Pak. J. Agri. Sci., Vol. 48(1), 25-33; 2011
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

INFLUENCE OF ZINC AND IRON ON YIELD AND QUALITY OF SUGARCANE PLANTED UNDER VARIOUS TRENCH SPACINGS

Abdul Ghaffar[1,*], Ehsanullah[1], Nadeem Akbar[1] and Sultan Habibullah Khan[2]

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan; [2]Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad, Pakistan
[*]Corresponding author's e.mail: abdulghaffaruaf@gmail.com

A field trial was conducted for two years to evaluate the effect of different trench spacings and doses of Zinc (Zn) and Iron (Fe) on yield and quality of sugarcane. The treatments comprised of three trench spacing at 75, 90 and 120 cm and three foliar applications of Zn+Fe @ 2.5+5, 5+10 and 7.5+15 Kg ha^{-1}, along with a check. Different trench spacing and levels of zinc and iron significantly affected the yield and all the quality parameters of sugarcane crop except cane juice purity. Crop planted at 120 cm spaced trenches produced the maximum yield of stripped cane in both years. Sub plot treatment with applied Zn+Fe @ 5.0+10 Kg ha^{-1} gave the maximum stripped cane yield of 106.4 & 110.4 t ha^{-1} during 2007-08 and 2008-09, respectively. The higher sucrose contents (18.61%) were obtained with foliar application of 5.0+10 Kg ha^{-1} of Zn+Fe, while 90 cm and 120 cm apart trenches gave similar sucrose contents but the higher than 75 cm apart trenches. The maximum sugar yield of 14.97 t ha^{-1} was obtained from crop grown at 120 cm spaced trenches. Foliar application of zinc and iron @ 5+10 kg ha^{-1} provided higher sugar yield of 15.25 t ha^{-1}. On the basis of two years study, it is recommended that sugarcane crop should be planted at 120 cm spaced trenches fertilized @ 5+10 kg ha^{-1} of Zn+Fe for better yield and quality production.
Keywords: trench spacing, zinc, iron, sugarcane, quality, sucrose contents, sugar yield

INTRODUCTION

Sugarcane is a major cash crop of Pakistan which not only provides the main stay to sugar industry but is also used as a raw material in many allied industries for alcohol and chip board manufacturing. It is a source of employment directly or indirectly to more than four million peoples of Pakistan. It plays a very important role in agro-industrial economy of Pakistan. The reasons for low cane and sugar production include conventional method of planting, poor management practices and imbalanced nutrient management resulting in poor plant population, lodging, dwarf and thin canes and poor recovery percentage. Therefore, it is imperative to develop such planting techniques and practices which may help in maintaining appropriate plant population to facilitate light capture, air circulation, water saving and cultural operations.

Sugarcane is conventionally planted at 60-75 cm spaced single rows which hinders various management practices necessary for good crop husbandry and hence, restrict the yield to a considerable extent (Chattha *et al*., 2004). On the other hand, trench planting is considered more suitable and proficient planting system that saves irrigation water and reduces lodging due to easy inter-culture and earthing up operations (Malik *et al*., 1996). Increase in yield with planting cane at one meter spaced trenches was reported by Sarwar *et al*. (1996). They also reported that canes of better juice quality were produced in wider than narrow trench spacings. An intra-row spacing of 90 cm produced more dry matter and cane yield over intra-row spacing 30 and 60 cm but quality parameters remained similar with different row spacings (Raskar and Bhoi, 2005). Mahmood *et al*. (2007) found that sucrose contents lowered in case of 100 cm spaced triple-row ditch planting against the maximum in 90 cm spaced double-row strips. Purity coefficient did not exhibit significant differences due to row spacing and seeding rates (Tej *et al*., 2006). Ali *et al*. (2001) recorded non significant differences in commercial cane sugar at different spatial arrangements and planting methods. Higher sugar yields were observed in narrow row planting as compared to wider row spacing, probably due to more stripped cane yield at narrower row space (Khan *et al*., 2004).

The second reason for low yield and poor quality of sugarcane is the imbalanced application of fertilizers. Continuous cropping with high yielding cultivars, monocropping and less attention to integrated nutrient management result in depletion of organic matter leading to micronutrient deficiencies (Rakkiyappan and Thangavelu, 2000). Many researchers have reviewed zinc deficiency in the soils of Pakistan (Hadi *et al*., 1997). High pH soils exhibit iron deficiency and create a problem for growers of low-rainfall areas. Pakistani soils are high in pH which results antagonistic interaction of Zn and Fe with other nutrients and, hence, Zn and Fe availability to plants is less.

