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MORPHOLOGICAL RESPONSES OF AUTUMN PLANTED SUGARCANE TO PLANTING GEOMETRY AND NUTRIENT MANAGEMENT ON DIFFERENT SOILS UNDER ARID CONDITIONS

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ABSTRACT

In a field experiment morphological response of sugarcane cultivar HSF 240 to different NPK doses like F_1 =0-0-0, F_2 =100-100-100, F_3 =150-150-100, F_4 =200-200-100 and F_5 =250-200-100 kg NPK ha^{-1} and different planting patterns like G_1 =60, G_2 =75 cm, spaced single row Planting pattern, G_3 =30/90, and G_4 =30/120cm spaced paired row strip Planting pattern were studied at the research area of the Gomal University Rukh Bibi campus Dera Ismaiel Khan and Main Line Lower Land Reclamation Research Station Chak No 37 TDA (Thal Development Authority) Bhakkar during 2003-04 and 2004-05. The experiment was laid out according to a randomized complete block design (RCBD) with a split plot arrangement in four replications giving more importance to planting patterns. The analysis of pooled data of D.I Khan and Bhakkar showed that all the NPK doses affected the yield, contributing parameters to a significant level. The maximum number of mill able canes m^{-2}, weight per stripped cane was recorded in 250-200-100 kg NPK ha^{-1} which were statistically non significant to those recorded in 200-200-100 kg NPK ha^{-1}. However maximum stripped-cane yield was recorded in 250-200-100 kg NPK ha^{-1} during both years. Among the planting patterns significantly higher mill able canes, cane weight, and stripped-cane yield were recorded in 30/90cm spaced paired row strip planting pattern followed by 75 and 60cm spaced single row planting pattern with minimum in 30/120cm spaced paired row strip planting pattern. Significantly higher mill able canes, cane weight and stripped-cane yield were recorded in the interaction of 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern which were at par with 200–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern and minimum in control x 30/120 cm spaced paired row strip planting pattern during both years. Therefore it is recommended that under arid conditions on Silt clay and sandy loam soils optimum stripped cane yield was obtained from nutrient dose of 200–200-100 kg NPK ha^{-1} and 30/90cm spaced paired row strip planting pattern.

Key words: *Saccharum officinarum L*., NPK management, planting geometry, yield components, autumn planted sugarcane, Pakistan.

INTRODUCTION

In Pakistan the average cane yield is much lower than production potential of our existing sugarcane cultivars due to improper nutrient management and planting geometry. Being a long duration crop 125 t ha^{-1} of Sugarcane removes an average 83 kg N, 37 kg P_2O_5, 168 kg K_2O (Yadava, 1991), therefore an adequate and balanced supply of all these nutrients in the effective root zone of crop is essential for obtaining sustainable cane yield. Ali and Afghan (2000) recorded the maximum number of mill able canes m^{-2}, weight per cane and stripped cane yield at 200-150-150 kg NPK ha^{-1}. On the other hand Iqbal *et al*. (2002) recorded the highest stripped-cane yield from the plots fertilized @ 200-150-0 kg NPK ha^{-1}. Moreover El-Tilib *et al*, (2004) reported that Phosphorus addition reflected a significant effect on stalk height, number of internodes and plant density of cane. Where as Shukla, (2003) reported that the highest level of nitrogen 187.5 kg ha^{-1} resulted in better tiller vigor, number and retention, besides better expression in growth parameters during both cropping seasons.

The economic yield is determined by the capability of plant to produce Photosynthates and their distribution to economically valuable plant parts. In order to realize the full benefits of the land and environmental resources, it is necessary to place the plants over the field in such a pattern that there is a least competition among them for essential growth factors. Mali and Singh (1985) recorded the maximum thickness of cane 7.48cm at 120cm spaced rows as compared to 90cm and 60cm spacing but opposite results had been reported by Fasihi *et al* (1974) that sugarcane planted in 60cm spaced rows produced a significantly greater number of mill able canes ha^{-1} than that planted either in 90cm or 120cm spaced rows Romas (1975) stated that 90cm inter-row spacing gave significantly higher cane yield than 150cm spacing. Similarly Kanwar *et al*. (1990) obtained significantly more cane yield from the crop planted in 90cm spaced rows than 60cm or 120cm spaced rows. On the other hand El-Geddawy *et al*. (2002) obtained significantly higher cane yield at a row spacing of 100cm than 120cm or 140cm spacing.

It is very important to mentioning that in past autumn planted sugarcane crop was totally neglected by research workers therefore it was considered worth with to develop concrete information on planting patterns and nutrient needs of the autumn sugarcane crop under the edaphic and agro climatic conditions of Dera Ismaiel Khan situated at (031^0 28.40 N ^{0} and 071^0 58.54 E ^{0}) with Silt clay soil in NWFP and Bhakkar situated at (031^0 36.365 N ^{0} and 071^0 9.844 E ^{0}) with sandy loam soil in Punjab.

MATERIALS AND METHODS

The studies were conducted at the research area of the Gomal University Rukh Bibi campus Dera Ismaiel Khan (D.I Khan) and Main line Lower Land Reclamation Research Station Chak No 37 TDA (Thal development authority) Bhakkar during 2003-04 and 2004-05.

Table-1 Soil analysis of both experimental sites

	DI Khan		Bhakkar	
	2003-04	2004-05	2003-04	2004-05
Soil Texture	Silt clay	Silt clay	Sandy Loam	Sandy Loam
N %	0.03	0.035	0.044	0.049
P ppm	8	8.5	3.55	4.75
K ppm	80	92.5	55	60

Analysis; by the soil and water testing laboratory, Directorate of Land reclamation Punjab; Canal Bank Mughal Pura Lahore

The NPK doses were F_1 =0-0-0, F_2 =100-100-100 kg NPK ha^{-1}, F_3 =150-150-100 kg NPK ha^{-1}, F_4 =200-200-100 kg NPK ha^{-1} and F_5 =250-200-100 kg NPK ha^{-1}. The planting patterns comprising G_1=60cm, G_2=75cm spaced single row Planting pattern, G_3=30/90cm and G_4=30/120cm spaced paired row strip planting pattern. The seed was used at the rate of 70,000 double-budded setts ha^{-1}. Cane cultivar "HSF 240" was used as test crop. The experiment was laid out in a randomized complete block design (RCBD) with a split plot arrangement keeping the NPK doses in main plots and planting patterns in sub-plots. The net plot size was 24m^2 with four replications. Each year the crop was planted during the 1st week of September and harvested during the first week of December next year. All the phosphorus, potassium and 1/4 of total N was applied at the time of seed bed preparation while remaining nitrogen was applied in two equal splits each at completion of germination and at the start of cane formation. The crop was kept free of weeds and irrigated as and when needed. All other agronomic practices were kept normal and uniform for all the treatments. The observations on number of mill able canes m^{-2}, individual stripped cane weight, and stripped-cane yield were recorded using standard procedures. The data were analyzed statistically using Fisher's analysis of variance technique and LSD test at 0.05 percent level of probability was employed to compare the differences among the treatment means (Steel and Torrie, 1984).

Table-1.1 Water received by the crop

D.I Khan		Bhakkar	
2003-04	2004-05	2003-04	2004-05
Water Received in mm			
1900	1700	2700	2700
Rainfall Received in mm			
328.00	584.00	373.23	380.24
Total number of Irrigations applied each of 100 mm			
19	17	27	27

RESULTS AND DISCUSSION

Mill able canes

The analysis of pooled data of D.I Khan and Bhakkar at mill able cane m^{-2} presented in Table-2 showed that different NPK doses significantly affected the mill able cane m^{-2}. The maximum number of mill able canes m^{-2} (13.46 and 13.58) during 2004 and 2005, respectively were recorded at 250-200-100 kg NPK ha^{-1}, (F_5) which were at par with those recorded at 200-200-100 kg NPK ha^{-1} (F_4) and minimum number of mill able canes m^{-2} (4.01 and 4.12) during 2004 and 2005, respectively were recorded in control (F_1). It was observed that 70.21, 69.74, 54.84, 42.88% and 69.66, 69.21, 54.32 and 43.48% higher number of mill able canes m^{-2} during 2003-04 and 2004-05, respectively were recorded in F_5, F_4, F_3 and F_2 respectively than control (F_1). It showed that optimum numbers of mill able canes at 200-200-100 kg NPK ha^{-1} may be due to increased nutrient availability which reduced shoot mortality and improved cane development and increase in Nitrogen level more than 200 kg ha^{-1} had no significant effect on number of mill able canes m^{-2}. Increase in NPK dose increased the number of mill able canes per unit area have been reported by Akhtar *et al*. 2000, Ali *et al*. 2000.

The effect of different planting patterns on mill able canes m^{-2} was highly significant. Maximum number of mill able canes m^{-2} (10.39 and 10.46) during 2003-04 and 2004-05, respectively in 30/90cm paired row strip Planting pattern (G_3) followed by 75cm (G_2) and 60cm single row planting pattern (G_1) and minimum (8.17 and 8.3) during 2003-04 and 2004-05, respectively in 30/120cm paired row strip Planting pattern (G_4) were recorded. It was examined that 21.37, 15.69, 9.52% and 20.65, 16.08, 10.37% higher number of mill able canes m^{-2} during 2003-04 and 2004-05, respectively were obtained in G_3, G_2, and G_1 respectively than G_4. It was also noted that too much increase in inter strip spacing as in 30/120 cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on number of mill able canes m^{-2}. Higher number of mill able canes per unit area at 100 cm apart rows than 120 or 140cm were reported by El-Geddawy *et al*. 2002.

Interactive effects of planting patterns and NPK doses on number of mill able canes were highly significant. Maximum number of mill able canes m^{-2} (11.75 and 11.77) during 2003-04 and 2004-05, respectively were recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) which were at par with 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and were minimum (3.73 and 3.77) during 2003-04 and 2004-05, respectively in control x 30/120 cm spaced paired row strip planting pattern (F_1xG_4). This increase in number of mill able canes m^{-2} may be ascribed to complimentary effect of increased nutrient availability and improved air circulation and light penetration in (F_4xG_3) which resulted in reduced shoot mortality and better cane development.

Individual stripped cane weight

The analysis of pooled data of D.I Khan and Bhakkar regarding individual stripped cane weight presented in Table-2 revealed that significantly different individual striped cane weight was recorded at different NPK doses. The highest individual stripped cane weight (0.99 and 1.03kg) during 2003-04 and 2004-05 was recorded at 250-200-100 kg NPK ha^{-1}, (F_5) but it was at par with that obtained from 200-200-100kg NPK ha^{-1}(F_4) and the lowest individual stripped cane weight (0.30 and 0.32kg) during 2003-04 and 2004-05, respectively was recorded in control (F_1). It was also observed that 69.70, 69.39, 52.38 42.31% and 68.93, 68.63, 53.62, and 42.86% higher individual stripped cane weight during 2003-04 and 2004-05 was recorded in F_5, F_4, F_3 and F_2, respectively than control F_1. It was seen that higher individual stripped cane weight at 200-200-100 kg NPK ha^{-1} may be due to increased nutrient availability which improved cane growth and development and increase in Nitrogen level more than 200 kg ha^{-1} had no significant effect on individual stripped cane weight. Ali and Afghan (2000) recorded maximum individual stripped cane weight with 200-150-150 kg NPK ha^{-1}.

The Effect of different planting patterns on individual stripped cane weight was significantly different and maximum individual stripped cane weight (0.76 and 0.80kg) during 2003-04 and 2004-05 was recorded in 30/90cm paired row strip Planting pattern (G_3) followed by 75 (G_2) and 60cm single row planting pattern (G_1) and minimum individual stripped cane weight (0.59 and 0.63kg) during 2003-04 and 2004-05, respectively was recorded in 30/120cm paired row strip Planting pattern (G_4). It was noted that 22.37, 18.06 11.94% and 21.25, 16, and 10% higher individual stripped cane weight during 2003-04 and 2004-05, was recorded in G_3, G_2, and G_1 respectively than G_4. It was further noted that higher individual cane weight at 30/90cm spaced paired row planting pattern may be due to improved air circulation and light penetration which improved photosynthetic efficiency and too much increase in inter strip spacing as in 30/120cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on individual stripped cane weight.

Interactive effects of NPK doses and planting patterns on individual stripped cane weight were significantly different. Maximum individual stripped cane weight (0.85 and 0.89kg) during 2003-04 and 2004-05, respectively was recorded in the interaction of 250–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern (F_5xG_3) which was also at par with 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and minimum individual stripped cane weight

(0.29 and 0.30kg) during 2003-04 and 2004-05, respectively was recorded in control x 30/120cm spaced paired row strip planting pattern (F_1xG_4). It was examined that increase in individual stripped cane weight in (F_4xG_3) may be ascribed to complimentary effect of increased nutrient availability and improved air circulation and light penetration in (F_4xG_3) which resulted in increased cane growth and development due to improved photosynthetic efficiency.

Stripped-cane yield

The analysis of pooled data of D.I Khan and Bhakkar in Table-2 revealed that cane yield was significantly different under different NPK doses and planting patterns. The highest stripped-cane yield of 147.81 and 149.37 t ha^{-1} during 2003-04 and 2004-05, respectively was recorded in 250-200-100 kg NPK ha^{-1} (F_5) followed by 200-200-100 kg NPK ha^{-1} (F_4), 150-150-100 kg NPK ha^{-1} (F_3), 100-100-100 kg NPK ha^{-1} (F_2) and the lowest stripped-cane yield of 44.06 and 45.37 t ha^{-1} during 2004 and 2005, respectively in control (F_1). It was also noted that 70.19, 69.76, 54.87, 42.94% and 69.63, 69.18, 54.29 and 43.42% higher stripped cane yield was obtained during 2003-04 and 2004-05, in $F_{5,}$ $F_{4,}$ F_3 and F_2 respectively than control (F_1). The increased stripped cane yield at 200-200-100 kg NPK ha^{-1} may be ascribed to increased nutrient availability and complementary effect of N, P, and K which resulted in higher number of mill able canes m^{-2} and improved individual cane weight. These results have also been supported by Ali (1999), Ayub (1999), Akhtar *et al* (2000) Ali and Afghan (2000), Ramesh (2000), Pandey and Shukla (2000), Sundara, *et al* (2002), Rana *et al*. (2003), El-Tilib *et al* (2004).

