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Effect of trench spacing and micronutrients on growth and yield of sugarcane (*Saccharum officinarum* L.)

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Abstract

Conventional planting methods, poor management practices and imbalanced use of nutrients are the major constraints responsible for low cane and sugar yield of sugarcane. A field trial was conducted during spring 2007-08 and 2008-09 to evaluate the effect of different trench spacing and doses of Zn and Fe on production of sugarcane. The treatments comprised; trench spacing (75, 90 and 120 cm apart) and foliar application of Zn+Fe @ 2.5+5, 5+10 and 7.5+15 kg ha^{-1}, along with a check. Different trench spacings and levels of Zn and Fe significantly affected the quantitative parameters of sugarcane including number of internodes, cane diameter and stripped cane weight. Higher crop growth rate of 11.87 and 11.74 g m^{-2} d^{-1} was recorded in 120 cm spaced trenches and with foliar application of 5.0+10 kg ha^{-1} of Zn+Fe. Crop planted at 120 cm spaced trenches produced maximum yield of stripped cane 104.6 and 112.8 t ha^{-1}; while application of Zn+Fe @ 5.0+10 kg ha^{-1} gave stripped cane yield of 106.4 and 110.4 t ha^{-1} in 2007-2008 and 2008-2009, respectively. Maximum net return of USD 1048 and USD 1511 was obtained from crop grown at 120 cm spaced trenches with foliar application of zinc and iron @ 5+10 kg ha^{-1} during both the years under study. In conclusion, sugarcane crop can be planted at 120 cm spaced trenches and fertilized with 5+10 kg ha^{-1} of Zn+Fe for enhanced yield and higher economic returns.

Keywords: Cost of production, Growth, Iron, *Saccharum officinarum*, Trench spacing, Yield, Zinc.
Abbreviations: Zn-Zinc; Fe-Iron; g-Gram; m-Meter; d-Day; kg-Kilogram; ha-Hectare; t-Ton; USD-US dollar; GoP-Government of Pakistan; HSF-Habeeb Sugar Faisalabad; $ZnSO_4$-Zinc sulphate; $FeSO_4$-Iron sulphate, MCGR-Mean crop growth rate.

Introduction

Sugarcane (*Saccharum officinarum* L.) is the major cash crop of Pakistan after cotton and rice which not only provides main stay to sugar industries but also raw material to many allied industries for alcohol and chip board manufacturing and a source of employment directly or indirectly to more than four million peoples of Pakistan (GoP, 2009; Akbar et al., 2011). It is grown on an area of 1.03 m ha in the country with average stripped cane yield of 48.63 t ha^{-1} (GoP, 2009) which is very low than the average stripped cane yield in other sugarcane producing countries like India (64.49 t ha^{-1}), China (68.08 t ha^{-1}), USA (77.63 t ha^{-1}), Brazil (78.85 t ha^{-1}) and Australia (80.39 t ha^{-1}) (FAO Stat., 2009). The major causes for low yield at farmer's field are conventional planting method, drought, poor management practices and imbalanced nutrient management, which result in less plant population, lodging, dwarf and thin canes and poor recovery percentage (Ehsanullah et al., 2007; Ali et al., 2009; Ehsanullah et al., 2011). Therefore, it is imperative to develop such planting techniques and practices which may help in maintaining proper plant population, facilitating light penetration, air circulation, water saving and inter-tillage operations (Hussain et al., 2008, 2010). Different planting techniques have been advocated for yield enhancement in sugarcane. Sugarcane is conventionally planted in 60-75 cm spaced single rows which may result increased plant population per unit area but hinders various management practices necessary for good crop husbandry and hence, restricting the yield to a considerable extent (Ehsanullah et al., 2011). Trench planting may be convenient and efficient planting system in saving irrigation water and reducing lodging due to easiness in inter-culture and earthing-up operations (Malik et al., 1996). Cane lodging importantly reduces the crop yields. New sugarcane varieties possess a yield potential of above 100 tons ha^{-1} which can be realized by avoiding the crop lodging. This can be achieved by placing the sets 40-50 cm deeper trenches in the soil. Trench planting plays an important role in establishing the plant population and cane yield. Planting cane at one meter spaced trenches increased the yield and juice quality than narrow trench spacing (Sarwar et al., 1996). The tillers, plant height, millable canes and stripped yield of cane produced by 90 and 120 cm spaced trenches were similar but higher than 60 cm apart trenches, 45 and 60 cm spaced furrows (Chattha et al., 2007). 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 were similar with different row spacings (Raskar and Bhoi, 2005). Whereas, Olivier and Singels (2003) found an increase of 25% in yield with decrease in row spacing from 150 cm to 90 cm, but, Garside et al. (2002) observed smaller increase in yield of sugarcane crop by reducing row spacing. Planting sugarcane under wider trenches with recommended seed rate gave higher economic returns than conventional method of planting (Bhullar et al., 2008; Ehsanullah et al., 2011). Continuous cropping with high yielding cultivars, monocropping and less attention on integrated nutrient management has resulted in depletion of organic matter leading to micronutrient deficiencies (Rakkiyappan and Thangavelu, 2000). In line with major or macro plant nutrients, micronutrients are also important in plant growth and development, although required in low concentrations (Alam, 1999; Jabran et al., 2011). Rashid and Rafique (1998) reported zinc deficiency as the third most severe crop nutrition disorder in the country after nitrogen (N) and phosphorus (P). High pH soils exhibit iron (Fe) deficiency and create a problem for growers of low-rainfall areas. Soils with pH (greater than 8.0) show better response to $FeSO_4.7H_2O$ than the soils with low pH (Hergert et al., 1996). Foliar application of micronutrients has many advantages such as less application rate, even distribution of nutrients and immediate response of plant to applied material (Jabran et al., 2011). Foliar application of zinc sulphate at 0.5 % increased cane yield (Chandra, 2005). High values for millable canes, cane height and per cane weight were recorded with the application of zinc sulphate and manganese sulphate (Tomer and Malik, 2004). 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). Rakkiyappan et al. (2002) stated that chlorophyll content, cane yield and sucrose content were increased by the foliar applied $FeSO_4$ as compared to soil application possibly due to the presence of high quantity of calcium carbonate content in the soil, and quick recovery from chlorosis with foliar application. Ghaffar et al. (2011) reported that application of micronutrients like Zn and Fe in addition to NPK fertilizers was necessary to obtain maximum benefits from sugarcane crop. Hence the present research was planned to evaluate the effect of different trench spacing and various rates of foliar applied zinc and iron on growth, yield economic gains of sugarcane.