Sugarcane cultivar LCP 85-384 was found sensitive to zinc deficiency and addition of zinc in calcareous soils increased the cane yield up to 24.8% over the control (Wang *et al*., 2005). High values for millable canes, cane height and per cane weight as well as brix, pol and purity were observed with the application of zinc sulphate and manganese sulphate (Tomer and Malik, 2004). Juice quality parameters were improved with the application of sulfur and zinc over recommended NPK (Bokhtiar and Sakurai, 2005). Rakkiyappan *et al*. (2002) reported an increase in chlorophyll content, cane yield and sucrose content with foliar applied iron sulphate as compared to soil application. This increase could be due to the presence of high quantity of calcium carbonate content in the soil, and quick recovery from chlorosis with foliar application. Sucrose percent, purity percent and sugar yield were increased with the interactive effect of Zn, Fe and their sources (Dhanasekaran and Bhuvaneswari, 2004). The present study was therefore undertaken to find out the suitable trench spacing and optimum dose of Zn and Fe for maximum yield and quality production of sugarcane.

MATERIALS AND METHODS

***Plant material and growing conditions*:** Sugarcane cultivar HSF-240 was grown in an irrigated field experiment conducted for two consecutive years. Physico-chemical analysis of experimental soil was conducted before sowing and after harvest of the crop during the both years of study. The soil analysis indicated that the experimental soil was a loam with slight alkaline reaction. The soil seemed to be productive without any problem for crop husbandry. It was medium in K_2O (107-131 ppm), marginal in zinc (0.81-1.19 ppm) and iron (3.06-3.65 ppm); but deficient in N (0.035-0.051%), P_2O_5 (6.1-8.9 ppm) and organic matter (0.62-0.98%).

The field was prepared uniformly during the both years. Each year before seedbed preparation, land was leveled with the help of laser land leveler. Chisel ploughing was done once. Pre soaking irrigation of 10 cm was applied. Once the soil reached the proper moisture level, the seedbed was prepared by cultivating the land with tractor mounted cultivator to a depth of 10-12 cm followed by planking. The treatments comprised of three trench spacings (75, 90 and 120 cm apart) and three foliar applications of Zn+Fe @ 2.5+5, 5+10 and 7.5+15 Kg ha^{-1}, along with a check. Trenches were made by ridger. Seed rate of 75,000 double budded setts per hectare was used and it was adjusted according to the width of the trenches. Fertilizers were applied at the rate of 175, 115 and 115 kg ha^{-1} N, P_2O_5 and K_2O, respectively. All of phosphorous, potash and half of the nitrogen were applied in trenches at the time of sowing in the form of SSP (Single Super Phosphate), SOP (Sulphate of Potash) and Urea, respectively. Remaining half of nitrogen was applied in two installments at the start of tillering and before earthing up. The foliar spray of 1/3 dose of Zn and Fe was applied 50 days after sowing and the remaining 2/3 was applied in two equal installments with 20 days interval after the 1st spray. The sources of Zn and Fe were Zn $SO_4.H_2O$ (35% Zn) and Fe $SO_4.7H_2O$ (19% Fe), respectively. Earthing up of sugarcane was done 90 days after planting. The plots were arranged according to split plot arrangement in RCBD with four replications, where the main plots corresponded to trench spacing. Net plot size was 4.5 m x 8.0 m for 75 cm and 90 cm spaced trenches while 4.8 m x 8.0 m for 120 cm spaced trenches. Sixteen irrigations (1600 mm) were applied to crop during each year of experiment in addition to 339 and 583 mm rainfall received during 2007-08 and 2008-09, respectively. Meteorological data for growing periods of the crop were collected from the Observatory, Pakistan Agriculture Research Council (PARC) unit, Ayub Agriculture Research Institute, Faisalabad, Pakistan as depicted in Figure 1.

The yield and quality parameters were recorded as described below:

***Stripped cane yield*:** All stripped canes from two trenches in each experimental unit were weighed and converted to tons per hectare.

***Quality parameters*:** Ten canes randomly selected from every plot were crushed using a cane crusher and the juice was collected in glass jars. With the help of polarimeter, pol reading of extracted juice of every treatment was recorded. Sucrose content in cane juice was calculated with the help of Schmitz's table (Spancer and Meade, 1963).