The highest stripped-cane yield of 114.2 and 115.10 t ha^{-1} during 2003-04 and 2004-05, respectively was recorded in 30/90cm (G_3) followed by 75cm (G_2), 60cm spaced single row planting pattern (G_1) and the lowest stripped-cane yield of 89.75 and 91.30 t ha^{-1} during 2004 during 2005, respectively in 30/120cm spaced paired row planting pattern (G_4). It was also noted that 21.41, 15.83, 9.66% and 20.68 16.12 and 10.36% higher stripped cane yield during 2003-04 and 2004-05, respectively was recorded in G_3, G_2 and G_1 respectively than G_4. It was observed that improvement in stripped cane yield in 30/90cm spaced paired row planting pattern was due to better air circulation and light penetration which enhanced the photosynthetic efficiency of plants, which reduced shoot mortality and increased number mill able canes m^{-2} and individual cane weight. It was also noted that too much increase in inter strip spacing as in 30/120 cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on yield and yield components of crop. Kanwar *et al.* (1990) and El-Geddawy *et al* (2002) also reported significantly higher stripped-cane yield in 90cm and 100cm row spacing respectively.

Table-2 Morphological response of autumn planted sugarcane to nutrient management and planting geometry on different soils under arid CONDITIONS

Treatments	Number of mill able Canes (m^{-2})		Individual stripped Cane weight (kg)		Stripped cane yield t ha^{-1}	
	Pooled data of D I Khan and Bhakkar					
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
(A)-N:P:K Fertilizer nutrient Doses (kg ha^{-1})						
F_1 = 0 : 0 : 0	4.01d	4.12d	0.3d	0.32d	44.06e	45.37e
F_2 = 100:100:100	7.02c	7.29c	0.52c	0.56c	77.22d	80.19d
F_3 = 150:150:100	8.88b	9.02b	0.63b	0.69b	97.63c	99.25c
F_4 = 200:200:100	13.25a	13.38a	0.98a	1.02a	145.69b	147.19b
F_5 = 250:200:100	13.46a	13.58a	0.99a	1.03a	147.81a	149.37a
LSD	0.63	0.63	0.04	0.04	0.67	1.28
(B)-Planting patterns (G)						
G_1 = 60 cm	9.03c	9.26c	0.67c	0.70c	99.35c	101.85c
G_2 = 75 cm	9.69b	9.89b	0.72b	0.75b	106.63b	108.85b
G_3 = 30/90 cm	10.39a	10.46a	0.76a	0.80a	114.20a	115.10a
G_4 = 30/120 cm	8.17d	8.3d	0.59d	0.63d	89.75d	91.30d
LSD	0.56	0.56	0.03	0.03	0.60	1.14
(C)-F x G						
F_1 x G_1	3.86k	4i	0.29j	0.30i	42.50r	44.00n
F_1 x G_2	4.07k	4.27i	0.31j	0.32i	44.75q	47.00m
F_1 x G_3	4.36K	4.45i	0.33j	0.34i	48.00p	49.00m
F_1 x G_4	3.73K	3.77i	0.28j	0.29i	41.00s	41.50n

F_2 x G_1	6.77ij	7.18gh	0.51hi	0.54gh	74.50n	79.00k
F_2 x G_2	7.51hi	7.68fg	0.56gh	0.58g	82.65m	84.50j
F_2 x G_3	7.89hi	7.98fg	0.58gh	0.61fg	86.75l	87.75i
F_2 x G_4	5.91j	6.32h	0.44i	0.48h	65.00o	69.50l
F_3 x G_1	8.64fgh	8.86ef	0.62fg	0.67ef	95.00k	97.50h
F_3 x G_2	9.18fg	9.36e	0.66f	0.71e	101.00j	103.00g
F_3 x G_3	9.73f	9.82e	0.69f	0.74e	107.00i	88.50i
F_3 x G_4	7.95ghi	8.05fg	0.57gh	0.61fg	87.50l	88.50i
F_4 x G_1	12.84cd	13.02bc	0.96d	0.99c	141.25f	143.25d
F_4 x G_2	13.75bc	13.93ab	1.02bcd	1.06bc	151.25d	153.25c
F_4 x G_3	14.89ab	14.98a	1.09ab	1.14a	163.75b	164.75a
F_4 x G_4	11.5e	11.59d	0.83e	0.88d	126.50h	127.50e
F_5 x G_1	13.05c	13.230b	0.97cd	1.00bc	143.50e	145.50d
F_5 x G_2	13.95abc	14.23ab	1.04abc	1.08ab	153.50c	156.50b
F_5 x G_3	15.09a	15.090a	1.12a	1.14a	165.50a	166.00a
F_5 x G_4	11.75de	11.77cd	0.85e	0.89d	128.75g	129.50e
LSD	1.26	1.26	0.08	0.08	1.33	2.56

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

Interactive effects of NPK doses and planting patterns on stripped cane yield were significantly different during both years. The maximum stripped cane yield of 165 and 166 t ha^{-1} during 2003-04 and 2004-05, respectively was obtained in the interaction of 250–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern(F_5 x G_3) which was at par with 200–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern (F_4 x G_3)and was minimum 41 and 41.5 t ha^{-1} during 2003-04 and 2004-05, respectively in control x 30/120 cm spaced paired row strip planting pattern (F_1xG_4). The optimum stripped cane yield in (F_4xG_3) may be due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which enhanced the photosynthetic efficiency which resulted in accelerated growth and development.

CONCLUSION

It was concluded that under arid conditions on Silt clay and sandy loam soils optimum stripped cane yield was obtained in the interaction of 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern. The plating pattern of 30/90cm paired row strip planting had few advantages over other planting patterns like, it facilitates interculture and earthing up of the crop without damaging the roots, 50% reduction in the number of inter-strip ditches/furrows, thus conserving irrigation water and saving almost 50% in labor and time required for earthing up, allows efficient and expeditious interculture and earthing up with tractor or bullock-drawn implements, permits systematic planting and handling of intercrops without affecting the associated cane crop. Moreover, planting of the main and intercrops in separate and independent strips not only reduces intercrop competition, but also enables the grower to meet the varying fertilizer requirements, growth patterns, and planting times of different crops, facilitates easy application of herbicides since the strips are well spaced, prevents lodging in case of unusual wind or rain since the strips provide plant support to each other, improves the air circulation and light penetration which enhances the photosynthetic efficiency of plants and reduces crop damages from trampling by wild animals looking for a space to rest.

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ABSTRACT

In a field trial physiological response of sugarcane cultivar HSF 240 to different nutrient doses like F_1=0-0-0, F_2=100-100-100, F_3=150-150-100, F_4=200-200-100 and F_5= 250-200-100 kg NPK ha^{-1} and planting patterns G_1=60cm, G_2=75cm single row planting pattern, G_3=30/90cm and G_4=30/120cm spaced paired row strip planting pattern was determined at the research area of the Gomal University Rukh Bibi campus Dera Ismaiel Khan and Main Line Lower Land Reclamation Research Station Bhakkar during 2003-04 and 2004-05. The experiment was laid out according to randomized complete block design (RCBD) with a split plot arrangement having four replications. The analysis of pooled data of D.I Khan and Bhakkar revealed that different nutrient doses influenced all the physiological traits to a significant level. The maximum Crop growth rate (CGR), Leaf area index (LAI), Leaf area duration (LAD) and Net assimilation rate (NAR), were recorded at a fertilizer level of 250-200-100 kg NPK ha^{-1} however CGR, LAI, LAD, NAR, were not statistically different from those recorded at 200-200-100 kg NPK ha^{-1} during both years. The maximum CGR, LAI, LAD, NAR were recorded in planting pattern of 30/90cm spaced paired row strip planting pattern followed by 75cm and 60cm single row planting pattern and was minimum in 30/120cm spaced paired row strip planting pattern where as LAI and NAR were non significant in all planting patterns during both years. The maximum CGR, LAI, LAD, NAR were recorded in 250–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern and these were also significantly higher than all other inter-active treatments and minimum in control x 30/120 cm spaced paired row strip planting pattern during both years. Where as CGR, LAI, LAD, NAR, were at par with 200–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern during both years. Therefore it is recommended that under arid conditions on Silt clay and sandy loam soils optimum LAI, LAD, CGR and NAR, were obtained from nutrient dose of 200–200-100 kg NPK ha^{-1} and 30/90cm spaced paired row strip planting pattern.

Key words: *Saccharum officinarum L.*, NPK management, planting geometry, agro-physiological parameters, autumn planted sugarcane, Pakistan

INTRODUCTION

In Pakistan the average cane yield is much lower than the production potential of our existing sugarcane cultivars due to improper nutrient management and planting geometry. Sugarcane is a along duration crop and its 125t ha^{-1} depletes an average 83 kg N, 37 kg P_2O_5, 168 kg K_2O (Yadava, 1991). Photosynthesis is the most practical way of harvesting solar energy. Sugarcane is considered to be the most efficient converter of solar energy to stored food energy in the form of carbohydrates. According to an estimate for every calorie of energy invested in sugarcane cultivation, about five calories of energy are harvested in its use able form i.e. in the form of sugar (Yadava, 1991). Therefore an adequate and balanced supply of all these nutrients in the effective root zone of crop is essential for obtaining sustainable cane yield (Ingawale *et al*.1992).

Colazo and Armas (1985) reported that crop growth rate and net assimilation rate increased when K was applied in addition to N. Lal (1991) found greater leaf area index at 225 kg nitrogen ha^{-1} as compared to 175 and 150 kg N ha^{-1}. Ali (1999) recorded significantly higher leaf area index, leaf area duration and crop growth rate with the use of 250-100-100 kg NPK ha^{-1} whereas the maximum net assimilation rate was obtained at 100-0-0 kg NPK ha^{-1}.

Efficient interception of radiant energy coming to crop surface requires adequate and uniformly distributed leaf area to give the maximum ground cover. This is achievable by proper orientation of plants over the land surface and their suitable nutrient management. Watson (1947) proposed leaf area index as the best measure for the capacity of crop for producing dry matter. Photosynthesis, respiration, dry matter accumulation and the growth could be expressed as a function of leaf area index. The leaf area index had been used to estimate light interception (Yadav, 1982). Mali (1980) and Singh and Singh (1984) reported that an increase in inter-row spacing from 60cm to 90cm increased leaf area index of sugarcane. Mali and Singh (1988) planted eight sugarcane cultivars in

60cm, 90cm and 120 cm spaced rows. They reported significant effect of both row spacing and cultivars on leaf area index, leaf area duration and crop growth rate. Ali (1999) observed the significant effect of planting pattern on net assimilation rate.

Physiological characters like leaf area index, leaf area duration, crop growth rate and net assimilation rate in crop communities responsible for higher yield, need investigation so that parameters for establishing quality cane tonnage could be ascertained and incorporated in future studies. It is specially mentioned that most of above mentioned work is done on spring planted sugar cane crop and autumn planted crop is totally neglected, therefore present study is designed to determine the impact of different nutrient doses and planting patterns on the physiological traits of autumn-planted sugarcane under the edaphic and agro climatic conditions of the remotest areas of two provinces of Pakistan which are Dera Ismaiel Khan situated at (031^0 28.40 N ^{0} and 071^0 58.54 E ^{0}) with Silt clay soil in NWFP and Bhakkar situated at (031^0 36.365 N ^{0} and 071^0 9.844 E ^{0}) with sandy loam soil in Punjab.

MATERIALS AND METHODS

The study was conducted at the research area of Rukh Bibi campus of Gomal University Dera Ismaiel Khan and Main Line Lower Land Reclamation Research Station Chak No 37 TDA (Thal Development Authority) Bhakkar during 2003-04 and 2004-05. The nutrient doses under study were F_1=0-0-0, F_2=100-100-100, F_3=150-150-100, F_4=200-200-100 and F_5 =250-200-100 kg NPK ha^{-1}.The planting patterns comprised of G_1=60cm, G_2=75cm spaced single row planting pattern and G_3=30/90cm, G_4=30/120cm spaced paired row strip planting pattern while the seed was used at the rate of 70,000 double-budded setts ha^{-1}. Cane cultivar “HSF 240” was used as test crop. The experiment was laid out in a randomized complete block design (RCBD) with a split plot arrangement keeping the nutrient doses in main plots and planting patterns in sub-plots. The net plot size was 24m^2 with four replications. The crop was planted during the 1st week of September and harvested in first week of December next year during both years at both locations. All the phosphorus, potassium and 1/4 of total nitrogen were applied at the time of seed bed preparation while remaining nitrogen was applied in two equal splits each at completion of germination and at the start of cane formation. The crop was kept free of weeds and irrigated when it was needed .All other agronomic practices were kept normal and uniform for all the treatments. Observations on crop growth rate, leaf area index, leaf area duration, and net assimilation rate, were recorded using standard procedures. The data was analyzed statistically using Fisher’s analysis of variance technique and LSD test at 0.05 percent level of probability was employed to compare the differences among the treatment means (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Crop growth rate

According to Gardner *et al*. (1988), crop growth rate (CGR) is the gain in weight of a community of plants per unit of land and of time. Analysis of pooled data of both locations D.I Khan and Bhakkar regarding CGR shown in Table-1 revealed that CGR was significantly different under different nutrient doses. Maximum CGR was recorded (8.02 and 8.23 g m^{-2} day^{-1})during 2003-04 and 2004-05, respectively in 250- 200-100 kg NPK ha^{-1} (F_5)and was at par with 200-200-100 kg NPK ha^{-1} (F_4)followed by 150-150-100 kg NPK ha^{-1} (F_3), 100-100-100 kg NPK ha^{-1}(F_2) and minimum (2.75 and 2.82 g m^{-2} day^{-1})during 2004 and 2005,respectively was recorded in control(F_1) It was observed that 62.64, 62.17, 49.91, 41.74% and 62.75, 62.40, 51.13 and 42.57% higher CGR was recorded during 2003-04 and 2004-05 in F_5, F_4, F_3, and F_2, then F_1, respectively indicating that optimum CGR at 200-200-100 kg NPK ha^{-1} may be due to increased nutrient availability which increased photosynthetic efficiency and improved cane growth and alone increase in N has no significant effect on CGR. Ali (1999) reported that CGR was affected significantly by different fertilizer levels and the maximum CGR was recorded at 250-100-100 kg NPK ha^{-1}.