Results and Discussion

Number of millable canes

Year effect on number of milable canes m^{-2} at final harvest was non-significant (Table 1). The data regarding number of millable canes revealed that trench spacing effect was non-significant during both the years. Average number of millable canes ranged from 12.0 to 12.65 m^{-2}. These results are in agreement with those of Cheema et al. (2002) who reported that number of millable canes was not affected by different row spacings. Micronutrients (Zn+Fe) application had non significant effect on number of millable canes m^{-2} because these nutrients were applied after 50, 70 and 90 days after sowing and had no effect on germination and tillering. Non-significant effect on number of millable canes was also reported with the application of Zn, Fe and B by Siddiqi et al. (2006). The interactive effect of trench spacing and nutrient levels on number of millable canes was also found to be non-significant. Dependence of stripped cane yield on number of

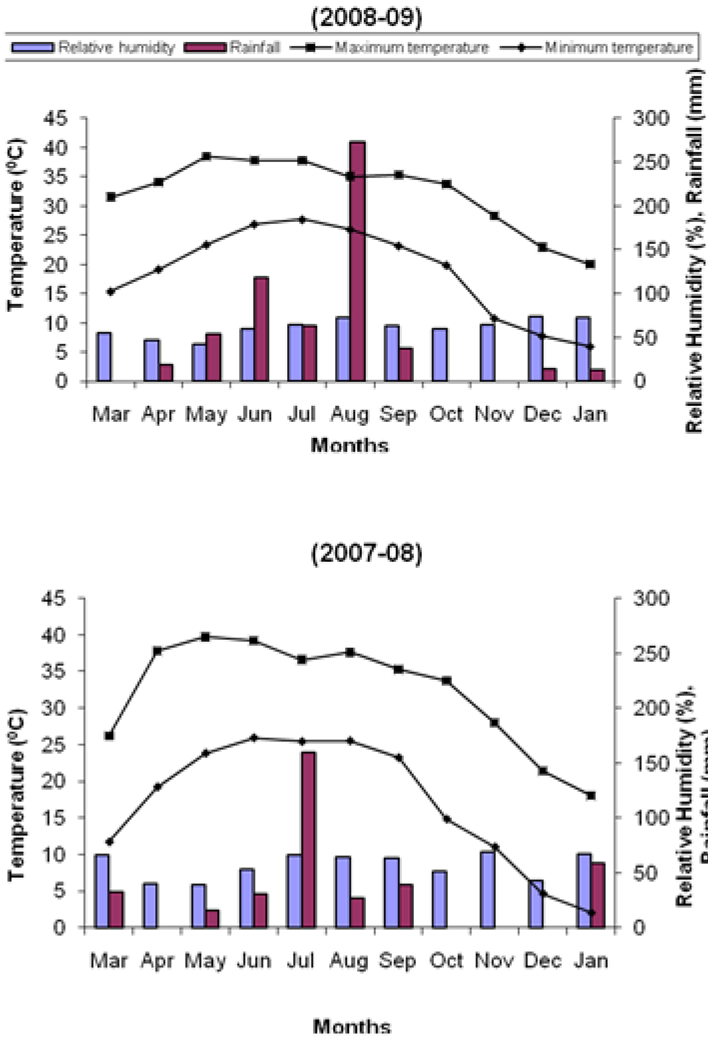

Fig 1. Meteorological data of experimental site.

