beet which was statistically similar with same cropping pattern in intercropping. The lowest sugar beet germination percentage (54.62) was recorded in 30/120 cm spaced paired row strips in intercropping. It was also noted that 5.63, 1.78 % and 4.61 and 0.60 % higher sugar beet germination % was obtained in sole and intercrop respectively from G_2 and G_1 than G_3.

Millable canes m^{-2}

Number of millable canes per unit area is the major yield component of sugarcane. The data pertaining to number of millable canes (m^{-2}) revealed that all treatments varied significantly among each other. The analysis of two years pooled data of millable canes (m^{-2}) presented in Table 2. Data showed that interactive effect of planting geometries and intercropping was highly significant. The highest number of millable canes (12.49 m^{-2}) was recorded with 30/90 cm spaced paired row strips in sole sugarcane crop, which was statistically similar with planting pattern in intercrop sugarcane crop with 30/90 cm spaced paired row strip and with planting pattern in sole sugarcane crop with 75 cm spaced paired row strip. The lowest number of millable canes (9.81 m^{-2}) was recorded with 30/120 cm spaced paired row strips in intercropping. It was also noted that 20.68, 14.59 % and 22.22, 12.95 % higher millable canes (m^{-2}) was obtained in sole and intercrop respectively from G_1 and G_2 respectively than G_3. Our results are in agreement with the findings of Nazir *et al.* (1988) who obtained the maximum number of millable canes per unit area from the crop planted in 30/90 cm spaced double row strips and minimum from that planted in 60 cm spaced single rows.

Ricaud and Cochran (1980), El-Fattah *et al*. (1986), Singh and Yadav (1986) and Domini and Plana (1989) reported an increase in millable canes at increased row spacing up to 100 cm among various planting patterns. Higher number of millable canes per unit area at 100 cm apart rows than 120 or 140cm were reported by Malik and Ali (1990) and El-Geddawy, Darweish, Sherbing and Eldin (2002). Whereas Singh, Lal and Prasad (2006); Saggu, Ahmad, Himayat ullah, Ayaz, Ahmad & Aslam (2010); Rehman. Ali, Iqbal, Qamar, Afghan and Majid (2014) reported significantly higher number of millable canes at 45 cm spacing followed by 60 cm and 75 cm in ratoon crop. Mathur, (1972), Akhtar et al. (2000) and Ali et al. (2000) have reported an increase in the number of millable canes m^{-2} at higher dose of NPK. The optimum number of millable canes (m^{-2}) in G_2-30/90 treatment might be ascribed to complimentary effect of increased nutrient availability and improved air circulation and light interception which resulted in reduced shoot mortality and better cane growth. Increase in nitrogen level more than 200 kg ha^{-1} showed no significant increase in number of millable canes (m^{-2}). The effect of different planting patterns on millable canes m^{-2} was highly significant.

Stripped cane yield t ha^{-1}

The analysis of two years pooled data of stripped cane yield are presented in Table 3.Data revealed that interactive effect of planting geometries and intercropping was highly significant. The highest cane yield (156.1 t ha^{-1}) was recorded with 30/90 cm spaced paired row strips in sole sugarcane while stirpcane yield (147.4 t ha^{-1}) in intercropping which was statistically at per with planting pattern in sole sugarcane crop with 75 cm spaced paired row strip. The lowest cane yield (121.7 t ha^{-1}) was recorded with 30/120 cm spaced paired row strip in intercropping. It was also noted that18.35, 9.48% and 21.12, 12.33 % higher stripped cane yield was obtained in sole and intercrop respectively from G_2 and G_1 respectively than G_3. Our results are in agreement with the findings of Broadhead and Ashley (1969), Romas (1975), Dixit and Saroj (1976), Kanwar et al. (1990) and El-Geddawy et al. (2002) reported that crop planted at interrow spacing of 0.72m produced maximum stripped cane yield than wider inter row spaces of 0.90 and 1.20 m, Paul et al. (2008) reported that with the residual effect of NPK applied to intercrop cane yield enhanced from 6 to 8% Alam et al. (2009).