The CGR was significantly different under various planting patterns. The maximum CGR (5.95 and 6.15 g m^{-2} day^{-1}) during 2003-04 and 2004-05, respectively was recorded in 30/90cm spaced paired row strip planting pattern (G_3) followed by 75cm (G_2) and 60cm single row planting pattern (G_1) and minimum (5.05 and 5.24 g m^{-2} day^{-1}) during 2003-04 and 2004-05, respectively in 30/120cm paired row strip planting pattern (G_4). It was observed that 15.13, 10.93 6.48% and 14.80, 10.58 and 6.26% higher CGR during 2003-04 and 2004-05, respectively in G_3, G_2 and G_1 respectively was recorded than G_4. The higher CGR at 30/90cm spaced paired row strip planting pattern was probably due to improved air circulation and light penetration which improved photosynthetic efficiency and too much increase in inter strip spacing as in 30/120cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on CGR. Mali and Singh (1988b) and Gill (1995) stated a significant effect of various planting patterns on cane CGR.

Interactive effect of different nutrient doses and planting patterns CGR was highly significant. Maximum CGR (8.02 and 8.23 g m^{-2} day^{-1}) during 2003-04 and 2004-05,respectivly was recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) followed by 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and was minimum (2.64 and 2.66 g m^{-2} day^{-1})during 2003-04 and 2004-05,respectivly in control x 30/120 cm spaced paired row strip planting pattern (F_1xG_4). The higher CGR in (F_5xG_3) may be due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which improved photosynthetic efficiency and resulted in increased CGR.

Leaf area index

The analysis of pooled data of both locations Dera Ismaiel Khan and Bhakkar regarding leaf area index (LAI) in Table-1 revealed that the cane leaf area index was significantly affected by different nutrient doses and was the highest (6.67 and 6.54) during 2004 and 2005,respectively in 250-200-100 kg NPK ha^{-1} (F_5) which was at par with 200-200-100 kg NPK ha^{-1} (F_4) and 150-150-100 kg NPK ha^{-1} (F_3), followed by 100-100-100 kg NPK ha^{-1} (F_2)and was the lowest (4.88 and 4.75) during 2003-04 and 2004-05,respectively. It was observed that 26.84, 26.62, 24.34, 22.42% and 27.37, 27.26, 25.31 and 21.88% higher LAI during 2003-04 and 2004-05 was recorded in $F_{5,}$ $F_{4,}$ $F_{3,}$ F_2 respectively than $F_{1.}$ It showed that increase in Nitrogen and Phosphorus level more than 150 kg ha^{-1} had no significant effect on LAI.

Non significant effect of LAI was recorded in different planting patterns. Alonso and Scandaliaris (1988) reported that LAI was not influenced by row spacing in any of the crops. Interactive effects of planting patterns and nutrient doses on LAI were non-significant except in Interactions of (F_1) control with all planting patterns.

Leaf area duration

The analysis of pooled data of D.I Khan and Bhakkar regarding leaf area duration (LAD) shown in Table-1 revealed that cane leaf area duration was significantly different under different nutrient doses and planting patterns. LAD was maximum (891.57 and 904.81 days) during 2003-04 and 2004-05,respectivly in 250-200-100 kg NPK ha^{-1} (F_5) but it was at par with 200-200-100 kg NPK ha^{-1} (F_4) and significantly superior to rest of the fertilizer levels and was minimum (478 and 476.83 days) during 2004 2005,respectivly in control (F_1) indicating that optimum LAD at 200-200-100 kg NPK ha^{-1} may be due to increased nutrient availability which increased photosynthetic efficiency and improved cane leaf senescence and alone increase in N has no significant effect on LAD. Ali (1999) reported that maximum LAD of 984 days was recorded in 250-100-100 kg NPK ha^{-1}.

LAD was affected significantly by different planting patterns and was maximum (817.93 and 829.20 days) during 2003-04 and 2004-05, respectively in 30/90cm paired row strip planting pattern (G_3) followed by 75cm (G_2), and 60cm single row planting pattern (G_1) and was minimum (749.32 and 758.56 days) during 2003-04 and 2004-05, respectively in 30/120cm paired row strip planting pattern (G_4). It was observed that 8.39, 5.17, 1.07% and 8.52, 5.36 and 1.7% higher LAD during 2003-04 and 2004-05, respectively was recorded in $G_{3,}$ $G_{2,}$ and G_1 respectively than G_4. The higher LAD at 30/90cm spaced paired row strip planting pattern was probably due to improved air circulation and light penetration which improved photosynthetic efficiency and too much increase in inter strip spacing as in 30/120cm paired row strip planting pattern number of plants per unit area had to increase to maintain optimum plant population, due to which inter plant competition increased causing adverse effects on LAD. Mali and Sing (1988) [b] has also reported significant difference in LAD in different row spacing.

Interactive effect of different nutrient doses and planting patterns on LAD was highly significant. Maximum LAD (946.24 and 964.93 days) during 2003-04 and 2004-05,respectivly was recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) which was at par with 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and was minimum (469.68 and 462.96 days) during 2003-04 and 2004-05,respectivly in control x

30/120cm spaced paired row strip planting pattern (F_1xG_4). The optimum LAD in (F_4xG_3) may be due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which improved photosynthetic efficiency and resulted in improved cane leaf area duration.

Net assimilation rate

Net assimilation rate (NAR) is the net gain of photosynthetic assimilates per unit of leaf area and time (Gardner *et al*., 1988). The analysis of pooled data of both locations D.I Khan and Bhakkar regarding NAR shown in Table-1 revealed that NAR was significantly different under different nutrient doses and was maximum (1.85 and 1.91 g m^{-2} day^{-1})during 2003-04 and 2004-05,respectively in 250- 200-100 kg NPK ha^{-1} (F_5)but it was at par with 200-200-100 kg NPK ha^{-1} (F_4)followed by 150-150-100 kg NPK ha^{-1} (F_3), 100-100-100 kg NPK ha^{-1} (F_2) and was minimum in control(F_1). It was observed that 29.73, 29.35, 11.56, 2.26% and 30.37, 30, 19.39, and 4.32% higher NAR higher NAR during 2004-2005, respectively in F_5, F_4, F_3, F_2 respectively than control F_1. The increased NAR at higher NPK dose was ascribed to increased nutrient availability and complementary effect of N, P, and K which resulted in higher CGR, LAI and LAD. It was also indicated that alone increase in N has no significant effect on NAR.

The data regarding NAR of different planting patterns was non significant. Interactive effects of different planting patterns and nutrient doses were significantly different. Maximum NAR (1.91 and 1.95 g m^{-2} day^{-1})during 2003-04 and 2004-05,respectivly was recorded in 250–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_5xG_3) which was at par with 200–200-100 kg NPK ha^{-1} x 30/90 cm spaced paired row strip planting pattern (F_4xG_3) and was minimum (1.26 and 1.3 g m^{-2} day^{-1}) during 2003-04 and 2004-05,respectivly in control x 30/120 cm spaced paired row strip planting pattern (F_1xG_4). It was also observed that optimum NAR in (F_4xG_3) was due to complimentary effect of increased nutrient availability and improved air circulation and light penetration which enhanced the photosynthetic efficiency which resulted in accelerated NAR.

Table-1 Physiological response of autumn planted sugarcane to nutrient management and planting geometry on different soils under arid conditions

Treatments	CGR (g m^{-2} day^{-1})		LAI		LAD (days)		NAR (g m^{-2} day^{-1})	
	Pooled data of D I Khan and Bhakkar							
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
(A)-N : P : K Fertilizer nutrient Doses (kg ha^{-1})								
F_1 = 0 : 0 : 0	2.75d	2.82d	4.88c	4.75c	478.00d	476.83d	1.30c	1.33d
F_2 =100:100:100	4.72c	4.91c	6.29b	6.08b	795.86c	809.67c	1.33c	1.39c
F_3 =150:150:100	5.49b	5.77b	6.45ab	6.36ab	837.35b	856.44b	1.47b	1.65b
F_4 =200:200:100	7.27a	7.50a	6.65ab	6.53ab	888.78a	903.36a	1.84a	1.90a
F_5 =250:200:100	7.36a	7.57a	6.67a	6.54a	891.57a	904.81a	1.85a	1.91a
LSD	0.22	0.22	0.38	0.38	4.16	4.16	0.06	0.06
(B)-Planting patterns (G)								
G_1 =60cm	5.40c	5.59c	6.10a	6.00a	757.40c	771.64c	1.57a	1.67a
G_2 =75cm	5.67b	5.86b	6.23a	6.12a	790.19b	801.48b	1.58a	1.66a
G_3 =30/90cm	5.95a	6.15a	6.34a	6.22a	817.93a	829.20a	1.60a	1.67a
G_4 =30/120cm	5.05d	5.24d	6.07a	5.95a	749.32d	758.56d	1.50a	1.63a
LSD	0.2	0.2	0.34	0.34	3.72	3.72	0.06	0.06
(C)-F x G								
F_1 x G_1	2.69l	2.77m	4.82b	4.73b	466.78m	472.69m	1.30fgh	1.34i
F_1 x G_2	2.78l	2.88m	4.89b	4.77b	481.75l	482.53l	1.30fgh	1.35hi
F_1 x G_3	2.90l	2.95m	4.96b	4.81b	493.79k	489.14l	1.32fgh	1.34i
F_1 x G_4	2.64l	2.66m	4.83b	4.68b	469.68m	462.96n	1.26gh	1.30i
F_2 x G_1	4.62jk	4.85kl	6.22a	6.13a	779.17i	796.49j	1.33fgh	1.65de
F_2 x G_2	4.93ij	5.07jk	6.34a	6.23a	809.13h	821.49i	1.37efgh	1.63de
F_2 x G_3	5.08hi	5.22jk	6.41a	6.29a	825.39g	838.80h	1.38defg	1.60ef
F_2 x G_4	4.27k	4.48l	6.19a	6.08a	769.74j	781.89k	1.25h	1.73cd
F_3 x G_1	5.39gh	5.66hi	6.38a	6.29a	818.31g	837.63h	1.48de	1.49fg
F_3 x G_2	5.61fg	5.92gh	6.41a	6.40a	847.18f	866.86ef	1.49de	1.49fg
F_3 x G_3	5.83f	6.15g	6.60a	6.48a	876.56c	889.42c	1.50d	1.50fg

F_3 x G_4	5.11hi	5.33ij	6.34a	6.27a	807.34h	831.84h	1.42def	1.47gh
F_4 x G_1	7.10d	7.30de	6.53a	6.43a	856.55e	875.11de	1.87ab	1.92ab
F_4 x G_2	7.48cd	7.67cd	6.70a	6.59a	902.73b	918.26b	1.86abc	1.92ab
F_4 x G_3	7.94ab	8.19ab	6.86a	6.75a	947.66a	963.71a	1.89a	1.94a
F_4 x G_4	6.56e	6.82f	6.49a	6.38a	848.17f	862.14fg	1.74c	1.81bc
F_5 x G_1	7.19cd	7.37cd	6.57a	6.43a	866.18d	876.30d	1.87ab	1.93ab
F_5 x G_2	7.56bc	7.78bc	6.73a	6.59a	910.17b	918.26b	1.87ab	1.92ab
F_5 x G_3	8.02a	8.23a	6.86a	6.75a	946.24a	964.93a	1.91a	1.95a
F_5 x G_4	6.66e	6.89ef	6.51a	6.35a	851.68ef	853.96g	1.76bc	1.84abc
LSD	0.44	0.44	0.75	0.75	8.33	8.33	0.12	0.12

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

CONCLUSION

It is concluded that under arid conditions on Silt clay and sandy loam soils optimum net assimilation rate was obtained in the interaction of 200–200-100 kg NPK ha^{-1} x 30/90cm spaced paired row strip planting pattern. The plating pattern of 30/90cm paired row strip planting had few advantages over other planting patterns like, it facilitates interculture and earthing up of the crop without damaging the roots, 50% reduction in the number of inter-strip ditches/furrows, thus conserving irrigation water and saving almost 50% in labor and time required for earthing up, allows efficient and expeditious interculture and earthing up with tractor or bullock-drawn implements, permits systematic planting and handling of intercrops without affecting the associated cane crop. Moreover, planting of the main and intercrops in separate and independent strips not only reduces intercrop competition, but also enables the grower to meet the varying fertilizer requirements, growth patterns, and planting times of different crops, facilitates easy application of herbicides since the strips are well spaced, prevents lodging in case of unusual wind or rain since the strips provide plant support to each other, improves the air circulation and light penetration which enhances the photosynthetic efficiency of plants and reduces crop damages from trampling by wild animals looking for a space to rest.

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EFFECT OF INTERCROPPING SHORT DURATION CROPS ON THE PRODUCTION OF SUGARCANE CROP

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ABSTRACT

The study on intercropping of autumn planted sugarcane with onion, wheat, Lentil, Mustard and Safflower was carried out at the experimental Field of Sugarcane Research Station, QAARI Larkana during the year 2005-2006. The experiment was laid out in Randomized Complete Block with four replications with ultimate plot size of 8 x 8m ($64m^2$). The results obtained were analysed and reported briefly. The results were statistically non-significant for germination %age, number of tiller per stool and plant height. Maximum germination (59.98%) was recorded when sugarcane was planted sole followed by sugarcane + Lentil intercropping i.e. (58.00%). The same trend was noted for number of tillers $stool^{-1}$, cane girth and internodes/cane. The cane yield ha^{-1} of sugarcane was maximum (120.97 m.t ha^{-1}), when sugarcane planted alone, whereas all the intercrops reduced cane yield significantly. Smoothly and competitive effect was observed for all intercrops when sown with sugarcane.