Cane juice purity was determined as described by Spancer and Meade (1963) as under:

$$\text{Cane juice purity (\%)} = \frac{\text{Pol (\%) juice}}{°\text{Brix juice}} \times 100$$

Commercial cane sugar (CCS %) was calculated by using the method of Spancer and Meade (1963) as under:

$$\text{CCS (\%)} = \frac{3}{2}P\left(1-\frac{F+5}{100}\right)-\frac{1}{2}B\left(1-\frac{F+3}{100}\right)$$

Where, P= Pol (%) in juice; B= °Brix in juice, F= Fiber (%) in juice (12.5%).

Cane sugar recovery percent (CSR %) was calculated by following formula:

$$\text{CSR (\%)} = \text{CCS(\%)} \times 0.94$$

Where, CCS is commercial cane sugar, and 0.94 is net titer (sugar losses).

Sugar yield (t ha^{-1}) was determined by the following formula:

$$\text{Sugar yield (t ha}^{-1}\text{)} = \frac{\text{Stripped cane yield}\left(\text{t ha}^{-1}\right) \times \text{CCS (\%)}}{100}$$

***Statistical analysis*:** Data collected from both experiments were statistically analyzed by MSTATC and differences among the treatment means were compared for significance using the Duncan's New Multiple Range Test (DNMRT) at 5% probability (Steel *et al*., 1997). The significance of regression (γ) was tested against tabulated values given by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

***Stripped cane yield*:** Stripped cane yield was more during 2008-09 than 2007-08. It was mainly attributed to more number of millable canes and higher stripped cane weight during 2008-09 than 2007-08. The yield differences between the years might be due to daily variation in the maximum and the minimum temperature resulting in different micro-climate across the season, and secondly due to more rainfall during the year 2008-09 as compared to 2007-08 (Fig. 1). Such environmental variations across the year promoted growth parameters during the later year which ultimately gave higher stripped cane yield.

During the both years 120 cm spaced trenches produced more stripped cane yield than 90 and 75 cm apart trenches (Table 1). The Higher stripped cane yield at 120 cm spaced trench planting might be attributed to higher values of yield contributing parameters like cane length, cane weight and cane diameter. These results are in line with Bashir *et al*. (2005) who reported that a row spacing of 120 cm was found optimum for higher stripped cane yields. Cheema *et al*. (2002) and Raskar and Bhoi (2003) also observed that cane yield was significantly higher in 90 cm spaced trenches compared with 60 cm row spacing.

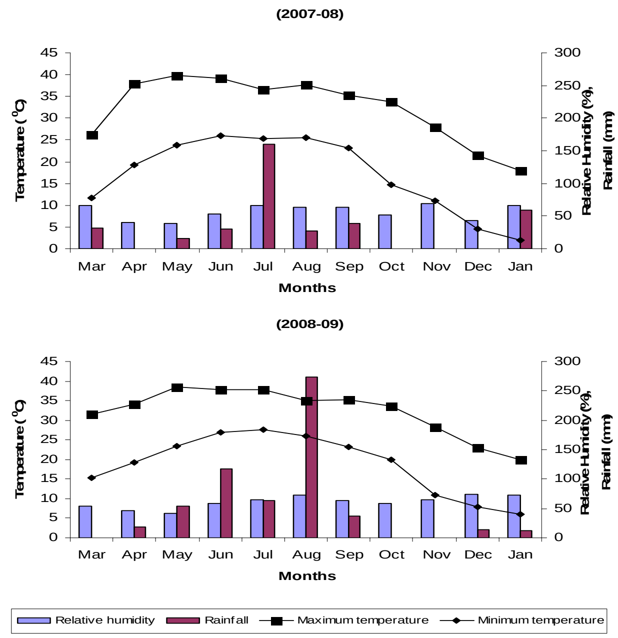

Figure 1. Meteorological data of experimental site

The stripped cane yield increased in quadratic manner with increasing level of Zn+Fe during the both experimental years (Table 1). F_2 treatment (5+10 kg Zn+Fe ha^{-1}) gave maximum stripped cane yield in all the trench spacings. The minimum stripped cane yield was noted in F_3 level (7.5+15 kg Zn+Fe ha^{-1}) that was almost similar to unfertilized plots. Significant increase in stripped cane yield up to an optimal level of zinc and iron has already been reported by Aslam *et al*. (2004) and Balaji *et al*. (2006). The decrease in stripped cane yield with higher level of zinc and iron may be due to their toxic effect at higher concentration. Nayyer *et al*. (1989) reported that all the yield contributing traits like tillers, plant height, cane length and per cane weight are positively affected by the application of Zn and Fe sources; they also observed that application of these elements beyond certain levels adversely affected the yield components of the crop.