millable canes was also indicated by regression line that was significant during both the years (Fig. 2).

Crop growth rate

Year effect on mean crop growth rate (MCGR) was highly significant. The data presented in Table 1 exhibited that during both years the spacing factor was found to be significant for linear effect. In the year 2007-08, there was 17.52% change in MCGR from S_1 (75 cm spaced trenches) to S_3 (120 cm spaced trenches) level. During 2008-09, MCGR was increased 10.47% from S_1 to S_3 level. Different crop growth rate in sugarcane grown at different trench spacings was ascribed to variable magnitude of total dry matter per unit area. This might be due to higher values of leaf area index in wider trenches that resulted more leaves expansion for light interception and ultimately gave higher values of CGR. Similarly, by increasing spacing, a 20% increase in per plant growth rate of sugarcane was reported by Pammenter and Allison (2002). Foliar application of nutrients was found to be significant for quadratic effect during 2007-08; and for quadratic and cubic effect during 2008-09 (Table 1). In the earlier year, there was 11.6% increase in MCGR from F_0 (Check) to F_2 (5+10 kg Zn+Fe ha^{-1}) level, but it suddenly

Table 1. Effect of different trench spacing and levels of zinc and iron on number of millable canes, mean crop growth rate and cane length of sugarcane

Treatment	Number of millable canes m^{-2}			Mean crop growth rate ($g\ m^{-2}\ d^{-1}$)			Cane length (cm)		
	2007-08	2008-09	Mean	2007-08	2008-09	Mean	2007-08	2008-09	Mean
Trench spacing									
75 cm spaced trenches	11.88	12.13	12.00	10.10 c	12.22 b	11.16	188.6 b	192.7 b	190.7 b
90 cm spaced trenches	12.03	12.48	12.25	10.87 b	12.61 b	11.74	199.4 ab	204.9 b	202.2 b
120 cm spaced trenches	12.66	12.63	12.65	11.87 a	13.50 a	12.68	217.6 a	228.8 a	223.2 a
Standard error 5%	0.572	0.358	0.337	0.129	0.119	0.088	6.41	4.82	4.01
Significance	NS	NS	NS	**	**	**	**	*	**
Linear	NS	NS		**	**		*	*	
Quadratic	NS	NS		NS	NS		NS	NS	
Zn+Fe									
Check	12.14	12.00	12.07	10.52 b	12.42 c	11.47	192.9 b	202.2 b	197.5 c
2.5+5 kg ha^{-1}	12.19	12.40	12.30	10.99 b	12.86 b	11.93	202.8 b	210.2 ab	206.5 b
5.0+10 kg ha^{-1}	12.33	12.98	12.65	11.74 a	13.42 a	12.58	215.1 a	220.1 a	217.6 a
7.5+15 kg ha^{-1}	12.09	12.27	12.18	10.53 b	12.39 c	11.46	196.8 b	202.8 b	199.8 bc
Standard error 5%	0.613	0.475	0.388	0.203	0.044	0.104	4.24	3.76	2.83
Significance	NS	NS	NS	**	**	**	**	**	**
Linear	NS	NS		NS	NS		NS	NS	
Quadratic	NS	NS		**	**		**	**	
Cubic	NS	NS		NS	**		NS	NS	
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year mean	12.19	12.41		10.95 b	12.77 a		201.9	208.8	
Significance 5%	NS			**			NS		
Standard error	0.277			0.072			3.27		

decreased in the crop plots fertilized @ 7.5+15 kg Zn+Fe ha^{-1} becoming at par with control plots. Almost similar results were observed during 2008-09; but the change in MCGR was 8.05% from F_0 to F_2 level. Alam (1999) and Jabran et al. (2011) reported that micronutrients required in small quantities are essential in plant growth and development like major plant nutrients. The interactive effect of different trench spacing and different doses of zinc and iron on mean crop growth rate was found to be statistically non-significant during both the experimental years.