Keyword: Sugarcane, Intercropping, Lentil, Mustard, Safflower, Wheat, Onion.

INTRODUCTION

Sustainable agriculture seeks, at least in principle, to use nature as the model for designing agricultural systems. Since nature consistently integrates her plants and animals into a diverse landscape, a major tenet of sustainable agriculture is to create and maintain diversity. Intercropping offers farmers the opportunity to engage nature's principle of diversity on their farms. Spatial arrangements of plants, planting rates, and maturity dates must be considered when planning intercrops. Intercrops can be more productive than growing pure stands. Many different intercrop systems are discussed, including mixed intercropping, strip cropping, and traditional intercropping arrangements (Preston, 2003).

Intercropping is the cultivation of two or more crops simultaneously on the same field. It also means the growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development. The rationale behind intercropping is that the different crops planted are unlikely to share the same insect pests and diseased-causing pathogens and to conserve the soil. There is a number of intercropping which include: (i) mixed or multiple cropping is the cultivation of two or more crops simultaneously on the same field without a row arrangement, (ii) relay cropping is the growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development, (iii) row intercropping is the cultivation of two or more crops simultaneously on the same field with a row arrangement, (iv) strip cropping is the cultivation of different crops in alternate strips of uniform width and on the same field. It has two types; contour strip cropping and field strip cropping. Contour strip cropping follows a layout of a definite rotational sequence and the tillage is held closely to the exact contour of the field. Field strip cropping has strips with uniform width that follows across the general slope of the land (Boller *et al*. 2004).

Intercropping in not a new concept but centuries old technique of intensive farming that has been persisted in many areas of the world which efficiently maximizes land and productivity per unit of area per season (Oad *et al.* 2001). The practice of intercropping of turnip with radish and carrot is gaining interest particularly among the farmers having small holdings, who are unable to manage their diversified domestic needs from limited area. The day to day requirement of the growers be modified and reexamined in the light of newly suggested planting system which besides allowing easy and free inter cultivation and provides good chance for kitchen and marketable production (Oad *et al.* 2001). Frances *et al.* (1982) suggested that intercropping should be carefully practiced without damaging to the main crop. They were also of the view that intercropping must be practiced intensively and owner can obtain more added benefits with low added costs. Therefore, it is important to investigate the added benefits of intercropping through economic analysis.

Intercropping has a number of advantages, (i) it reduces the insect/mite pest populations because of the diversity of the crops grown. When other crops are present in the field, the insect/mite pests are confused and they need more time to look for their favorite plants; (ii) reduces the plant diseases, (iii) the distance between plants of the same species is increased because other crops (belonging to a different family group) are planted in between, (iv) reduces hillside erosion and protects topsoil, especially the contour strip cropping, (v) attracts more beneficial insects, especially when flowering crops are included the cropping system, (vi) minimizes labor cost on the control of weeds, (vii) a mixture of various crops gives often a better coverage of the soil leaving less space for the development of weeds, (viii) utilizes the farm area more efficiently, (ix) Results in potential increase for total production and farm profitability than when the same crops are grown separately and (x) provides 2 or more different food crops for the farm family in one cropping season (Wolfe, 2000).

Singh (2002) suggested that inter cropping reduced the cane yield. However, additional harvest of inter crops, increased the net income. The fertilizer and irrigation water both are consumed efficiently by the plants, the inter space in crop, is better utilized and cost of interculture is reduced. Wheat, onion, sunflower, canola and mustard are successfully grown in upper and lower Sindh. Siddiqui *et al*. (2004) reported that highest cane yield was obtained when onion was used as the first intercrop. In this experiment sugarcane was planted intercropped with each of the above four crops. The effect of the intercrops on sugarcane yield was studied and the economics were also worked out. They further reported that yield obtained under sole cropping was statistically at par with sugarcane + rape seed intercropping. Highest net returns were obtained from cane + rape and cane + mustard inter crops, which is higher than that obtained under sole sugarcane. Cropping, where as Alam *et al*. (2001) conducted that among inter crops highest mungbean yield were obtained with Lentil and Onion. Keeping in view the above facts, the present study was designed to evaluate the effect of intercrops on quantitative and qualitative characters of sugarcane. The main objective of this study is to select the crops for intercropping in sugarcane, which would be economical and have minimum smothering and competitive effect on sugarcane.

MATERIALS AND METHODS

Experiment was conducted designed to evaluate the effects of intercrops on cane yield of sugarcane variety Larkana-2001, experimental Field of Sugarcane Research Station, QAARI Larkana during the year 2005-2006. Six intercropping treatments such as sugarcane alone, sugarcane +onion, sugarcane+wheat, sugarcane+ lentil, sugarcane + mustard and sugarcane+safflower were examined in a four replicated Randomized Complete Block Design having net plot size of $64m^2$. The cane was cut in to two budded set and treated with fungicide. The recommended fertilizer dose i.e. 268+134+268 kg NPK were applied. After one month of sugarcane planting, onion, wheat, safflower, lentil and mustard were intercropped in between the rows of sugarcane. The sugarcane crop was planted in the month of August 26, 2004. The onion was transplanted in October, wheat during 3rd week of November, mustard and safflower was planted in early November. The first dose of recommended fertilizer was applied before its sowing. Other cultural operations were performed as recommended by Agronomist. Irrigation and fertilizer was applied in all the sugarcane planted plots. Observations were recorded on all the growth and yield contributing characters for principal as well as intercrops. The data thus collected were analysed statistically following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1. Germination percentage

It is explicit from the data that germination percentage ranged from 53-60 percent. The maximum 59.98 per cent of sugarcane was recorded when planted alone followed by Mustard (58.27 percent), Lentil (58.00), onion (54.74), mustard (54.46) and wheat (53.33 per cent) respectively, when intercropped with sugarcane. Wheat intercropped with sugarcane recorded the minimum germination percentage and other crops increased germination percentage. Sugarcane also increased germination percentage over the intercrop (sugarcane + wheat). The results are confirmed by Sain, *et al*. (2003) who reported that sugarcane planted alone recorded maximum germination.

2. Number of tillers stool^{-1}

The summarized observations regarding average number of tillers per stool, recorded at the time of harvesting revealed that significantly more number of tillers per stool were produced in the plots having sugarcane alone (6.45) followed by sugarcane with wheat (5.52), sugarcane with lentil (5.32), sugarcane with onion (5.46), sugarcane with mustard (5.11) and sugarcane with safflower (4.30). The analysis of variance showed that number of tillers per stool was significantly higher in sugarcane alone.

The difference in number of tillers stool^{-1} of sugarcane with intercrops showed statistically non-significant. The results clearly manifest that all the test intercrops had smothering and competitive effect on sugarcane, but is much pronounced in case of safflower. Therefore, it could be inferred on the basis of these results that intercropping of mustard and safflower with sugarcane had significant smothering and competitive effect on cane plant. Similar results have also been reported by Sain, *et al*. (2003) who reported that sugarcane planted alone recorded highest number of shoots and cane yield t ha^{-1}.

3. Cane height (cm)

Cane height indicated that cane attained more height in sugarcane alone and onion intercropping (223.00). The differences among all the other intercrop combinations, regarding cane height were non-significant. The best was sugarcane alone (216.75 cm) followed by sugarcane + lentil (214.50), sugarcane + safflower (207.25 cm), sugarcane + mustard (202.75 cm) and sugarcane + wheat (190.58 cm), respectively. It is clear from the data presented in Table-3, that all the tested intercrops affected the plants height. This effect was more pronounced in case of sugarcane + wheat (190.58 cm), on the basis of these results, it could, therefore be inferred that wheat, mustard and safflower with planted crops had more smothering and competitive effect on cane plants, reducing the plant height and ultimately reducing the yield. The results are confirmed by Singh, *et al*. (2001) who reported that sole sugarcane stand recorded greater cane length as compared to sole sugarcane.

Cane girth

The cane girth was affected significantly ($P<0.01$) by the intercrops. A perusal of the data showed that average cane girth was significantly affected by different intercrops. The maximum cane girth (2.59 cm) was recorded in the plots of sugarcane alone while in other plots, with different intercrops, the cane girth was variable. The differences in cane girth with lentil (2.12cm), onion (2.07cm), wheat (1.99 cm) and mustard (2.07 cm) intercrops were statistically not significant. It was observed that safflower affected the cane girth much (1.74 cm) and their effect was statistically highly significant. Wheat and safflower reduced the cane girth which ultimately reduced the yield of sugarcane. Nazir, *et al*. (2002) conducted experiment on agronomic benefits of some autumn sugarcane intercropping system and reported that cane yield reduced with intercropping of respective crops and obtained more cane thickness in sole sugarcane crop than intercrops.

Number of internodes

The data revealed that number of internodes varied significantly with the intercrops in sugarcane. The maximum average number of internodes (19.65) was found in sugarcane planted alone. The analysis of variance showed that the differences in number of internodes of sugarcane having onion and lentil as intercrops were (15.05 and 18.32). The number of internodes was significantly the least (15.55) when planted with safflower as intercrop. The internodes were maximum in sugarcane when planted alone followed by sugarcane with lentil (18.32), onion (18.02), wheat (17.15), mustard (16.15) and safflower (15.55) intercrops respectively. The number of internodes contribute significant part in the yield of sugarcane. On the basis of these result, it is concluded that wheat, mustard and safflower, intercrops reduced the number of internodes of cane which ultimately reduced the cane yield. Supporting the present findings, Vashist *et al*. (2003) reported that cane more number of internodes in pure stands than in intercrops.

6. Cane yield m. tons ha^{-1}

It is clear from the data that the maximum yield ha^{-1} (120.97 m. tons) was obtained when sugarcane was planted alone followed by sugarcane with onion (106.66), wheat (98.12), Lentil (94.23), mustard (81.81) and safflower (77.77) intercrops respectively. The differences in yield were non-significant, when wheat and lentil were intercropped with sugarcane. Similarly, the difference in yield of sugarcane when intercropped by mustard and safflower were non-significant. As intercropping of wheat, mustard, onion, lentil and safflower with sugarcane reduced the yield, therefore, on the basis of these results, it may be inferred that the intercropping of these crops with sugarcane is un-economical under local conditions. The results are confirmed by Sain *et al*. (2003) who reported that sugarcane planted alone recorded maximum cane yield ha^{-1}. Vashist *et al*. (2003) reported that cane yield was highest in pure cane stand and Singh *et al*. (2001) confirmed that sole sugarcane stand recorded highest yield and millable canes.

Table-1 Mean germination percentage of sugarcane as influenced by different varieties

Intercrops	Germi-nation %	Number of tillers/ stool	Cane Height (cm)	Cane girth (cm)	Number of Internodes /cane	Cane yield (M. tons) ha-1
T1=Sugarcane alone	59.98	6.45	216.75	2.59 a	19.65 a	120.97 a
T2=Sugarcane-Onion	54.74	5.46	223.00	2.07 b	18.05 b	106.66 b
T3=Sugarcane-Wheat	53.33	5.52	190.50	1.99 c	17.15 bc	98.12 c
T4= Sugarcane-Lentil	58.00	5.32`	214.50	2.12 b	18.32 b	94.23 c
T5=Sugarcane-Canola	54.46	5.11	202.75	2.06 b	16.15 c	81.81 d
T6=Sugarcane-Safflower	58.27	4.30	207.25	1.74 c	15.55 d	77.77 de
S.E±	2.120	0.025	10.57	0.0600	0.3600	2.345
LSD1 0.05	-	-	-	0.1807	1.0844	4.989
LSD2 0.01	-	-	-	0.2503	1.5019	6.087

Mean values followed by same letters do not differ significantly at 0.05 probability level.

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PERFORMANCE OF *TRICHOGRAMMA CHILONIS* FOR THE CONTROL OF GURDASPUR BORER IN SUGARCANE IN VARIOUS DISTRICTS OF NWFP

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ABSTRACT

Different doses of parasitoid eggs of *Trichogramma chilonis* viz. 8000, 10000, 12000, 14000, 16000, 18000 and 20000 per acre were tested against gurdaspur borer *Bisetia steniellus* in sugarcane ratoon crop during 2005 and 2006 in different districts of NWFP. Data were recorded on the basis of percent infestation from July through September, while cane yield (tons/ha) was recorded at the time of harvest. Cane samples of each treatment were analyzed in sugar analysis laboratory for commercial cane sugar percentage (CCS %) to calculate sugar yield (t/ha). The results showed that, all doses of parasitoid significantly reduced borer infestation and improved cane and sugar yields as compared to check plots. Significantly lowest borer infestation and highest cane and sugar yields were recorded in those plots where 16000 to 20000 (8 to 10 tricho cards per acre) were applied.

Key words: Sugarcane, Ratoon crop, Gurdaspur borer*, Bisetia steniellus, Trichogramma chilonis*

INTRODUCTION

Sugarcane crop is a multiple source of food, fodder and cash need of the growers and readily available energy in human diet. This crop is grown in three provinces of Pakistan namely Sindh, Punjab and NWFP. Total area of sugarcane in Pakistan during 2003-04 was 10,75,000 hectares with production of 5,37,76,000 tons. Out of which NWFP has1,05,000 hectares with production of 47,45,000 tons (Malik and Gurmani, 2005) .

Among the factors contributing to lower yield in our country, the attack of insect pests is of great importance. Various insect pests like termites, borers, pyrilla, whitefly, bugs and mites etc. attack this crop and cause heavy losses in terms of low yield and quality (Atwal, 1994). Sugarcane borers make tunnels in stubbles and internodes due to which food supply to aerial parts of stem and leaves become stopped. Moreover these tunnels pave way for diseases. Amongst all borers gurdaspur borer (*Bissetia steniellus*) is noted to be quite destructive pest of sugarcane in Pakistan. The newly hatched larvae of this pest feed gregariously in common hole of top intern ode for 10-12 days. At this stage the affected plants cane be identified easily due to its dry tops. These larvae then come out from the common hole and migrate to canes in the same or adjoining clumps individually, where they enter inside the internodes and bore the stem in a spiral to words the periphery and then bore straight upward. With out some effective measures, the crop cannot be protected from the ravages of insect pests specially borers. A natural enemy of borers *(Trichogramma chilonis)* control caterpillars of different crops specially sugarcane borers through out the world. Trichogramma are tiny wasps that kill the eggs of Lepidoptera. Its egg hatches into a small larva, which feeds inside of the moth eggs and kill them.