Sugar beet yield t ha^{-1}

The analysis of two years pooled data of sugar beet yield t ha^{-1} as presented in Table 3 revealed that interactive effect of planting geometries and intercropping was highly significant. The highest (76.67 t ha^{-1}) beet yield was recorded with 30/90 cm spaced paired row strips with sole beet crop which was statistically at per with planting pattern in intercropping sugarcane crop with 30/90 cm spaced paired row strip and with planting pattern in sole sugarcane crop with 75 cm spaced paired row strip.. The lowest beet yield was noted with 30/120 cm spaced paired row strip in intercropping. It was also noted that 26.02, 18.47 % and 29.23 and 14.69 % higher beet yield was obtained in sole and intercrop respectively from G_2 and G_1 respectively than G_3. Our results are also with agreement of Naik et al. (2008).

Sugar recovery %

Although the quality components of sugarcane are mainly genetic characters, they are also influenced by various agronomic practices like crop nutrition and planting geometry.

The analysis of two years pooled data of sugar cane recovery % presented in Table 4. Data revealed that interactive effect of planting geometries and intercropping was highly significant. The highest sugar cane recovery (9.83%) was recorded with 30/120 cm spaced paired row strips in sole sugarcane followed by (9.69 %) in intercropping of sugarcane-sugar beet were found statistically at per with each other. The lowest sugar cane recovery (8.77 %) was recorded with planting pattern in intercrop sugarcane crop with 75 cm spaced paired row strip. It was also noted that 11.42, 10.08 % and 10.49, 3.88 % higher sugar cane recovery % was obtained in sole and intercrop respectively from G_3 and G_2 respectively than G_1.

The maximum sugar recovery percentage was recorded in 30/120 cm spaced paired row strip planting pattern followed by 30/90 cm and 75 cm. Sugar recovery percentage was minimum at 60 cm spaced single row planting pattern. The increase in sugar recovery percentage with increase in inter strip spacing might be due to improved light interception and air circulation which enhanced photosynthetic activity and resulted in increased SR%. These results are in line with those of Singh and Singh (1984), Mahmood. (1988), Kathirisan and Narayanasmy (1991), who reported that sugarcane grown in widely spaced rows, had higher sucrose contents than that grown in narrow spaced rows. On the contrary, Vains *et al.* (2000) and Singh *et al.* (2006) reported that sucrose contents in cane juice were not significantly affected by different spatial arrangements and plantation methods. Such differential impact of row spacing on sucrose content might be due to different climatic and soil conditions under which the various experiments were conducted.

Total sugar yield t ha^{-1}

Total sugar yield t ha^{-1} is an important economical parameter for sugarcane and sugar beet crop. Sugar yield (t ha^{-1}) is the interactive effect of stripped cane yield t ha^{-1} and sugar recovery percentage. Analysis of two years pooled data of sugarcane and sugar beet total sugar yield t ha^{-1} of sole and intercropped crop are presented in Table 5. Planting geometries and intercropping affected the sugarcane and sugar beet sugar yield t ha^{-1}of both either in sole cultivation or intercropping. Data revealed that sugarcane and sugar beet total sugar yield t ha^{-1} was significantly affected by different planting geometries and intercropping in both cropping systems. The means regarding intercropping also depicted that total sugar yield t ha^{-1} significantly increased in intercrop as compared to sole crop. Maximum total sugar yield (15.79 t ha^{-1}) was observed with 30/90 cm spaced paired row strips in intercropping. Minimum total sugar yield (8.87 t ha^{-1}) was harvested in 75 cm spaced paired row strips in sole sugar beet, followed by sole sugar beet (9.20 t ha^{-1}) with 30/90 cm spaced paired row strips. Next to this sole sugar beet produced (10.06 t ha^{-1}) total sugar yield with 30/90 cm spaced paired row strips.

Sugarcane BCR

The analysis of two years pooled data of sugar cane BCR as presented in Table 6. Data revealed that interactive effect of planting geometries and intercropping was highly significant. The highest sugar cane BCR (5.09 %) was recorded with 30/90 cm spaced paired row strips in intercrop sugarcane while G_1 in intercropped sugarcane (4.67%) followed by G_3 with inter crop sugarcane (4.00%). The lowest sugar cane BCR (3.42%) was recorded in G_3 with sole crop followed by (3.73%) in G_1 with sole sugarcane. It was also noted that 18.12, 9.35 % and 23.50, 13.00 % higher sugar cane BCR was obtained in intercrop and sole respectively from G_2 and G_1 respectively than G_3. Our results are in agreement with the findings of Rehman et al. (2014).