Cane length

Data regarding cane length (Table 1) indicated that trench spacing had significant effect on cane length for linear response during both the years, while the year effect was non-significant. Trench spacing of 120 cm produced maximum cane length of 223.2 cm. Crop planted at 90 cm spaced trenches gave 202.2 cm taller canes which were statistically similar to 75 cm spaced trenches giving cane length of 190.7 cm. More cane length at wider trenches may be attributed to more light interception that resulted in increased crop growth rate (Table 1). Cheema et al. (2002) reported an increase in cane height in wider rows than narrow row spacing while non-significant differences in cane length under various planting systems were observed by Ehsanullah et al. (2011). The response of zinc and iron application at different levels was highly significant for quadratic effect during both the years (Table 1). Averaged over years, maximum cane length (217.6 cm) was given by 5+10 kg Zn+Fe ha^{-1} and this was followed by the crop fertilized @ 2.5+5 kg Zn+Fe ha^{-1} that produced 206.5 cm cane length. Minimum cane length of 197.5 cm was recorded in unfertilized plots which was at par with the plots treated with highest level of Zn+Fe producing cane length of 199.8 cm. Increase in cane length up to a certain level might be attributed to availability of balanced nutrients, which accelerated the crop growth rate (Table 1) resulting in more internodal length that finally produced longer canes. Soomro et al. (2005) recorded significant increase in cane length with the application of zinc; they reported cane length of 145.4 cm with the application of 1.50 kg Zn ha^{-1}. Linear relationship between cane length and stripped cane yield was indicated by regression analysis during both the years (Fig 3).

Weight per stripped cane

The data (Table 2) revealed that the year effect on weight per stripped cane was non-significant. Averaged over years, the crop sown in 120 cm spaced trenches resulted significantly more weight per stripped cane (0.90 kg) and was followed by 90 cm spaced trenches producing canes of 0.83 kg that was statistically similar with 75 cm spaced trenches producing stripped cane weight of 0.77 kg. More stripped cane weight in 120 cm trench spacing was due to more cane length and diameter (Table 1) in the particular spacing. The linear increase in weight per stripped cane with increase in trench spacing was also justified by the findings of Ehsanullah et al. (2011) and Cheema et al. (2002); they reported significantly heavier canes in 90 and 120 cm spacing than 60 cm spacing. Fertilizer response was highly significant for pooled data (Table 2), and maximum weight per stripped cane (0.89 kg) was recorded in the plots fertilized with 5+10 kg Zn+Fe ha^{-1} that was at par with the application of 2.5+5 kg Zn+Fe ha^{-1} producing stripped cane weight of 0.85 kg. Minimum stripped cane weight (0.79 kg) was measured in F_3 level (7.5+15 kg Zn+Fe ha^{-1}) that was statistically similar with