***Sucrose contents*:** The data presented in Table 1 showed that year effect on sucrose contents was highly significant and more sucrose contents of 19.01% were measured during 2007-08 than the later year producing sucrose content of 17.61%. This huge difference in sucrose content might be due to climatic changes, as high rainfall was noted during the growth period of the crop during 2008-09 (Fig. 1) that resulted in high water contents in the cane juice and lesser sucrose content.

Table 1. Effect of different trench spacing and levels of zinc and iron on stripped cane yield, sucrose contents and cane juice purity of sugarcane

Treatments	Stripped cane yield (t ha^{-1})			Sucrose contents (%)			Cane juice purity (%)		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Trench spacing									
75 cm spaced trenches	87.82 b	94.40 c	91.11	18.91	17.32 b	18.11	87.51	86.47	86.99
90 cm spaced trenches	98.01 ab	101.95 b	99.98	19.11	17.72 a	18.42	88.48	86.06	87.27
120 cm spaced trenches	104.57 a	112.78 a	108.68	19.00	17.81 a	18.40	86.55	86.25	86.40
Standard error 5%	3.44	2.01	1.99	0.128	0.110	0.084	0.436	0.138	0.229
Significance	*	**	**	NS	*	*	NS	NS	NS
Linear	*	**		NS	*		NS	NS	
Quadratic	NS	NS		NS	NS		NS		
Zn+Fe									
Check	90.87 b	99.35 b	95.11	18.80 b	17.28 b	18.04	86.55 b	86.23	86.39
2.5+5 kg ha^{-1}	96.73 ab	104.11 ab	100.42	19.01 b	17.75 ab	18.38	87.15 b	86.53	86.84
5.0+10 kg ha^{-1}	106.38 a	110.38 a	108.38	19.30 a	17.93 a	18.61	89.04 a	86.69	87.86
7.5+15 kg ha^{-1}	93.22 b	98.33 b	95.78	18.93 b	17.49 ab	18.21	87.32 b	85.58	86.45
Standard error 5%	3.64	3.11	2.39	0.089	0.158	0.91	0.460	0.353	0.292
Significance	*	*	**	**	*	**	**	NS	**
Linear	NS	NS		NS	NS		NS	NS	
Quadratic	*	*		**	**		*	NS	
Cubic	NS	NS		NS	NS		NS	NS	
Interactions	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Year mean	**96.80 b**	**103.04 a**		**19.01 a**	**17.61 b**		**87.51**	**86.26**	
Significance 5%	*			**			**		
Standard error	1.63			0.069			0.187		

Sucrose content of cane juice was not affected significantly by different trench spacing during 1st year, but was significantly affected during 2008-09. In the later year, sucrose content decreased with decrease in trench spacing and maximum sucrose content (17.81%) was noted in 120 cm spaced trenches that was statistically similar with 90 cm spaced trenches (17.72%). The minimum sucrose content (17.32%) was noted in 75 cm spaced trenches. The results are in agreement with Kathirisan and Narayanasamy (1991) who reported that sugarcane planted in 80 cm spaced rows produced more sucrose than in 60 cm spaced rows.

Different fertilizer levels significantly affected the sucrose contents for quadratic trend during both the years (Table 1). In 2007-08, the maximum sucrose content (19.30%) was produced with the application of 5+10 kg Zn+Fe ha^{-1} followed by treatment F_1 (2.5+5 kg Zn+Fe ha^{-1}) producing sucrose content of 19.01%. The minimum sucrose content (18.80%) was noted in unfertilized plots that were at par with application of 5+10 kg Zn+Fe ha^{-1} producing 18.93% sucrose content. Similar results were observed during 2008-09. On contrary, foliar spray of 0.5% iron and zinc (Pawar *et al*., 2003), and soil applied zinc and iron (Sharma *et al*., 2002) showed non significant response to sucrose content. Interactive effect of different trench spacing and fertilizer levels was found to be statistically similar.

***Cane juice purity*:** The purity of juice refers to the proportion of sucrose to total solids in the cane juice and is expressed as percentage. The high quality sugarcane should be of high juice purity with a smaller proportion of solids other than sucrose, moderate fiber, high milling quality and sucrose content. Data showed that year effect on cane juice purity was highly significant and more juice purity (87.51%) was measured during 2007-08 than in the 2nd year producing juice purity of 86.26% (Table 1). This difference in cane juice purity might be due to environmental differences (339 mm rainfall during 2007-08 and 583 mm during 2008-09) during the growth period of the crop during both years (Fig. 1).