Sugar beet BCR

The analysis of two years pooled data of sugar beet BCR are also presented in Table 6. Data revealed that interactive effect of planting geometries and intercropping was highly significant. The highest sugar beet BCR (5.09 %) was recorded with 30/90 cm spaced paired row strips in intercrop sugar beet while G_1 in intercropped sugar beet (4.67%) followed by G_3 with inter crop sugar beet (4.00%) . The lowest sugar beet BCR (2.61%) was recorded in G_3 with sole crop followed by (2.76%) in G1 with sole sugar beet. It was also noted that 25.72, 18.12 % and 23.50, 13.00 % higher beet BCR was obtained in sole and intercrop respectively from G_2 and G_1 respectively than G_3. Our results are in agreement with the findings of Rehman *et al*. (2014). Who also reported an increase in sugar cane germination % with planting geometries? It was further noted that higher BCR at 30/90 cm spaced paired row planting pattern might be due to the improved air circulation and light interception which improved photosynthetic efficiency.

CONCLUSIONS

It can be concluded that under arid condition in silt clay soils optimum stripped cane yield could be obtained at the interaction of sole sugarcane x 30/90 cm spaced paired row strip planting pattern. The plating pattern of 30/90 cm paired row strip planting had advantages over other planting patterns, thus conserving irrigation water and saving almost 50% labor and time required for earthing up, allows efficient and expeditious intercultural earthing up with tractor or bullock-drawn implements, permit systematic planting handling of intercrops without effecting the associate cane crop, moreover, planting of the main and intercrops in separate and independent strips not only reduces intercrop competition, but also enables the growers to meet the varying fertilizer requirements, facilitates easy application of herbicide since the strips or well-spaced, prevents lodging in cause of wind or rain since the strips provide the plant support to each other, improve the air circulation and light penetration which enhances photosynthetic efficiency of plants.

TABLE 1: Pooled average data of 2009-10 and 2010-11, germination percentage of autumn sugarcane & sugar beet influenced by Planting Patterns (G) & intercropping on silty clay soils.

Crops	Planting Patterns (G)	Planting Patterns (G) and intercropping		
		Sole crop	Intercrop	Means
Sugarcane	G1-75 cm	52.24ab	51.35bc	51.79ab
	G2-30/90 cm	52.70a	51.89a-c	52.30a
	G3-30/120 cm	51.67a-c	50.80c	51.24b
	Means	52.20	51.35	
Sugarbeet	G1-75 cm	56.63bc	54.95cd	55.79b
	G2-30/90 cm	58.77a	57.14ab	57.95a
	G3-30/120 cm	55.64b-d	54.62d	55.13b
	Means	57.01	55.57	

→	Sugarcane	Sugar beet
LSD $_{0.05}$ Planting Patterns (G)	0.7996	1.261
LSD $_{0.05}$ Planting Patterns x Intercropping	1.131	1.783
CV (%)	1.45%	2.10%

Means in the same column do not differ significantly at 5% level of probability

TABLE 2: Pooled average data of 2009-10 and 2010-11 regarding millable canes $m^{-2}$of autumn sugarcane and beet per m^{-2} influenced by Planting Patterns (G) & intercropping on silty clay soils

Crops	Planting Patterns (G)	Planting Patterns (G) and intercropping		
		Sole crop	Intercrop	Means
Sugarcane	G1-75 cm	11.86ab	11.08bc	11.47b
	G2-30/90 cm	12.49a	11.99a	12.24a
	G3-30/120 cm	10.35cd	9.81d	10.08c
	Means	11.57	10.96	
Sugar beet	G1-75 cm	3.93bc	3.83cd	3.88b
	G2-30/90 cm	4.15a	4.06ab	4.10a
	G3-30/120 cm	3.08de	3.61e	3.66c
	Means	3.93	3.83	

→	Sugarcane	Sugar beet
LSD $_{0.05}$ Planting Patterns (G)	0.6205	0.3192
LSD $_{0.05}$ Planting Patterns x Intercropping	0.8775	0.5221
CV (%)	5.87%	2.73%

Mean in the respective category do not differ significantly at 5% level of Probability according to LSD test

TABLE 3: Pooled average data of 2009-10 and 2010-11 regarding stripped cane yield t ha^{-1} of autumn sugarcane and sugar beet yield t ha^{-1} influenced by Planting Patterns (G) & intercropping.