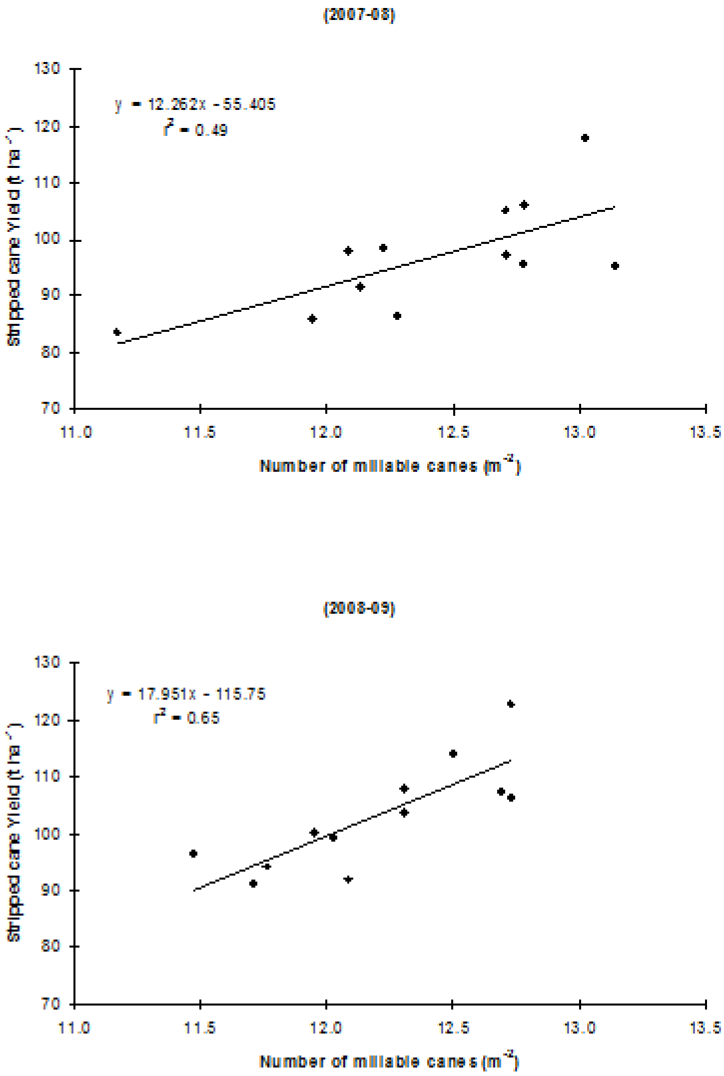

Fig 2. Relation between number of millable canes and stripped cane yield of sugarcane.

stripped cane weight of 0.80 kg produced by F_0 treatment. This gain in weight per stripped cane may be attributed to role of zinc and iron as co-factor or activator of enzymes involved in physiological processes of plants, and better utilization of applied macronutrients that increased leaf area duration and CGR. Tomer and Malik (2004) recorded increase in stripped cane weight with the application of zinc sulphate and manganese sulphate. The interactive effect between trench spacing and fertilizer levels was found to be statistically non-significant. Weight per stripped cane and stripped cane yield were linearly related and the regression accounted for 92% and 89% of the variation during 2007-08 and 2008-09, respectively (Fig. 4).

Stripped cane yield

Year effect on stripped cane yield was significant (Table 2) and stripped cane yield was 6.45% more during 2008-09 (103.04 t ha^{-1}) than 2007-08 (96.80 t ha^{-1}) that might be due to favorable climatic conditions during 2nd year of study (Fig. 1). This was mainly attributed to more number of millable

Table 2. Effect of different trench spacing and levels of zinc and iron on stripped cane weight, stripped cane yield and unstripped cane yield of sugarcane

Treatment	Weight per stripped cane (kg)			Stripped cane yield (t ha^{-1})			Unstripped cane 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	0.74 b	0.80 b	0.77 b	87.82 b	94.40 c	91.11	106.08 b	118.37 c	112.22
90 cm spaced trenches	0.81 ab	0.85 ab	0.83 b	98.01 ab	101.95 b	99.98	119.36 a	127.07 b	123.21
120 cm spaced trenches	0.89 a	0.91 a	0.90 a	104.57 a	112.78 a	108.68	126.54 a	141.69 a	134.12
Standard error 5%	0.032	0.024	0.020	3.44	2.01	1.99	3.77	2.08	2.151
Significance	*	*	**	*	**	**	*	**	**
Linear	**	*		*	**		**	**	
Quadratic	NS	NS		NS	NS		NS	NS	
Zn+Fe									
Check	0.78 b	0.82 b	0.80 b	90.87 b	99.35 b	95.11	110.46 b	124.82 b	117.64
2.5+5 kg ha^{-1}	0.83 ab	0.86 ab	0.85 a	96.73 ab	104.11 ab	100.42	118.22 ab	129.98 ab	124.10
5.0+10 kg ha^{-1}	0.87 a	0.91 a	0.89 a	106.38 a	110.38 a	108.38	126.87 a	137.08 a	131.97
7.5+15 kg ha^{-1}	0.77 b	0.81 b	0.79 b	93.22 b	98.33 b	95.78	113.76 b	124.30 b	119.03
Standard error 5%	0.022	0.027	0.017	3.64	3.11	2.39	4.30	3.12	2.66
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	0.81	0.85		96.80 b	103.04 a		117.33 b	129.05 a	
Significance 5%	NS			*			**		
Standard error	0.016			1.63			1.76		