Rajendran and Hanif (1996) tested release techniques for *Trichogramma chilonis*, an egg parasitoid against sugarcane borers in Tamil Nadu, India. They observed that the release of parasitoid by the closed cup mechanism and loose egg exposure were the best release techniques with higher percentage emergence of parasitoid as compared with the conventional technique of open card release tied to plants. Abbas (1997) stated that during 1987-1996, sugarcane plants in Egypt infested with *Chilo agamemnon* treated with *Trichogramma evanescens* has higher yields than untreated plants. *T. evanescens* was released once each year early in the season at 20, 000/feddan (1 feddan = 0.42 ha). this treatment reduced infestation by 50-79 % at the end of the season. Greenberg *et al* (1998) assessed the role of *Trichogramma minutum* and *T. pretiosum* (reared on *Helicoverpa zea* eggs) as parasitoids of the Mexican rice borer, *Eoreuma loftini*, and sugarcane borer, *Diatraea saccharalis* under laboratory and greenhouse conditions. *Trichogramma minutum* parasitized 42.0% of sugarcane borer eggs in laboratory conditions. In the greenhouse, *T. pretiosum* parasitized an average of 55.3% of the Mexican rice borer eggs (distributed on sugarcane plants). Results show that, about 21.0% eggs of sugarcane borers were parasitized. Based on results, they suggested that there is great potential for the use of *Trichogramma spp*. to control sugarcane stalk borers in a field IPM program. Soula et al (2002) released 15000 *Trichogramma chlonis* per hectare against spotted stalk borer *Chilo sacchariphagus* Bojor, a major pest of sugarcane in Southern Asia, the Indian Islands and Mozambique in Southern Africa. The parasitoids were released at two sites Savannah (SAV) and Sainte-Marie (SMA) and compared them with untreated plots. In treated plots, the percentage of bored internodes at harvest was 45 % less than the controls at SAV and 35 % at SMA. Colong (2003) reviewed the literature pertaining to the biology and control of *Eldona saccharina* on its indigenous host plants and sugarcane. Because of multi host infestation, biological control has been considered a major option in limiting the impact of this pyralid stalk borer in sugarcane. Based on results of numerous published papers, a classically based biological control approach could be more successful in limiting borer numbers in sugarcane. Hearne *et al* (2003) stated that African stalk borer, *Eldana saccharina* has become a serious pest to the sugar industry in South Africa. Sugar Association of South Africa investigating numerous indigenous and exotic parasitoids from past decade as a means of biologically controlling stalk borer infestation in sugarcane. Laboratory results indicate that *Gonionus natalensis* to be one of the most promising parasitoids for this purpose. They further pointed out, that change in farming practices could lead to a self-sustaining parasitoids population with 60 % reduction in crop damage. Shenhmar *et al* (2003) conducted large scale field demonstration using *Trichogramma chilonis* against sugarcane stalk borer *Chilo auricilius* in Punjab, India during 2000-2001. *Trichogramma chilonis* was released @ 50, 000 per hectare at 10 days interval from July to October. In terms of borer incidence, they recorded a reduction in damage over the control by 52.04 % during 2000 while 60.03 5 during 2001. Mustafa *et al* (2006) tested *Trichogramma* @ 16 cards having 400-500 eggs per card in sugarcane crop in farmer fields at 15 days different localities of districts Faisalabad, Toba Tek Singh and Jhang to know the efficacy of *Trichogramma* against sugarcane borers. The cards were applied at fortnightly basis from April to September during 2003-2004. Data were recorded on the infestation of borers during May-June and December – January at crop harvest, respectively. Results show that tiller infestation ranged from 2.7 to 7.0 % in treated and 4.7 to 13.5 5 in untreated fields. The loss reduction in tiller infestation due to release of *Trichogramma* ranged from 29.3 to 61.4 %. The internodes damage ranged from 3.9 to 10.5 % in treated and 9.6 to 18.6 % in untreated plots. The internodes damage reduction due to *Trichogramma* treatment ranged from 28.6 to 59.7 %.

Keeping in view the importance of sugarcane borers especially gurdaspur borer, the experiments were carried out to study the effect of *Trichogramma chilonis* (an excellent egg parasitoid of sugarcane borers) in different districts of NWFP to enhance yield capabilities of comparatively low cost.

MATERIALS AND METHODS

The experiments were conducted at Sugar Crops Research Institute (SCRI) Mardan and farmers fields during 2005 and 2006 in the major districts of NWFP. Those fields of ratoon crops were selected where attack of gurdaspur borer was noted maximum during previous year in plant crop. At each location, the experiments comprised of eight treatments including check were laid out in randomized complete block (RCB) design having four replications. Plot size was maintained as 20 × 6.75 m^2. The experiments were conducted twice for confirmation of the results. The parasitoid *(Trichogramma chilonis)* was cultured on the eggs of Angoumois Grain Moth *(Sitotroga cerealella)* in the laboratory as per required procedure. Different doses/parasitized eggs of *trichogramma* pasted on ivory cards (Tables: 1.1 – 1.5) were applied during July to September at 15 days interval. Infestation of gurdaspur borer (dry tops) was recorded by counting the number of infested tops/plants at monthly interval during last week of each month. Average cumulative data for 3 months (July- September) of each district was tabulated (Table-1.1 to 1.5). Results were based on mean data of both the years.

Cane yield in tons/ha was recorded at the time of harvest. Commercial Cane Sugar percentage (CCS %) data was recorded after cane juice analysis of each treatment in sugar analysis laboratory at Sugar Crops Research Institute Mardan as per method developed by Chen, 1985. For this purpose samples of 20 canes randomly were collected from each treatment at the time of harvest. Sugar yield tons/ha was calculated with the help of the following formula.

$$\textbf{Sugar yield} = \frac{\textbf{Cane yield} \times \textbf{CCS\%}}{\textbf{100}}$$

Mean data were statistically analyzed and LSD test was used as test statistics

RESULTS AND DISCUSSION

Results of the experiments conducted at SCRI Mardan and farmer fields in different districts of NWFP to check the infestation of gurdaspur borer *Bissetia steniellus* Hampson (Crambidae; Lepidoptera) using different doses of egg parasitoid (*Trichogramma chilonis*) as 8000 parasitoid eggs (T1), 10000 parasitoid eggs (T2), 12000 parasitoid eggs (T3), 14000 parasitoid eggs (T4), 16000 parasitoid eggs (T5), 18000 parasitoid eggs (T6), 20000 parasitoid eggs (T7), the untreated check (T8) and the resultant effect of these treatments on cane yield (tons/ha), Commercial Cane Sugar (CCS %) and sugar yield (t/ha) are presented in tables 1.1 to 1.5 Statistically analyzed data in all districts showed that, infestation of gurdaspur borer (dry tops), cane and sugar yield (t/ha) and CCS% were significantly different except sugar yield (t/ha) for district D.I.Khan.

Results presented in Table-1.1 revealed that mean infestation of gurdaspur borer in district Mardan) during 2005 and 2006 was significantly the lowest (2.29%) in T7 followed by 2.50, 3.02, 3.73, 4.33, 4.82 and 5.29 in T6, T5, T4, T3, T2 and T1 respectively, while its lowest infestation (6.17%) was recoded in check (T8) plots. Analysis of the data further showed that, mean cane yield was significantly the highest (37.50 t/ha) in T7 followed by 35.97, 31.66, 31.63, 31.46, 31.49 and 31.04 t/ha. In T6, T5, T4, T3, T2 and T1 respectively against the lowest (30.41 t/ha) in check (T8). CCS% was ranged from 12.11 to 12.26 % in T1 and T7, it was significantly lowest (12.05%) in check (T8). Sugar yield was significantly the highest (4.54 t/ha) in T7 followed by 4.40, 3.87, 3.86, 3.81, 3.82 and 3.76 t/ha in T6, T5, T4, T3, T2 and T1 against the lowest (3.66 t/ha) in Check (T8).

Table-1.2 revealed that, in district Charsadda, mean infestation of gurdaspur borer was recorded as lowest (2.50%) in T7 followed by 2.53, 3.37, 4.59, 4.85, 5.05 and 5.54 in T6, T5, T4, T3, T2 and T1 respectively, while it was significantly the highest (6.63%) in T8 (check). Mean cane yield was ranged from 22.28 to 25.15 t/ha in T1 and T7, while it was lowest (20.48 t/ha) in check (T8). CCS% was minimum 11.27% in T1 to Maximum 11.77% in T7 and was lowest (11.07%) in check (T8).Maximum sugar yield (2.95 t/ha.) was recorded in T7 while it was minimum 2.51 t/ha for T1. Lowest sugar yield (2.26 t/ha) was recorded for T8. In district Peshawar (Table-1.3) reveal that mean infestation of borer was ranged from 2.78% in T7 to 5.33% in T1 against the highest (6.32%) in check (T8). Cane yield, CCS% and Sugar yield were minimum 23.28 (t/ha), 10.18 (%) and 2.37 (t/ha) in T1 to maximum 24.66 (t/ha), 10.97% and 2.71 (t/ha) in T7 against the lowest 20.78 (t/ha), 10.12% and 2.10 (t/ha) in check (T8). Statistically analyzed data in Table-1.4 showed that, in district Bunnu, mean infestation of borer in the treated plots was ranged from 2.24 to 4.24% in T7 and T1 against the lowest (5.73%) in check (T8). Cane yield, CCS% and sugar yield were significantly the highest (22.77 t/ha, 11.40% and 2.58 t/ha) in T7 against the lowest (20.45 t/ha, 11.11% and 2.27 t/ha) in check (T8). Results in table- 1.5 revealed that in D.I Khan district, borer infestation was higher (5.00%) in T1 and lowest (2.31%) in T7 against highest (6.19%) in T8. Maximum cane yields, CCS% and Sugar yield (25.13 t/ha, 9.95% and 2.50 t/ha) were recoded in T7. Based on statistically analyzed data, results of all locations revealed that the effect of parasitoid was almost the same on two maximum doses i.e. 18000 and 2000/acre being non-significant on these two doses. These findings are closely in agreement with those of Rajendran and Hanif (1996), Abbas (1997), Soula *et al* (2002), Colong and Shenhmar *et al* (2003) and Mustafa (2006. These workers reported that, release of *Trichogramma* against sugarcane borers alone and in combination with other IPM methods significantly minimized borers infestation and improved cane and sugar yield compared to check plots.

CONCLUSION

It is concluded that, biological control agent (*Trichogramma chilonis)* significantly reduced infestation of gurdaspur borer in sugarcane ratoon crops during the grand growth period (July to September) and also increased cane and sugar yields as compared to untreated plots in all districts. Keeping in view the above study, parasitoid eggs of the above parasitoid @ 16000 to 2000 in the form of 8 to 10 tricho cards per acre should be used for gurdaspur borer in sugarcane at 15 days interval. Awareness about this parasitoid should also be disseminated among the growers as it is selective for borers control and environment friendly compared to other IPM methods specially chemical control having side effects on environment and human beings.

TABLE-1: EFFECT OF DIFFERENT DOSES OF TRICHOGRAMMA ON THE INFESTATION OF GURDASPUR BORER, CANE YIELD, COMMERCIAL CANE SUGAR PERCENTAGE (CCS %) AND SUGAR YIELD (SUGARCANE RATOON FIELDS)

TABLE-1.1:- DISTRICT MARD (Sugar Crops Research Institute Mardan)

Treatments (Parasitized eggs/Acre)	% gurdaspur borer attack			Cane yield (t/ha)			CCS (%)			Sugar yield (t/ha)		
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
8000 (T1)	5.18 b	5.40 b	5.29 b	31.00	31.08	31.04 d	12.12	12.10	12.11 e	3.76	3.76	3.76 e
10000 (T2)	4.45 c	5.19 b	4.82 c	31.45	31.33	31.39 cd	12.15	12.13	12.14 de	3.85	3.80	3.82 d
12000 (T3)	4.02 d	4.65 c	4.33 d	31.51	31.41	31.46 cd	12.15	12.15	12.15 d	3.82	3.81	3.81 d
14000 (T4)	3.38 e	4.08 d	3.73 e	31.69	31.58	31.63 c	12.20	12.22	12.21 c	3.86	3.86	3.86 c
16000 (T5)	2.24 f	3.81 d	3.02 f	31.73	31.60	31.66 c	12.20	12.25	12.22 bc	3.87	3.87	3.87 c
18000 (T6)	2.57 f	2.43 e	2.50 g	36.11	35.83	35.97 b	12.25	12.25	12.25 ab	4.42	4.38	4.40 b
20000 (T7)	2.20 f	2.38 e	2.29 g	37.25	37.75	37.50 a	12.25	12.27	12.26 a	4.56	4.63	4.54 a
Check (T8)	6.05 a	6.29 a	6.17 a	30.25	31.58	30.41 e	12.10	12.00	12.05 f	3.66	3.66	3.66 f

TABLE-1.2:- DISTRICT CHARSADDA (FARMER FIELD OF VILLAGE SHAHIDAN)

Treatments (Parasitized eggs/Acre)	% gurdaspur borer attack			Cane yield (t/ha)			CCS (%)			Sugar yield (t/ha)		
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
8000 (T1)	5.55	5.54	5.54 b	22.12	22.45	22.28 e	11.25	11.30	11.27 g	2.48	2.54	2.51 f
10000 (T2)	5.03	5.07	5.05 c	22.29	22.56	22.42 de	11.30	11.45	11.37 f	2.52	2.58	2.55 ef
12000 (T3)	4.82	4.89	4.85 cd	22.54	22.60	22.57 cde	11.36	11.50	11.43 e	2.56	2.60	2.58 de
14000 (T4)	4.57	4.61	4.59 d	22.85	22.65	22.75 cd	11.45	11.53	11.49 d	2.62	2.61	2.61 cd
16000 (T5)	2.65	4.10	3.37 e	22.95	22.85	22.90 c	11.45	11.61	11.53 c	2.63	2.65	2.64 c
18000 (T6)	2.52	2.54	2.53 f	24.12	25.12	24.62 b	11.70	11.75	11.72 b	2.82	2.95	2.88 b
20000 (T7)	2.50	2.50	2.50 f	24.45	25.85	25.15 a	11.75	11.79	11.77 a	2.87	3.04	2.95 a
Check (T8)	6.72	6.54	6.63 a	20.25	20.71	20.48 f	11.00	11.15	11.07 h	2.22	2.31	2.26 g