Spacing factor was non-significant during both the years. In different trench spacing, percent purity ranged from 86.55-88.48% and 86.06-86.47% during 2007-08 and 2008-09, respectively. As such, purity coefficient did not exhibit significant differences for varied row spacing and seeding rates (Tej *et al*., 2006). Whereas, Kathirisan and Narayanasamy (1991) observed that sugarcane planted in 80 cm spaced rows gave more cane juice purity (85.64%) than in 60 cm spaced rows.

Purity of cane juice was not affected significantly by different nutrient levels in the 2nd year, but was significantly affected for quadratic trend during the earlier year (Table 2). During 2007-08, maximum juice purity (89.04%) was produced by the plots fertilized @ 5+10 kg Zn+Fe ha^{-1}. Minimum purity (86.55%) was noted in untreated plots that was at par with treatment F_1 (2.5+5 kg Zn+Fe ha^{-1}) and treatment F_3 (7.5+15 kg Zn+Fe ha^{-1}) producing juice purity of 87.15% and 87.32%, respectively. Dhanasekaran and Bhuvaneswari (2004) also noticed that zinc and iron either alone or in combination significantly increased percent purity of cane juice. However, Sharma *et al*. (2002) reported non significant effect of zinc application on purity co-efficient of cane juice. The interactive effect between different trench spacing and levels of zinc and iron on cane juice purity was found to be statistically non-significant during both the experimental years.

***Commercial cane sugar*:** The real cane quality is reflected by its commercial cane sugar (CCS) percentage. Data (Table 2) revealed that year effect on CCS percentage was highly significant and more CCS (14.34%) was measured during 2007-08 than the later year producing CCS of 13.17%. This difference in CCS might be due to environmental differences during both the years of study (Fig. 1).

CCS percentage was not affected significantly by different trench spacing in earlier year; but was significantly affected during 2008-09 with linear trend. During 2008-09, percent CCS increased with increase in trench spacing and maximum CCS (13.31%) was noted in 120 cm spaced trenches that were statistically similar with 90 cm spaced trenches providing CCS of 13.23%. The minimum CCS (12.96%) was noted in 75 cm spaced trenches. Khan *et al*. (2004) also recorded maximum CCS of 12.73% with crop planted at wider inter row spacing than narrow row space, producing 11.52% CCS. On the other hand, Malik *et al*. (1996) and Vains *et al*. (2000) reported non-significant differences in commercial cane sugar at different spatial arrangements and planting methods.

Different Zn+Fe levels significantly affected the percent CCS for quadratic response during both the years (Table 2). Application of 5+10 kg Zn+Fe ha^{-1} produced maximum CCS of 14.72% and 13.45% during 2007-08 and 2008-09, respectively. Whereas, the minimum CCS of 14.08% and 12.92%, was noted in unfertilized plots that was also at par with F_3 treatment (7.5+15 kg Zn+Fe ha^{-1}) producing 14.26% and 13.01% CCS in 2007-08 and 2008-09, respectively. The significant response of different nutrient levels to CCS% might be due to their significant effects on sucrose contents

Table 2. Effect of different trench spacing and levels of zinc and iron on commercial cane sugar, cane sugar recovery percentage and total sugar yield of sugarcane

Treatment	Commercial cane sugar (%)			Cane sugar recovery (%)			Total sugar yield (t ha^{-1})		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Trench spacing									
75 cm spaced trenches	14.27	12.96 b	13.62	13.41	12.19 b	12.80	12.54 b	12.26 c	12.40 c
90 cm spaced trenches	14.52	13.23 a	13.88	13.65	12.44 a	13.04	14.26 ab	13.49 b	13.87 b
120 cm spaced trenches	14.24	13.31 a	13.77	13.36	12.51 a	12.94	14.92 a	15.02 a	14.97 a
Standard error 5%	0.135	0.075	0.077	0.138	0.070	0.077	0.583	0.296	0.327
Significance	NS	*	NS	NS	*	NS	*	**	**
Linear	NS	*		NS	*		*	**	
Quadratic	NS	NS		NS	NS		NS	NS	
Zn+Fe									
Check	14.08 b	12.92 c	13.50	13.24 b	12.14 c	12.69	12.80 b	12.85 b	12.83 c
2.5+5 kg ha^{-1}	14.30 b	13.30 ab	13.80	13.45 b	12.50 ab	12.97	13.86 b	13.86 ab	13.86 b
5.0+10 kg ha^{-1}	14.72 a	13.45 a	14.08	13.84 a	12.64 a	13.24	15.65 a	14.84 a	15.25 a
7.5+15 kg ha^{-1}	14.26 b	13.01 bc	13.64	13.37 b	12.23 bc	12.80	13.32 b	12.80 b	13.06 bc
Standard error 5%	0.103	0.102	0.072	0.096	0.095	0.068	0.543	0.404	0.338
Significance	**	**	**	**	**	**	**	**	**
Linear	NS	NS		NS	NS		NS	NS	
Quadratic	**	**		**	**		**	**	
Cubic	NS	NS		NS	NS		NS	NS	
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Year mean	**14.34 a**	**13.17 b**		**13.48 a**	**12.38 b**		**13.91**	**13.59**	
Significance 5%	**			**			NS		
Standard error	0.063			0.063			1.76		