canes (1.80%) and higher stripped cane weight (4.94%) during 2008-09 than 2007-08. The yield differences between the years might be ascribed to daily variation in maximum and 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. Differences in stripped cane yield for different trench spacings were significant for linear effect during both the years. In 2007-08, the maximum stripped cane yield (104.57 t ha^{-1}) was produced by 120 cm spaced trenches which was at par with 90 cm spaced trenches that had stripped cane yield of 98.01 t ha^{-1}. Minimum stripped cane yield of 87.82 t ha^{-1} was recorded in 75 cm spaced trenches. The change in stripped cane yield from S_1 (75 cm spaced trenches) to S_3 level (120 cm spaced trenches) was 19.07%, while during 2008-09, 19.47% increase in stripped cane yield was noted from S_1 (75 cm spaced trenches) to S_3 (120 cm spaced trenches). Higher stripped cane yield at 120 cm spaced trench planting might be attributed to higher values of yield contributing parameters like cane length (Table 1) and cane weight (Table 2). These results are in line with Ghaffar et al. (2011) who reported that a row spacing of 120 cm was found optimum for higher stripped cane yields. Cheema et al. (2002) also observed that cane yield was significantly higher in 90 cm spaced trenches compared with 60 cm row spacing. Zinc and Fe levels had significant effect on stripped cane yield (t ha^{-1}) for quadratic trend during both the years (Table 2). During 2008-09, the maximum stripped cane yield of 110.38 t ha^{-1} was produced by F_2 treatment (5+10 kg Zn+Fe ha^{-1}) and was at par with treatment F_1 (2.5+5 kg Zn+Fe ha^{-1}) giving stripped cane yield of 104.11 t ha^{-1}. Minimum stripped cane yield (98.33 t ha^{-1}) was noted in F_3 level (7.5+15 kg Zn+Fe ha^{-1}) that was statistically similar to unfertilized plots producing 99.35 t ha^{-1} stripped cane yield. Treated plots @ 5+10 kg Zn+Fe ha^{-1} increased 11.1% in stripped cane yield over control in 2008-09, whereas during 2007-08, 17.07% increase in stripped cane yield was observed from F_0 to F_2 level. Significant increase in stripped cane yield up to an optimal level of zinc and iron has already been reported by Ghaffar et al. (2011) 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 as described by Nayyer et al. (1989) who 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. Interactive effect of different trench spacing and levels of zinc and iron was found to be statistically non-significant during both the years of study.

Unstripped cane yield

Year effect on un-stripped cane yield was highly significant (Table 2) and 9.99% higher un-stripped cane yield (129.05 t ha^{-1}) was recorded during 2008-09 than 2007-08 (117.33 t ha^{-1}). Spacing factor was highly significant for linear effect during both the growing periods. In 2007-08, wider spaced sugarcane at 120 cm apart trenches produced 19.29% higher un-stripped cane yield as compared with 75 cm spaced trenches. While during 2008-09, change in un-stripped cane yield was noted up to 19.7% from S_1 (75 cm spaced) to S_3 (120 cm spaced) level. Higher biomass production was associated with higher crop growth rate (Table 1) as

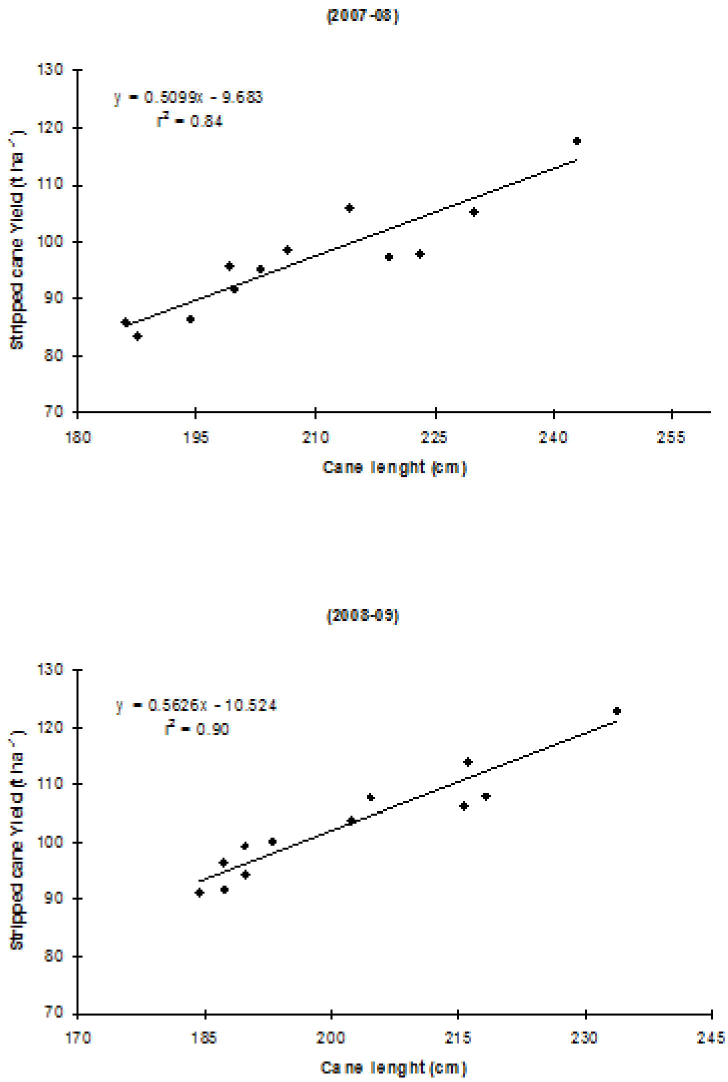

Fig 3. Relation between cane length and stripped cane yield of sugarcane.