Figures in columns having same letters are non-significant at α =0.05

TABLE-1.3- DISTRICT PESHAWAR (FARMER FIELD OF VILLAGE GULBELLA)

Treatments (Parasitized eggs/ Acre)	% gurdaspur borer attack			Cane yield (t/ha)			CCS (%)			Sugar yield (t/ha)		
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
8000 (T1)	5.04	5.62	5.33 b	23.45	23.12	23.28 f	10.15	10.21	1018 b	2.38	2.36	2.37 b
10000 (T2)	5.06	5.09	5.07 bc	23.51	23.46	23.48 e	10.35	10.25	10.30 b	2.43	2.40	2.41 b
12000 (T3)	4.98	4.90	4.94 c	23.62	23.58	23.60 de	10.42	10.25	10.33 b	2.46	2.42	2.44 b

14000 (T4)	3.94	4.32	4.13 d	23.75	23.65	23.70 d	10.45	10.29	10.37 b	2.48	2.43	2.45 b
16000 (T5)	3.75	2.94	3.34 e	23.79	23.97	23.88 c	10.48	10.29	10.38 b	2.29	2.46	2.37 b
18000 (T6)	2.79	2.85	2.82 f	24.33	24.53	24.43 b	10.85	10.75	10.80 a	2.64	2.63	2.63 a
20000 (T7)	2.74	2.82	2.78 f	24.60	24.72	24.66 a	11.00	10.95	10.97 a	2.71	2.71	2.71 a
Check (T8)	6.30 a	6.35 a	6.32 a	20.86	20.71	20.78 g	10.10	10.15	10.12 b	2.11	2.10	2.10 c

TABLE-1.4:- DISTRICT BUNNU (FARMER FIELD OF VILLAGE AZIZABAD)

Treatments (Parasitized eggs/Acre)	% gurdaspur borer attack			Cane yield (t/ha)			CCS (%)			Sugar yield (t/ha)		
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
8000 (T1)	4.60	4.08	4.34 b	21.83	21.35	21.59 c	11.12	11.18	11.15 cd	2.42	2.38	2.40 c
10000 (T2)	4.03	3.38	3.70 c	21.85	21.31	21.58 c	11.13	11.21	11.17 cd	2.43	2.38	2.40 c
12000 (T3)	3.78	3.16	3.47 c	21.89	21.51	21.70 c	11.18	11.23	11.20 bcd	2.44	2.41	2.47 abc
14000 (T4)	3.09	2.98	3.03 d	21.98	21.96	21.97 b	11.20	11.26	11.23 bc	2.46	2.47	2.46 bc
16000 (T5)	2.90	2.13	2.51 e	22.15	22.24	22.19 b	11.22	11.28	11.25 bc	2.48	2.51	2.49 abc
18000 (T6)	2.42	2.15	2.28 e	22.55	22.64	22.59 a	11.33	11.29	11.31 ab	2.55	2.55	2.55 ab
20000 (T7)	2.38	2.10	2.24 e	22.75	22.80	22.77 a	11.38	11.40	11.39 a	2.58	2.59	2.58 a
Check (T8)	5.52	5.94	5.73 a	20.33	20.58	20.45 d	11.10	11.12	11.11 d	2.26	2.29	2.27 d

TABLE-1.5- DISTRICT D.I.KHAN (FARMER FIELD OF VILLAGE)

Treatments	% gurdaspur borer attack			Cane yield (t/ha)			CCS (%)			Sugar yield (t/ha)		
(Parasitized eggs/Acre)	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
8000 (T1)	5.13	4.88	5.00 b	24.31	24.11	24.21 f	9.65	9.72	9.68 f	2.34	2.34	2.34 a
10000 (T2)	4.27	4.65	4.46 c	24.35	24.15	24.25 ef	9.73	9.75	9.74 e	2.37	2.35	2.36 a
12000 (T3)	3.27	3.67	3.47 d	24.38	24.20	24.29 de	9.81	9.75	9.78 d	2.39	2.36	2.37 a
14000 (T4)	3.17	3.26	3.21 d	24.41	24.25	24.33 d	9.85	9.78	9.81 cd	2.40	2.37	2.38 a
16000 (T5)	2.92	2.15	2.53 e	24.45	24.36	24.40 c	9.85	9.81	9.83 c	2.41	2.39	2.40 a
18000 (T6)	2.51	2.13	2.32 e	24.95	24.89	24.92 b	9.89	9.90	9.89 b	2.47	2.46	2.46 a
20000 (T7)	2.50	2.12	2.31 e	25.15	25.12	25.13 a	9.95	9.95	9.95 a	2.50	2.50	2.50 a
Check (T8)	6.00	6.38	6.19 a	21.14	21.10	21.12 g	9.40	9.41	9.40 g	1.99	1.98	1.98 a

Figures in columns having same letters are non-significant at α =0.05

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SUGAR INDUSTRY ABSTRACTS

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Development of a dependable microsatellite-based fingerprinting system for sugarcane

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For long sugarcane breeders have been investing lots of efforts to develop a reliable molecular marker-based fingerprinting system that could aid in many ways the breeding programs. The International Union for the Protection of New Varieties of Plants (UPOV) has also been pursued such a system that, once meets the standard of a DUS (Distinctness, Uniformity and Stability) test, would be used in addition to or to replace morphological characterization used to guarantee the breeders' property rights until now. A large EST database was screened and ~37,000 SSR motifs were identified in 33,000 sequences. Candidate clusters (112 loci) were selected and validated (primer design, PCR amplification and PAGE/DNA sequencer analyses) in a group of sugarcane accessions sharing diverse levels of genetic relationship. These loci were classified according to their PIC values and visual quality of molecular profiles. The top loci were elected to form a "Sugarcane Microsatellite-based Fingerprinting System". Three loci discriminated a collection of 1,205 entries of a germplasm bank with at least two differences (discriminatory alleles). This system is being routinely used in our laboratory in several process such as: i) quality control of the tissue culture facility to avoid varietal mislabeling; ii) identification of duplicated accessions in germplasm bank; iii) determination of genetic similarity indexes to aid the selection of crosses to be performed; iv) determination of selfing levels in seed samples; v) identification of male progenitor of clones originated from polycrosses; vii) identification of hybrids. In the near future we plan to use it as an additional tool for the protection of our varieties. The system has passed several evaluations for stability and repeatability. Protocols for high throughput genotyping in DMA sequencer have been developed. We believe that this system will discriminate all varieties and related sugarcane genotypes existing in the world, qualifying it to become an important tool for all those involved in breeding and property rights of sugarcane varieties.

Experience with micro-propagated plants of sugarcane in the Herbert [Australia]*

G.J. Shannon, R. Pace and L.P. Di Bella

Micro-propagation of sugarcane can be used for rapid propagation of smut resistant varieties for the Australian sugar industry. In the Herbert, a pilot system involving raising smut resistant KQ228'[1]' from plantlets to field trials for release as a clean seed plant source in 2008 has been very successful. This paper outlines the steps taken to achieve this.

Performance-based standards (PBS) vehicles for transport in the agricultural sector*

P A Nordengen, H Prem and PWL Lyne

The South African sugar industry spends in the order of R750 million per annum on sugarcane transport. Although rationalisation processes are in progress, innovative systems are needed to reduce these costs even further. The current fleet of haulage vehicles in South Africa complies with a set of prescriptive regulations which specify a number of parameters. However, it has been recognised that these regulations do not address a vehicle's dynamic performance, and place a constraint on the innovative use of technology to develop new transport vehicles. The objectives of the Performance-Based Standards (PBS) philosophy are to utilize technology to reduce road damage, improve safety, increase payloads and reduce costs. To overcome the limitations of prescriptive legislation, it has been proposed that PBS regulations be introduced. With this system the criteria for design is that the vehicle should conform to a set of performance standards that will achieve the above objectives. This paper will discuss the standards proposed for use in South Africa, the demonstration projects to test these standards, and the way forward to introduce PBS to the sugar industry.

Harvest planning for growers
D. Prestwidge, T. Stainley, D. Skocaj, L. Di Bella, and A. Higgins

Most sugar mill districts in Australia are characterized by large geographical and variety differences in sugar yield that vary throughout a harvest season. Growers are increasingly looking for ways to increase profitability by capitalising on these differences. This is a complex task as there are several variables such as variety, crop class, crop age, CCS, cane yield, and soil type to consider simultaneously when planning the harvest. Sugar Max is a computer-based tool that has been developed to assist growers by capturing information on these variables to provide growers with the flexibility to simulate different harvest schedules for their farms. Sugar Max uses CCS and cane yield trends based on historical productivity trends, linked with optimisation, to select the best combination of harvest times for cane land across the farms. Sugar Max accommodates grower harvest rounds to ensure consistency with harvester equity as well as providing the grower with flexibility to include management decisions such as plough-out, rainfall risk and pests. In the Tully region, 18 growers developed harvest plans across 45 farms for the 2007 season using Sugar Max. Growers in the Herbert region are using Sugar Max to develop scenarios for partnering harvesting groups that take advantage of geographic differences in yield and rainfall throughout the season. They have also used Sugar Max principles to identify areas in the region that would benefit from an early harvest start date. Growers surveyed in Tully enthusiastically support Sugar Max as a valuable tool for farm harvest planning. The development of a web interface to enable wider adoption of the harvest planning tools in the Tully region is currently underway.

Genetic transformation of two Mauritian sugarcane varieties for resistance to the herbicide Basta®
K Mulleegadoo and A Dookun-Saumtally

Two transgenic Mauritian sugarcane varieties, M 292/70 and M 3035/66, resistant to the herbicide Basta® (glu-fosinate-ammonium) were obtained by micro projectile bombardment of embryogenic callus using plasmid pAHC25. This construct contains the *bar* and B-g/ucuronidase (gus) genes both under the control of the maize ubiquitin (Ubi) promoter. Targets were placed at a distance of 6 cm from the macro carrier launch assembly and bombarded at a pressure of 1550 psi. They were osmotically treated prior to and after bombardment. Callus was selected and regenerated on bialaphos-supplemented medium. All plants were treated with the herbicide Basta® six weeks after transfer to the glasshouse and were assayed for herbicide tolerance ten days later. The transgenic nature of the resistant plants was determined by PCR and Southern hybridization. Northern blot analysis confirmed the presence of the *bar* gene transcript.

Evaluation of release quantity and economics of *Epiricania melanoleuca* against *Pyrilla perpusilla* in sugarcane crop
D. C. Rajak, R. A. Verma and R. K. Singh

An experiment was carried out to evaluate the impact of releasing eggs and cocoons of *Epiricania* me/ano/euca Fletcher for the management of *Pyrilla perpusilla* Walker in sugarcane. Parasitization (%) increased, progressively either with increasing number of cocoons viz., 4000, 7000 and 10000 ha^{-1} (36.7%, 46.0% and 52.0%) or with with increasing numbers of eggs released, namely 0.4, 0.7 and 1.0 million ha'^{1} (38.7%, 50.7% and 56.0%, respectively) 45 days after initial release in the field. The percent parasitization by E. me/ano/euca was significantly higher than that recovered in the control plots at all sampling periods except at the beginning of the experiment. These results suggest that 7000 to 10000 cocoons ha^{-1} or 1.0 million eggs of H. me/ano/euca far' provided the highest level of parasitism in field on all days when observations were made. There was no significant difference in the levels of parasitism between eggs or cocoons. Parasitization was noticed in the control plots also but at very low level. This was attributed to the dispersal of E. me/ano/euca along with pyrilla. Costings indicated that management of pyrilla with H. me/ano/euca was cheaper (Rs.216 ha^{-1}) than chemical control with endosulfan 35 E.C@ 2kg ha^{-1} (Rs.1164 ha^{-1}) and ecologically safer. [I U$ = INR 51.6]

"On-the-spot" estimation of rodent infestation in sugarcane
D. C. Srivastava and Rajesh Kumar

Since rodent infestation in sugarcane fields cannot be estimated instantly by the existing methods using population indices, a new criterion namely 'Percentage of rodent infested row segments' was conceived. Counts in 8 and 10 row segments of I Om length each showed the highest infestations and were significantly correlated with the most commonly used criterion viz. 'live burrow counts.' Rodent infestations in sugarcane fields can now be estimated instantly by recording the presence of rodent burrows in 8 samples of 10m long row segments and expressing these in terms of percentage of infested row segments.

Breeding and Genetics
Agronomic performance and genetic characterization of sugarcane transformed for resistance to sugarcane yellow leaf virus
R.A. Gilbert N.C. Glynn, J.C. Comstock and M.J. Davis

Sugarcane yellow leaf virus (SCYLV, a *Poleovirus* of the Luteoviridoe family) is already widespread in Florida, and resistance in the Canal Point (CP) sugarcane population is limited. Genetic transformation of sugarcane for disease resistance holds promise but tissue culture and transformation processes produce undesirable agronomic characteristics necessitating thorough field evaluation. A 3-year sugarcane (a complex hybrid of *Saccharum* species) field study was conducted in Belle Glade, FL with the following objectives: (I) thoroughly evaluate the agronomic performance of two transgenic lines transformed for SCYLV resistance (6-1,6-2) compared with parental cultivar control CP 92-1666, (2) determine level of SCYLV resistance in the transgenic lines, and (3) characterize genetic differences in the transgenic lines compared with CP 92-1666 using simple sequence repeat (SSR) genotyping. Sugarcane yields of CP 92-1666 were superior to both transgenic lines, as well as tissue culture (C-l) and npdl marker gene (20-1) controls, in the plant cane, first ratoon and second ratoon crops. CP 92-1666 recorded an average of 6-5-8.7 tons sucrose ha^{-1} yr^{1} more than genotypes subjected to tissue culture and biolistic transformation. However, SCYLV infection rates in transgenic lines were only 0-5%, compared with 98% in CP 92-1666. Kanamycin field assays indicated that selectable marker gene nptll was stably expressed in all co-transformed lines. SSR genotyping showed 35 additional fragments to be present and 25 existing fragments absent among 6-1, 6-2, C-l and 20-1 compared with CP 92-1666. Although all dones had unique genotypes, the four regenerated clones showed a greater genetic distance from the donor done CP 92-1666 (mean GD 0.4) than to one another (mean GD 0.03). This study reports the first successful gene transfer of SCYLV resistance in sugarcane and the first report of variations in mkrosateilite repeat number associated with regeneration from embryogenic callus. Our results highlight the potential of genetic transformation methods to incorporate desirable traits into sugarcane, combined with the necessity of thorough agronomic evaluation of transgenic genotypes. Transgenic lines 6-I and 6-2 are being used as parents in crosses designed to combine SCYLV resistance from these genotypes with agronomic characteristics of high-yielding materials.