(Table 1). In line with our results, Pawar *et al*. (2003) found significant increase in CCS% with foliar application of phosphorus and 0.5% zinc and iron as compared to control. According to Wang *et al*. (2005) and Sharma *et al*. (2002), commercial cane sugar was not altered significantly with zinc application. Combined effect of both the factors was found to be statistically non-significant during both the study years.

***Cane sugar recovery percent*: ** Cane sugar recovery (CSR) percent is an indicator of cane quality and depends upon genetic make up of cane cultivars and climatic conditions. The data expressed in Table 2 showed that year effect on percent CSR was highly significant and more CSR (13.48%) was measured during 2007-08 than the later year producing CSR of 12.38%. This large difference in CSR might be due to environmental changes, as high rainfall and relative humidity was received during the growth period of the crop in 2008-09 (Fig. 1) that resulted in high water contents in the cane juice and lesser sucrose content that ultimately resulted in less recovery percentage.

Trench spacing significantly affected percent CSR for linear trend in the year 2008-09, but did not significantly affect percent CSR in 2007-08 (Table 2). During 2008-09, maximum CSR (12.51%) was recorded in 120 cm spaced trenches and was at par with 90 cm spaced trenches providing 12.44% CSR. The minimum CSR (12.19%) was noted in 75 cm spaced trenches. These results are in contrary with those of Murayama *et al*. (1990) who reported non-significant differences in sucrose contents by planting sugarcane either at wider or narrow row spacing.

Different Zn+Fe levels significantly affected the percent CSR for quadratic response during both the years of study (Table 2). Application of 5+10 kg Zn+Fe ha^{-1} produced highest CSR of 13.84% and 12.64% during 2007-08 and 2008-09, respectively. The lowest CSR of 13.24% was recorded in control plots and was at par with the application of 7.5+15 kg Zn+Fe ha^{-1} and 2.5+5 kg Zn+Fe ha^{-1} producing CSR of 13.37% and 13.45%, respectively, in 2007-08. During 2008-09, the minimum CSR (12.14%) was noted in unfertilized plots that was at par with the application of 7.5+15 kg Zn+Fe ha^{-1} providing 12.23% CSR. In line with our results, percent sugar recovery of the cane juice also increased with the application of zinc as reported by Gawad *et al*. (1992). The interactive effect of different levels of Zn+Fe and trench spacing was found to be statistically non-significant during both the years of study.

***Total sugar yield*: ** The total sugar yield (t ha^{-1}) is the interactive effect of stripped cane yield (t ha^{-1}) and CCS %. The data presented in Table 2 revealed that the year effect on total sugar yield was non-significant. The mean total sugar yield was 13.91 t ha^{-1} and 13.59 t ha^{-1} in 2007-08 and 2008-09, respectively.

Averaged over years, trench spacings had highly significant effect on total sugar yield. The crop planted at 120 cm spaced trenches gave significantly more total sugar yield (14.97 t ha^{-1}) and was followed by 90 cm spaced trenches producing total sugar yield of 13.87 t ha^{-1}, whereas, the minimum total sugar yield (12.40 t ha^{-1}) was recorded in 75 cm spaced trenches. The increasing trend of total sugar yield with increase in trench spacing was also justified with the findings of Durai *et al*. (1989) who reported that significantly higher sugar yield was recorded at wider row spacing as compared with narrow row spacing. In contrary, higher sugar yields were observed in narrow row planting than at wider row spacing, probably due to more stripped cane yield at narrow row space (Khan *et al*., 2004).

Nutrient factor was highly significant for quadratic effect during both the years. Averaged over years, maximum total sugar yield (15.25 t ha^{-1}) was recorded with the application of 5+10 kg Zn+Fe ha^{-1} followed by treatment F_1 (2.5+5 kg Zn+Fe ha^{-1}) that produced total sugar yield of 13.86 t ha^{-1}. The minimum total sugar yield (12.83 t ha^{-1}) was measured in unfertilized crop plots that was statistically similar with total sugar yield of 13.06 t ha^{-1} recorded with application of 7.5+15 kg Zn+Fe ha^{-1}. Significant differences in sugar yield at different zinc and iron levels observed in the present study may be due to different stripped cane yield and CCS% (Table 2). Sugar yield differences under different zinc and iron levels were also reported by Dhanasekaran and Bhuvaneswari (2004), Chandra (2005) and Wang *et al*. (2005). However, according to Sharma *et al*. (2002) sugar yield was not altered with the application of zinc.