described by Khaliq et al. (2009) that total dry matter depends upon crop growth rate. The results are confirmed by the findings of Cheema et al. (2002) who reported maximum biomass production in wider spacing as compared with 60 cm spacing. Different levels of zinc and iron were significant for quadratic effect during both the years (Table 2). There was 14.86% increase in un-stripped cane yield from F_0 (unfertilized plots) to F_2 (5+10 kg Zn+Fe ha^{-1}) level during 2007-08. Whereas in 2008-09, 9.82% increase in un-stripped cane yield was observed from F_0 to F_2 level. Almost similar results were reported by Siddiqi et al. (2006) who observed an increase in total biomass production of main crop up to 7.79% with the application of 25 kg Zn SO_4 + 13.6 kg borax + 215 kg gypsum ha^{-1}, over control. The interactive effect between trench spacing and Zn+Fe levels on un-stripped cane yield was found to be statistically non-significant during both the years.

Net returns

The variability in net returns is more important than variability in crop yields (Jabran et al., 2008). During 2008-

Table 3. Effect of different trench spacing and levels of zinc and iron on net return of sugarcane.

Treatment	Gross income (Rs ha^{-1})		Variable cost (Rs ha^{-1})		Total cost (Rs ha^{-1})		Net return (Rs ha^{-1})	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
S_1F_0 = Check, at 75 cm apart trenches	2165	2625	385	420	1804	1839	361	786
S_1F_1 = 2.5+5 kg ha^{-1} Zn+Fe, at 75 cm apart trenches	2242	2714	423	459	1843	1878	399	836
S_1F_2 = 5+10 kg ha^{-1} Zn+Fe, at 75 cm apart trenches	2469	2885	480	503	1899	1922	570	963
S_1F_3 = 7.5+15 kg ha^{-1} Zn+Fe, at 75 cm apart trenches	2225	2646	453	481	1872	1900	353	746
S_2F_0 = Check, at 90 cm apart trenches	2375	2857	422	457	1841	1876	534	981
S_2F_1 = 2.5+5 kg ha^{-1} Zn+Fe, at 90 cm apart trenches	2551	2990	478	503	1897	1922	653	1068
S_2F_2 = 5+10 kg ha^{-1} Zn+Fe, at 90 cm apart trenches	2749	3110	530	539	1949	1958	800	1153
S_2F_3 = 7.5+15 kg ha^{-1} Zn+Fe, at 90 cm apart trenches	2483	2782	499	503	1918	1922	565	860
S_3F_0 = Check, at 120 cm apart trenches	2523	3098	449	496	1868	1915	655	1184
S_3F_1 = 2.5+5 kg ha^{-1} Zn+Fe, at 120 cm apart trenches	2726	3287	510	551	1929	1970	798	1317
S_3F_2 = 5+10 kg ha^{-1} Zn+Fe, at 120 cm apart trenches	3051	3537	584	607	2003	2026	1048	1511
S_3F_3 = 7.5+15 kg ha^{-1} Zn+Fe, at 120 cm apart trenches	2538	3065	509	548	1928	1967	610	1098

1 USD = 86.84 Pak. Rs. Support price of stripped cane during 2007-08 = Rs. 25.9 t^{-1} ,Support price of stripped cane during 2008-09 = Rs. 28.8 t^{-1}, Harvesting, loading and transportation charges = Rs. 4.61 t^{-1} $ZnSO_4$ = Rs. 0.921 Kg^{-1} $FeSO_4$ = Rs. 0.368 Kg^{-1} Application charges = Rs. 8.64 ha^{-1}

09, higher net returns were recorded as compared with 2007-08 (Table 3) due to more stripped cane yield and support price of sugarcane during the later year. Maximum net returns of USD 1048 and USD 1511 ha^{-1} were achieved with the application of Zn+Fe @ 5+10 kg ha^{-1} on sugarcane planted at 120 cm spaced trenches during 2007-08 and 2008-09, respectively. The minimum net returns of USD 353 and USD 746 ha^{-1} were obtained in 75 cm spaced trenches where Zn+Fe were applied @ 7.5+15 kg ha^{-1}. The economic analysis of sugarcane planted under various planting methods revealed that cost of production was greater in ring pit system than conventional method of planting and deep trenches, but more net return was recorded by deep trenches than the other planting methods (Yadav et al., 1991). Ghaffar et al. (2011) reported that in micronutrient deficient soils, application of micronutrients like Mn, Zn, Cu and Fe in addition to NPK fertilizers was necessary to obtain maximum benefits from sugarcane crop. In conclusion, sugarcane crop can be planted at 120 cm spaced trenches and fertilized with 5+10 kg ha^{-1} of Zn+Fe for enhanced yield and higher economic returns.