Characterization of a sugarcane (Saccharum spp.) gene homolog to the brassinosteroid insensitive I-associated receptor kinase I that is associated to sugar content
Renato Vicentini, Juliana de Maria Felix, Marcelo Carnier Dornelas and Marcelo Menossi

The present article reports on the characterization of ScBAK I, a leucine-rich repeat receptor-like kinase from sugarcane *(Saccharum* spp.), expressed predominantly in bundle-sheath cells of the mature leaf and potentially involved in cellular signaling cascades mediated by high levels of sugar in this organ. In this report, it was shown that the ScBAK I sequence was similar to the brassinosteroid insensitive I-associated receptor kinase I (BAKI). The putative cytoplasmatic domain of ScBAK I contains all the amino acids characteristic of protein Wnases, and the extracellular domain contains five leucine-rich repeats and a putative leucine zipper. Transcripts of ScBAK I were almost undetectable in sugarcane roots or in any other sink tissue, but accumulated abundantly in the mature leaves. The ScBAK I expression was higher in the higher sugar content individuals from a population segregating for sugar content throughout the growing season. In situ hybridization in sugarcane leaves showed that the ScBAK I mRNA accumulated at much higher levels in bundle-sheath cells than in mesophyll cells. In addition, using biolistic bombardment of onion epidermal cells, it was shown that ScBAKI-GFP fusions were localized in the plasma membrane as predicted for a receptor kinase. All together, the present data indicate that ScBAK I might be a receptor involved in the regulation of specific processes in bundle-sheath cells and in sucrose synthesis in mature sugarcane leaves.

Engineering sugarcane cultivars with bovine pancreatic trypsin inhibitor (aprotinin) gene for protection against top borer *(Scirpophaga* excerpta/is Walker)

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The inhibitory activity of bovine pancreatic trypsin inhibitor (aprotinin), a natural polypeptide and a proteinase inhibitor, was demonstrated on gut proteinases of three lepidopteran borers of sugarcane using commercially available aprotinin.A synthetic gene coding for aprotinin, designed and codon optimized for better expression in plant system (Shantaram 1999), was transferred to two sugarcane cultivars namely CoC 92061 and Co 86032 through particle bombardment. Aprotinin gene expression was driven by maize ubiquitin promoter and the plant selection marker used was hygromycin resistance. The integration, expression and functionality of the transgene was confirmed by Southern, Western and insect bioassay, respectively. Southern analysis showed two to four integration sites of the transgene in the transformed plants. Independent transgenic events showed varied levels of transgene expression resulting in different levels (0.16-0.50%) of aprotinin. In in vivo bioassay studies, larvae of top borer *Scirpophaga excerptalis* Walker (Lepidoptera: Pyralidae) fed on transgenics showed significant reduction in larval weight which indicated impairment of their development. Results of this study show the possibility of deploying aprotinin gene for the development of transgenic sugarcane cultivars resistant to top borer.

Efficient silencing of reporter transgenes coupled to known functional promoters in sugarcane, a highly polyploid crop species

Stephen R. Mudge, Kenji Osabe, Rosanne E. Casu, Graham D. Bonnett, John M. Manners and Robert G. Birch

Sugarcane is a crop of great interest for engineering of sustainable bio-materials and biofuel production. Isolated sugarcane promoters have generally not maintained the expected patterns of reporter transgene expression. This could arise from defective promoters on redundant alleles in the highly polyploid genome, or from efficient transgene silencing. To resolve this question we undertook detailed analysis of a sugarcane gene that combines a simple pattern in genomic Southern hybridization analysis with potentially useful, sink-specific, expression. Sequence analysis indicates that this gene encodes a member of the SHAQYF subfamily of MYB transcription factors. At least eight alleles were revealed by PCR analysis in sugarcane cultivar Q117 and a similar level of heterozygosity was seen in BAC clones from cultivar Q200. Eight distinct promoter sequences were isolated from Q117, of which at least three are associated with expressed alleles. All of the isolated promoter variants were tested for ability to drive reporter gene expression in sugarcane. Most were functional soon after transfer, but none drove reporter activity in mature stems of regenerated plants. These results show that the ineffectiveness of previously tested sugarcane promoters is not simply due to the isolation of nonfunctional promoter copies from the polyploid genome. If the unpredictable onset of silencing observed in most other plant species is associated with developmental potyploidy, approaches that avoid efficient transgene silencing in polyploid sugarcane are likely to have much wider utility in molecular improvement.

Informative genomic microsatelHte markers for efficient genotyping applications in sugarcane

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Genomic microsatellite markers are capable of revealing high degree of polymorphism. Sugarcane *(Saccharum* sp.), having a complex polyploid genome requires more number of such informative markers for various applications in genetics and breeding. With the objective of generating a large set of microsatellite markers designated as Sugarcane Enriched Genomic Microsatellite (SEGMS), 6,318 clones from genomic libraries of two hybrid sugarcane cultivars enriched with 18 different microsatellite repeat-motifs were sequenced to generate 4.16 Mb high-quality sequences. Microsatellite were identified in 1,261 of the 5,742 non-redundant clones that accounted for 22% enrichment of the libraries. Retro-transposon association was observed for 23.1% of the identified microsatellite. The utility of the microstate containing genomic sequences were demonstrated by higher primer designing potential (90%) and PCR amplification efficiency (87.4%).A total of 1,315 markers including 567 class I microsatefce were designed and placed in the public domain for unrestricted use. The level of polymorphism detected by these among sugarcane species, genera, and varieties was 88.6X cross-transferability rate was 93.2% within Saccharum and 25% to cereals. Cloning and sequencing of size variant revealed that the variation in the number of repeat-unto was the main source of SEGMS fragment length polymorphism. of polymorphism and wide range of genetic diversity (O.I6-QJ82 «Mi an average of 0.44) assayed with the SEGMS markers their usefulness in various genotyping applications in sugarcane.

Characterization of new polymorphic functional markers for sugarcane
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Expressed sequence tags (ESTs) offer the opportunity to exploit single, low-copy, conserved sequence motifs for the development of simple sequence repeats (SSRs). The authors have examined the Sugarcane Expressed Sequence Tag database for the presence of SSRs. To test the utility of EST-derived SSR markers, a total of 342 EST-SSRs, which represent a subset of over 2005 SSR-containing sequences that were located in the sugarcane EST database, could be designed from the nonredun-dant SSR-positive ESTs for possible use as potential genie markers. These EST-SSR markers were used to screen 18 sugarcane (Soccnorum spp.) varieties. A high proportion (65.5%) of the above EST-SSRs, which gave amplified fragments of foreseen size, detected polymorphism. The number of alleles ranged from 2 to 24 with an average of *755* alleles per locus, while polymorphism information content values ranged from 0.16 to 0.94, with an average of 0.73. The abOty erf each set of EST-SSR markers to discriminate between varieties was generally higher than the polymorphism information content analysis. When tested for functionality, 82.1% of these 224 EST-SSRs were found to be functional, showing homology to known genes. As the EST-SSRs are within the expressed portion of the genome, they are likely to be associated to a particular gene of interest improving their utility for genetic mapping; identification of quantiabve trait loci, and comparative genomics studies of sugarcane. The development of new EST-SSR markers will have important i tions for the genetic analysis and exploitation of the resources of sugarcane and related species and wrii a more direct estimate of functional diversity.

Pest Control
Genotypic variation of resistance to the spotted stalk borer Chifo *sacchariphagus* (Bojer) in sugarcane: evidence of two distinct resistance mechanisms
S. Nibouche and R. Tibere

We carried out an assessment of the resistance status to the spotted stalk borer *Chilo sacchariphagus* in a sample of 32 international sugarcane clones in Reunion. Our objectives were to characterize the genotypic variability of resistance and to characterize the role of leaf and stalk resistance in the global resistance. A significant genotypic variability in the % exited tunnels and in the leaf feeding injuries confirmed the existence of two resistance mechanisms located respectively in the leaves and in the stalk. Leaf resistance and stalk resistance exhibited genotypic and phenotypic correlation with stalk tunnelling injuries. No phenotypic or genotypic correlations were observed between leaf resistance and stalk resistance. Both resistances contributed independently to the global resistance quantified by the stalk tunnelling. The resistance status of the two main cultivars cultivated in Reunion was assessed within our germplasm sample: 'R 570' was one of the most resistant clones and 'R 579' proved to be moderately susceptible.

Isobutyl amides-potent compounds for controlling D/otroeo *saccharalis*
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A dkhloromethane-methanol extract of the seeds of *Piper tuber-culatom* jacq. (Piperaceae) and two isobutyl amides, 4,5-dihy-dropiperlonguminine (I) and pellitorine (2), which were isolated by chromatographic methods, were assayed for their lethality against the sugarcane borer D/otroeo socchorofe F. (Lepidoptera: Pyralidae). Bioassays were carried out with fourth-instar caterpillars through topical application of test solutions to the dorsal surface of the prothorax, and dose-response correlations were determined. Significant insect mortalities were observed 24, 48 and 72 h after treatment at concentrations of > 100 ug insec^{-1}. The LD_{50} and LD_{90} values for compound I were 92.83 and 176.50 ug insect-1, and for compound 2 they were 91.19 and 184.56 ug insec^{-1}. According to the LD50 and LD90 for compounds I and 2, it can be inferred that the values reflect an acute lethal response to both compounds, based on interaction(s) of the toxicants with a primary target or series of targets.Thus, the amides were demonstrated to have potential value in the control of the sugarcane borer.

Estimating the economic injury level and the economic threshold for the use of a-cypermethrin against the sugarcane borer, *Eldana sac-charina* Walker (Lepidoptera: Pyralidae)
Graeme W. Leslie

Five years of data from insecticide trials that assessed the value of using oc-cypermethrin (Fastac®) against the sugarcane borer *Eldana saccharina* Walker (Lepidoptera: Pyralidae) were used to estimate the economic injury level (EIL) and the economic threshold (ET) for this pest. The analysis was based on estimates of borer damage (percentage of internodes bored) and larval numbers, and the effect of these on estimated percentage recoverable sugar (ERC%) and tonnes ERC/ha. The EIL, based on percent internodes bored (%IB) and ERC%, was more reliable than estimates based on larval numbers and ERC%, and was estimated to be 5.8%IB (± 1.32) or 7.3%IB *(*± 1.65), depending on the level of treatment efficacy selected (50 and 40%, respectively). Where tonnes ERC/ha was used, estimated EIL was 9.3%IB (+1.96) or I I.5%IB (±2.45) for efficacy levels of 50 and 40%, respectively. Least reliable were estimates based on assessments of larval numbers. This was attributed to the weak association between larval populations and intensity of damage over time. Based on estimates of damage accumulation over time, the ET based on %IB and ERC% was estimated to be 2%IB, assuming a 40% treatment efficacy. Such estimates provide useful measures that can aid in deciding whether or not the use of an insecticide is justified.

Life cycle and larval morphology of *Diomus* ter-*minatus* (Coleoptera: Coccinellidae) and its potential as a biological control agent of *Melanaphis sacchari* (Hemiptera: Aphididae)
W Akbar, C. Carlton, and T. E. Reagan

The life cycle, morphology, and potential of *Diomus terminatus* Say (Coleoptera: Coccinellidae) to control the sugarcane aphid, *Melanaphis sacchari* (Zehntner) (Hemiptera: Aphididae), were examined in the laboratory. The morphologies of first and fourth instars are described and illustrated, with emphasis on characters of first instar that differ from those of later instars. Dramatic differences exist in the relative size and abundance of specialized setae between early and late instars. Field-collected late instars of D. *terminatus* were successfully reared to adult stage at 26°C by using *M. sacchari* feeding on small pieces of sugarcane *(Saccharum* spp.) leaves. The eggs laid on the sugarcane leaves hatched in 4.5 ± 0.1 d. Larval and pupal stages lasted an average of 6.8 ± 0.6 and 4.9 ± 0.2 d, respectively. D. *terminatus* required 12.1 ± 0.6 d from egg hatch to adult emergence. The adult longevity test with single adults in petri dishes revealed that D. *terminatus* remained alive for 26 ± 1.9 d when feeding on aphids of mixed ages. The larvae consumed a total of 30 ± 1.8 aphid nymphs, with a daily consumption rate of 4.7 ± 0.4.The adult voracity test showed that D. *terminatus* could consume as many as 19 ± 0.9 aphids per d. These results are discussed with respect to their implications for aphid control in Louisiana sugarcane.