The combined effect of both factors on total sugar yield was statistically similar during both years of experiment. Regression model indicated the dependence of sugar yield on stripped cane yield during both years (Fig. 2).

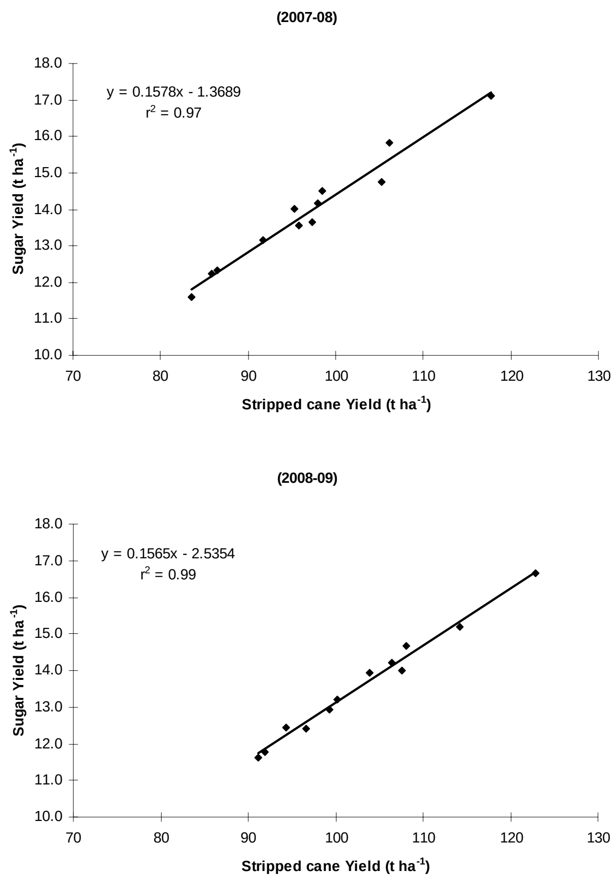

Figure 2. Relation between sugar yield and stripped cane yield of sugarcane

REFERENCES

Ali, F.G., M. Akhtar, M. Saeed and S. Afghan. 2001. Effect of planting methods and weed management on cane quality and quality parameters in spring cane. Pak. Sug. J. 16:15-17.

Aslam, M., Z. Ali and A.A. Chattha. 2004. Effect of soil applied micronutrients on the growth and yield of sugarcane. Pak. Sug. J. 19:32-34.

Balaji, T., S. Mani, A. Saravanan and T.N. Rao. 2006. Balanced fertilization for maximising the yield of sugarcane in Periyar Vaigai Command area. Ind. Sug. 56:43-50.

Bashir, S., A. Ali and M. Yasin. 2005. Sugarcane varieties and row spacing effect on sugarcane traits. Pak. Sug. J. 20:18-20.

Chandra, K. 2005. Response of foliar application of zinc sulphate, muriate of potash and potassium nitrate on growth, yield and quality of sugarcane ratoon under rainfed situation. Ind. Sug. 55:41-44.

Chattha, A.A., M. Afzal and M.U. Chattha. 2004. Sustainable cultivation of sugarcane for revival of sugar industry in Pakistan. Proc. 39th Ann. Convent., Pak. Soc. Sug. Technol. p.36-49.

Cheema, I.A., M. Ayub and A. Jabbar. 2002. Bio economic efficiency of spring planted sugarcane as influenced by spatial arrangement and nutrient management. Pak. Sug. J. 17:62-68.

Dhanasekaran, K. and R. Bhuvaneswari. 2004. Effect of zinc and iron humates application on the yield and quality of sugarcane. Ind. Sug. 53:907-912.

Durai, R., S.N. Ahmed, B.J. Pandian and S. Rajasekaran. 1989. Studies on the effect of spatial variations on yield and quality of sugarcane in plant and ratoon crops. Bharatiya Sug. 14:37-39.

Gawad, A.A.A.E., N.A.N.E. Din, I.H.E. Geddawi and N.B. Azazy. 1992. Effect of nitrogen and zinc application on growth criteria of sugarcane plant. Pak. Sug. J. 6: 3-10.