Crops	Planting Patterns (G)	Planting Patterns (G) and intercropping		
		Sole crop	Intercrop	Means
Sugarcane	G1-75 cm	144.4b	136.7c	140.6b
	G2-30/90 cm	156.1a	147.4b	151.7a
	G3-30/120 cm	131.9c	121.7d	126.8c
	Means	144.13	135.27	
Sugar beet	G1-75 cm	68.35b	64.74b	56.54b
	G2-30/90 cm	75.85a	72.94a	74.39a
	G3-30/120 cm	60.11c	57.83c	58.97c
	Means	68.10	65.17	

→	Sugarcane	Sugar beet
$LSD_{0.05}$ Planting Patterns (G)	4.792	2.894
$LSD_{0.05}$ Planting Patterns x Intercropping	6.777	4.093
CV (%)	3.22%	4.08%

Means in the same column do not differ significantly at 5% level of probability

TABLE 4: Pooled average data of 2009-10 and 2010-11 regarding sugar cane recovery % of autumn sugarcane and sugar beet recovery % influenced by Planting Patterns (G) and intercropping on silty clay soils of D.I.Khan under arid conditions.

Crops	Planting Patterns (G)	Planting Patterns (G) and intercropping		
		Sole crop	Intercrop	Means
Sugarcane	G1-75 cm	8.93cd	8.77b	8.85c
	G2-30/90 cm	9.26b	9.11bc	9.17b
	G3-30/120 cm	9.83a	9.69a	9.76a
	Means	9.34	9.19	
Sugar beet	G1-75 cm	12.38c	12.28c	12.33c
	G2-30/90 cm	13.11b	13.03b	13.07b
	G3-30/120 cm	13.75a	13.64a	13.69a
	Means	13.08	12.99	

→	Sugarcane	Sugar beet
$LSD_{0.05}$ Planting Patterns (G)	0.2261	0.3370
$LSD_{0.05}$ Planting Patterns x Intercropping	0.3197	0.4072
CV (%)	2.30%	2.42%

Means in the same column do not differ significantly at 5% level of probability

TABLE 5: Pooled average data of 2009-10 and 2010-11 regarding total sugar yield and beet sugar yield t ha^{-1} influenced by Planting Patterns (G) and intercropping on silty clay soils of D.I.Khan under arid conditions.

Crops	Planting Patterns (G)	Planting Patterns (G) and intercropping			
		Sole sugarcane	Sole sugar beet	Intercropping	Means
Sugarcane + Sugarbeet	G1-75 cm	12.91e	8.87 g	19.91 b	13.90 b
	G2-30/90 cm	14.43d	10.06 f	22.90 a	15.79 a
	G3-30/120 cm	13.01e	9.20 fg	18.70 c	13.63 b
	Means	13.45 b	9.37 c	20.50 a	

	Sugarcane + sugar beet
LSD $_{0.05}$ Planting Patterns (G)	0.6439
LSD $_{0.05}$ Intercropping (I)	0.6439
LSD $_{0.05}$ Planting Patterns (G) **x** Intercropping	1.115
CV %	5.29%

TABLE6. Pooled average data of 2009-10 and 2010-11 sugar cane BCR and beet BCR influenced by Planting Patterns (G) and intercropping on silty clay soils of D.I.Khan under arid conditions.

Crops	Planting Patterns (G)	Planting Patterns (G) and intercropping	
		Sole crop	Intercrop
Sugarcane	G1-75 cm	1	1.86
	G2-30/90 cm	1	1.90
	G3-30/120 cm	1	1.73
	Means	1	1.83

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