Evaluation of damage caused by stalk borers, *Sesamia* spp. (Lepidoptera: Noctuidae), on sugarcane quality in Iran
Alireza Askarianzadeh, Saeed Moharramipour, Karim Kamali, and Yaghub Fathipour

The noctuid stalk borers, *Sesamia* spp. (S. *cretica* Led. and S. *nonagrioides* Lef.), damage a considerable percentage of sugar-cane internodes annually in the province of Khuzestan, Iran. A study was conducted to quantify the relationship between stalk borer damage and sugar quality to estimate the monetary loss incurred at these levels of damage at harvest time. Three commercial varieties of sugarcane (SP70-I 143, CP69-I062 and CP48-I03) were studied to determine the effects of damage on sugar quality. Stalks were separated into seven groups: control (without damage); one to five bored internodes per stalk; and more than five bored internodes per stalk. The percentage of bored internodes and several parameters, such as pol and brix, were measured. Sugar in the control group was 123.78, 123.72 and 104.84 kg/ton for SP70-II43, CP69-I062 and CP48-103, respectively. Sugar per ton, juice purity, pol and brix were all significantly inversely correlated to the percentage of bored internodes. Estimated sugar losses for every 1% bored internode were 0.17, 0.39 and 0.23% (equal to 210, 482 and 241 kg sugar) in SP70-1 143, CP69-1062 and CP48-103, respectively. These varieties could tolerate damage of up to 18.1, 11.7 and 18.9% bored internodes, respectively, compared to the control. Regression slopes for CP69-1062 were slightly higher than those of the other two varieties. Therefore, based on quality damage, CP69-I062 is susceptible to stalk borer damage.

Selection and life history traits of tebufenozide-resistant sugarcane borer (Lepidoptera: Crambktae)

W. Akbar, J. A. Ottea, J. M. Beuzetn, T. E. Reagan and F. Huang

Varying susceptibility to tebufenozide was recorded in the sugarcane borer, *Diatraea socdtank* (F.) (Lepidoptera: Crambidae), collected from Louisiana sugarcane locations with different selection pressures. Results from diet incorporation bioassays with tebufenozide indicated significant increases in LC_{SO} (3.78-fold) and LC_{90} (7-fold) values for a colony from Duson (DU), an area with higher selection pressure, compared with a colony from Alexandria (ALEX), an area with no selection pressure. Differences were not detected in LC_{50} values among colonies from areas where use of tebufenozide was discontinued or rotated with other chemistries. Selections with tebufenozide of DU larvae over 12 generations resulted in a highly resistant colony (DU-R) with 27.1- and 83.3-fold increases in LC_{50} and LC_{90} values, respectively. Comparison of pupal weight, days to pupation, and emergence after exposure to an equitoxic (LC_{20}) concentration of tebufenozide revealed a decrease in pupal weight (34 and 33% for males and females, respectively), and an increase in days to pupation (47 and 40% for males and females, respectively), and emergence (43 and 33% for males and females, respectively) for the DU-R colony compared with the parent DU colony. Fecundity of DU-R females decreased to 72 eggs per female compared with 180 (DU) and 261 (ALEX). Egg viability of the ALEX and DU colonies was 61 and 56%, respectively, whereas only 27% of eggs laid by females from the DU-R colony hatched. These results are discussed in terms of their practical implications for control of D. *saccharalis* in Louisiana sugarcane.

Physiology

Purification, kinetic and thermodynamic characterization of soluble acid invertase from sugarcane (*Socchorum officinorum* L.)

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We report for the first time kinetic and thermodynamic properties of soluble acid invertase (SAI) of sugarcane (Socchorum officinorum L.) salt sensitive local cultivar CP77-400 (CP-77). The SAI was purified to apparent homogeneity on FPLC system. The crude enzyme was about 13 fold purified and recovery of SAI was 35%. The invertase was monomeric in nature and its native molecular mass on gel filtration and subunit mass on SDS-PAGE was 28 kDa. SAI was highly acidic having an optimum pH lower than 2. The acidic limb was missing. Proton transfer (donation and receiving) during catalysis was controlled by the basic limb having a pKa of 2.4. Carboxyl groups were involved in proton transfer during catalysis. The kinetic constants for sucrose hydrolysis by SAI were determined to be: k_m= 55 mg ml'^{1}. k_{cat}= 21 $-', k_{cat}/k_m= 0.38, while the thermodynamic parameters were: AH* = 52.6 kj moM, AG* = 71.2 kj mol-^{1}, AS* = -57 J moM 1C^1, AG*$_{E\_S}$= 10.8 kj mol"^{1} and AG*^^ 2.6 kj mol"^{1}. The kinetics and thermodynamics of irreversible thermal denaturation at various temperatures 53-63°C were also determined. The half -life of SAI at 53 and 63°C was I 12 and 10 min, respectively. At 55°C, surprisingly the half-life increased to twice that at 53°C. AG*, AH* and AS* of irreversible thermal stability of SAI at 55°C were 107.7 kj mol-^{1}, 276.04 kj moM and 513 J mol-'K-', respectively.

Differential expression of genes in the leaves of sugarcane in response to sugar accumulation

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In C_4 sugarcane (*Socchorum* spp. hybrids), photosynthetic activity has been shown to be regulated by the demand for carbon from sink tissues. There is evidence, from other plant species, that sink-limitation of photosynthesis is facilitated by sugar-signaling mechanisms in the leaf that affect photosynthesis through regulation of gene expression. In this work, we manipulated leaf sugar levels by cold-girdling leaves (5°C) for 80 h to examine the mechanisms whereby leaf sugar accumulation affects photosynthetic activity and assess whether signaling mechanisms reported for other species operate in sugarcane. During this time, sucrose and hexose concentrations above the girdle increased by 77% and 81 %, respectively. Conversely, leaf photosynthetic activity (A) and electron transport rates (ETR) decreased by 66% and 54%, respectively. Quantitative expression profiling by means of an Affymetrix GeneChip Sugarcane Genome Array was used to identify genes responsive to cold-girdling (56 h). A number of genes (74) involved in primary and secondary metabolic pathways were identified as being differentially expressed. Decreased expression of genes related to photosynthesis and increased expression of genes involved in assimilate partitioning, cell wall synthesis, phosphate metabolism and stress were observed. Furthermore four probe sets homologous to trehalose 6-phosphate phosphatase (TPP; EC 5.3.1.1) and trehalose 6-phosphate synthase (TPS; EC 2.4.1.15) were up- and down-regulated, respectively, indicating a possible role for trehalose 6-phosphate (T6P) as a putative sugar-sensor in sugarcane leaves.

The predicted subcellular localisation of the sugarcane proteome
Renato Vicentini and Marcelo Menossi

Plant cells are highly organized, and many biological processes are associated with specialized sub cellular structures. Sub cellular localization is a key feature of proteins, since it is related to biological function. The sub cellular localization of such proteins can be predicted, providing information that is particularly relevant to those proteins with unknown or putative function. We performed the first in *silica* genome-wide sub cellular localization analysis for the sugarcane tran-scriptome (with 11 882 predicted proteins) and found that most of the proteins were localized in four compartments: nucleus (44%), cytosol (19%), mitochondria (12%) and secretary destinations (11%). We also showed that ~ 19% of the proteins were localized in multiple compartments. Other results allowed identification of a potential set of sugarcane proteins that could show dual targeting by the use of N-truncated forms that started from the nearest downstream in-frame AUG codons. This study was a first step in increasing knowledge about the sub cellular localization of the sugarcane proteome.

Agronomy
Management of drip irrigated sugarcane in western India
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The present study on drip irrigation in sugarcane was undertaken to assess crop yield, quality of juice, nutrient uptake and its utilization efficiency, irrigation water use efficiency, and soil moisture status for two crop years at the Research Farm of Water Management, Mahatma Phule KrishiVidhyapeeth, Rahuri, Maharashtra (long. 19°45' to 19°57' north; lat 74° 18' to 74°6S' east), India. Drip irrigation at 2-, 3-, and 4-day intervals produced 20, 16 and 13% higher cane yield than furrow irrigation at 75 mm cumulative pan evaporation (CPE) in which the cane yield was 131.4 t ha^{-1}. During the crop growth period, soil moisture depletion was 34-46% in furrow-irrigated treatment and 5-20% in drip-irrigated treatment Similarly, 108% higher irrigation water use efficiency was achieved in 2-day drip irrigation over furrow irrigation in which the irrigation water efficiency was 787 kg ha^{-1}cm. Fertilization through drip improved agronomic efficiency, physiological efficiency, and apparent recovery considerably more than furrow irrigation.

Effects of sugarcane residue and green manure practices in sugarcane-ratoon-wheat sequence on productivity, soil fertility and soil biological properties
Ramesh Chandra, N. S. Rana, Sanjay Kumar and G. S. Panwar

In a field experiment conducted during 2002 to 2004 in silt clay loam soil at Pantnagar, India, treatment of trash burning + *Sesbania aculeata* green manure (GM) incorporation gave the highest increases of 50.6 and 17.7% in ratoon cane yield and 15.0 and 19.4% in wheat grain yield over trash removal and trash burning treatments, respectively. Soil organic C and available N after ratoon and wheat crops were highest with trash removal + GM incorporation and available P and K with trash removal + GM mulch. The different treatments of trash and GM management were also superior to trash removal and trash burning in organic C and available N and P in soil at termination of the study. Soil microbial biomass C and dehydrogenase activity at the end were at a maximum with trash burning + GM mulch and trash removal + GM mulch treatments, respectively. Compared to trash removal and trash burning, counts of bacteria in soil after ratoon and wheat crops were significantly more only with different GM treatments; however, all GM and trash application treatments recorded significantly higher counts of fungi and actinomycetes. Irrespective of the treatments, population of total bacteria in soil decreased, while that of fungi and actinomycetes increased as compared to their initial counts following sugarcane-ratoon-wheat sequence.

Effects of organic and inorganic fertilizer on growth, yield, and juice quality and residual effects on ratoon crops of sugarcane

S. M. Bokhtiar, G. C. Paul and K. M. Alam

Field experiments were carried out for three consecutive years (2003-2006) at Bangladesh Sugarcane Research Institute farm soil on plant (first crop after planting) and subsequent two ratoon crops of sugarcane. The main objectives of the study were to assess the direct and residual effects of organic and inorganic fertilizer on growth, yield, and juice quality of plant and ratoon crops. The plant crop consisted of four treatments. After harvesting of plant crop to evaluate the residual effects on ratoon crop the plots were subdivided except the control plot. Thus, there were seven treatments in the ratoon crop. Application of recommended fertilizer [nitrogen (N 1_{50}), phosphorus (P_{52}). potassium (K^), sulfur (Sjj), and zinc (Zn_3) kg ha~'] singly or 25% less of it either with press mud or farmyard manure (FYM) at 15 t ha^{-1} produced statistically identical yield ranged from 67.5 to 69.0 t ha^{-1} in plant crop. In the ratoon experiment when the recommended fertilizer was applied alone or 25% less of its either with press mud or FYM at 15 or even 7.5 t ha^{-1} again produced better yield; it ranged from 64.8 to 69.2 in first ratoon and 68.2 to 76.5 t ha^{-1} in second ratoon crops. Results showed that N, P, K, and S content in leaf progressively decreased in ratoon crops over plant crop. Juice quality parameters viz. brix, pol, and purity % remained unchanged both in plant and ratoon crops. Furthermore, organic carbon (C), available N, P, K, and S were higher in post harvest soils that received inorganic fertilizer in combination with organic manure than control and inorganic fertilizer treated soil. It may be concluded that the application of 25% less of recommended fertilizer ($N_{|12}$, P_{40}, K_{68}, S_{26}, and Zn_{225} kg ha^{-1}) either with press mud or FYM at 15 t ha^{-1} was adequate for optimum yield of plant crop. Results also suggest that additional N (50% extra dosage) keeping all other fertilizers at the same level like plant crop i.e. NI_{68}, $P_{40>}$ K_{68}, S_{26}, and Zn_{22S} kg ha^{-1} either with press mud or FYM at 7.5 t ha^{-1} may be recommended for subsequent ratoon crops to obtain good yield without deterioration in soil fertility.

Environmental Issues

Environmental, land-use and economic implications of Brazilian sugarcane expansion 1996-2006

Gerd Sparovek, Alberto Barretto, Goran Berndes, Sergio Martins and Rodrigo Maule

Governments are promoting biofuels and the resulting changes in land use and crop reallocation to biofuels production have raised concerns about impacts on environment and food security. The promotion of biofuels has also been questioned based on suggested marginal contribution to greenhouse gas emissions reduction, partly due to induced land use change causing greenhouse gas emissions. This study reports how the expansion of sugarcane in Brazil during 1996-2006 affected indicators for environment, land use and economy. The results indicate that sugarcane expansion did not in general contribute to direct deforestation in the traditional agricultural region where most of the expansion took place. The amount of forests on farmland in this area is below the minimum stated in law and the situation did not change over the studied period. Sugarcane expansion resulted in a significant reduction of pastures and cattle heads and higher economic growth than in neighboring areas. It could not be established to what extent the discontinuation of cattle production induced expansion of pastures in other areas, possibly leading to indirect deforestation. However, the results indicate that a possible migration of the cattle production reached further than the neighboring of expansion regions. Occurring at much smaller rates, expansion of sugarcane in regions such as the Amazon and the Northeast region was related to direct deforestation and competition with food crops, and appear not to have induced economic growth. These regions are not expected to experience substantial increases of sugarcane in the near future, but mitigating measures are warranted.

Environmental Factors

Sugarcane response to nitrogen fertilization on a Histosol with shallow water table and periodic flooding

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Sugarcane *(Saccharum* spp.) is increasingly exposed to periodic floods and shallow water tables on Histosols in Florida's Everglades Agricultural Area (EAA). In the past, when these soils were usually well drained, they provided excess N for sugarcane through microbial oxidation. It is not known if supplemental N would now improve yields because microbial oxidation is reduced by shallow water tables and periodic floods. The purpose of this study was to evaluate the effects of N fertilizer rates on two sugarcane cultivars exposed to a 25-cm water-table depth with and without repeated 2-day floods. Two studies were planted in containers in 2001 and 2002 with two sugarcane cultivars and five equally spaced rates of N fertilizer from 0 to 200 kg ha^{-1}. Leaf, stalk and root weights were reduced by periodic flooding and the magnitude of the reduction sometimes differed between cultivars. Plant weights, leaf chlorophyll content (SPAD) and leaf N content were often highest near an N rate of 100 kg ha^{-1}. Usually, N fertilizer rate did not interact with water treatment. Nitrogen fertilization may be useful for sugarcane exposed to water-table depths of 25 cm with and without 2-day repeated floods on EAA Histosols.