Hadi, A., S.A. Taran, A. Azeem, Z. Saeed and A. Aslam. 1997. Wheat response to zinc application in rice growing area of Balochistan. Pak. J. Soil Sci. 13:25-27.

Kathirisan, G. and R. Narayanasamy. 1991. Fixing the spacing, seed rate and nitrogen levels for COC 8201, sugarcane cultivar. Ind. Sug. 41:241-242.

Khan, M.Z., S. Bashir and M.A. Bajwa. 2004. Performance of promising sugarcane varieties in response of inter-row spacings towards stripped cane and sugar yield. Pak. Sug. J. 19:15-18.

Mahmood, A., M. Ishfaq, J. Iqbal and M.S. Nazir. 2007. Agronomic practices and juice quality of autumn planted sugarcane (*Saccharum officinarum* L.) as affected by flat, ditch and pit planting under different spatial arrangements. Int. J. Agric. Biol. 9:167-169.

Malik, K.B., F.G. Ali and A. Khaliq. 1996. Effect of plant population and row spacing on cane yield of spring-planted cane. J. Agric. Res. 34:389-395.

Murayama, S., S.M.M. Uddin, A. Nose and Y. Kawawitsu. 1990. Effect of agronomical practices on sugarcane yield. Sci. Bull. College Agri., Uni., Ryukyus, Okinawa, Japan 37:1-6.

Nayyer, V.K., S.P. Singh and P.N. Takkar. 1989. Response of sugarcane to zinc and iron sources. J. Res. Punjab Agric. Univ. 21:134-136.

Pawar, M.W., S.S. Joshi and V.T. Amodkar. 2003. Effect of foliar application of phosphorus and micronutrients on enzyme activities and juice quality in sugarcane. Sug. Technol. 5:161-165.

Rakkiyappan P., S. Thangavelu and R. Radhamani. 2002. Effect of ferrous sulphate on sugarcane varieties grown in iron deficient soil. Sug. Technol. 4:33-37.

Rakkiyappan, P. and S. Thangavelu. 2000. Effect of iron on ratoon crops of six sugarcane varieties grown in iron deficient soil. Proc. Int. Conf. on Manag. Natural Resources for Sustainable Agric. held on Feb. 14-18, 2000, New Delhi, India. p.266-268.

Raskar, B.S. and P.G. Bhoi. 2003. Response of sugarcane to planting materials, intra-row spacings and fertilizer levels under drip irrigation. Ind. Sug. 53:685-690.

Raskar, B.S. and P.G. Bhoi. 2005. Dry matter accumulation and yield performance of pre-seasonal sugarcane Co 86032 with intra-row spacings, fertilizer levels and planting materials. J. Maharashtra Agric. Univ. 30:150-153.

Sarwar, M., M.A. Gill and K.B. Malik. 1996. Comparison of pit and trench planting of sugarcane at different fertilizer levels. Pak. Sug. J. 10:11-13.

Sharma, B.L., A.K. Mishra, P.K. Singh, R.R. Singh and S.B. Singh. 2002. Micronutrient fertilization on sugarcane; effect of zinc and boron in calcareous soil. Ind. Sug. 52:439-443.

Snedecor, G.W. and W.G. Cochran. 1989. Statistical Methods, 8th Ed. Iowa State Univ. Press, Iowa, USA. p. 473.

Spancer, G.L. and G.P. Meade. 1963. Cane sugar handbook, 9th Ed. G.P. Meade. John Wiley and Sons, Inc. New York. p.17.

Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principles and Procedures of Statistics-A Biometrical Approach, 3rd ed. McGraw Hill Book Int. Co., Singapore. p. 204-227.

Tej, P., R. Singh and P.P. Singh. 2006. Studies on the effect of row spacing, seed rate and fertility levels on growth and yield of sugarcane (*Saccharum officinarum* L.). Ind. Sug. 56:29-34.

Thomas, J.R., F.G. Salinas and L.N. Namken. 1977. Growth and yield of sugarcane as affected by row spacing. Int. Sugar J. 83:302.

Vains, S.N., R. Ahmad, A. Jabbar, T. Mahmood and A. Ahmad. 2000. Biological traits of autumn sugarcane as influenced by spatial arrangement and plantation method. Pak. Sug. J. 15:15-19.

Wang, J.J., C.W. Kennedy, H.P. Viator, A.E. Arceneaux and A.J. Guidry. 2005. Zinc fertilization of sugarcane in acid and calcareous soils. J. Amer. Soc. Sugarcane Technol. 25:49-61.