Materials and methods

Experimental site

The study regarding trench spacing and nutrient management in spring planted sugarcane was conducted for two consecutive years during 2007-08 and 2008-09 on a loam soil at Post-graduate Agricultural Research Station, University of Agriculture, Faisalabad (31°.26' N, 73°.06' E), Pakistan. Physico-chemical analysis indicated that the experimental soil was a loam with slight alkaline reaction and deficient in Zn and Fe.

Layout and the experimental design

The experiment was laid out according to randomized complete block design with split plot arrangement using four replications. Net plot size was 4.5 m × 8.0 m for 75 cm and 90 cm spaced trenches while 4.8 m × 8.0 m for 120 cm spaced trenches. The treatments comprised; trench spacing (75, 90 and 120 cm apart) and foliar application of Zn+Fe @ 2.5+5, 5+10 and 7.5+15 Kg ha^{-1}, along with a check. Trenches were made with the help of tractor drawn ridger. The foliar spray of 1/3rd dose of Zn and Fe was done 50 days after sowing while remaining 2/3 was applied in two equal splits with 20 days interval after the 1st spray. The sources of Zn and Fe were $ZnSO_4.H_2O$ (35% Zn) and $FeSO_4.7H_2O$ (19% Fe), respectively.

Crop husbandry

Sugarcane variety HSF-240 with seed rate of 75,000 double budded setts per hectare was sown in March during 2007-08 and 2008-09. Fertilizer was applied at the rate of 175, 115 and 115 kg NPK ha^{-1}.

Data recording

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, and depicted in Fig. 1. Crop was harvested at maturity by taking an area of two trenches x 8.0 m from each plot and stripped cane yield ha^{-1} was estimated. A sub sample of ten plants at random from each

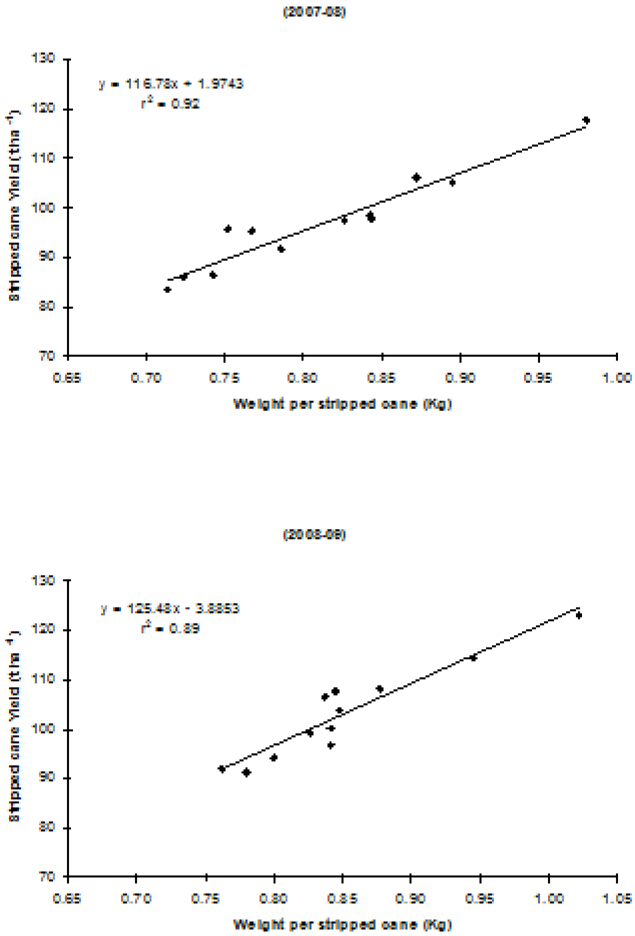

Fig 4. Relation between stripped cane weight and stripped cane yield of sugarcane.

plot was taken to determine the yield components of the crop. Crop growth rate was worked out as proposed by Hunt (1978).

$$CGR\ (g\ m^{-2}\ d^{-1}) = (W_2 - W_1) / (T_2 - T_1)$$

Where W_1 and W_2 are the total dry weights harvested at times T_1 and T_2, respectively.

Statistical analysis

The data collected were statistically analyzed using Fisher's analysis of variance technique (Steel et al., 1997) and the treatments means were compared by Duncan's Multiple Range (DMR) test at level of 0.05 probability. The significance of regression (γ) was tested against tabulated values given by Snedecor and Cochran (1989). Net returns of different treatment combinations were also determined (CIMMYT, 1988).

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