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Full Length Article

Evaluation of New Sugarcane Genotypes for Biometric Traits, Resistance to Red Rot and Borers Complex under Agro-Climatic Conditions of Faisalabad, Pakistan

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Abstract

Adaptability of new candidate sugarcane genotypes is challenging in different sugarcane growing regions of Pakistan due to diverse edaphic and climatic conditions. Climate change is hampering productivity of commercial varieties due to elevated attack of sugarcane diseases, red rot in particular and insect pests intensity. This two-year study was conducted to evaluate the performance of five promising sugarcane genotypes against check variety CPF 247 for biometric evaluation and resistance to red rot and borers complex for two consecutive growing seasons (2014–2015 and 2015–2016). Results indicated a significant varietal difference among the clones for adaptability and genotypic response in semi-arid conditions of Faisalabad. The genotype, S2006 SP-93, exhibited higher sprouting, stalk diameter, stalk length, cane yield and sugar yield than all others including check variety. Among all six clones, only genotype S2006 SP-93 showed moderately resistant reaction whereas rest of clones were remained susceptible to red rot disease during both years. Genotypic response for resistance against borers complex was not consistent for both years of study. All clones were found resistant or moderately resistant except Thatta-910 and CSSG-32, which were moderately susceptible for 1st and 2nd year, respectively. In conclusion, new sugarcane genotype S2006 SP-93 found superior owing to good agronomic and qualitative performance, better resistance to red rot and borers complex than other clones tested under the agro-ecological conditions of Faisalabad.

Keywords: Sugarcane; Biometric performance; Sucrose contents; Red rot; Borers resistance

Introduction

Sugarcane (*Saccharum officinarum* L.) is widely cultivated in 105 countries of the world. Brazil is the largest sugarcane producer while Pakistan positioned at fifth for area and production (F.A.O. 2017). Sugarcane is an important cash crop in Pakistan, mainly cultivated for sugar production. It represents 2.9% share in agriculture value addition and 0.5% in Gross Domestic Production of the country. Average national yield is 61 tons of canes ha^{-1} (TCH) against the 71 TCH production at global level (FAO 2017; GOP 2019). Sugarcane provides raw material to 90 sugar mills in the country, and among them 45 are in Punjab province (PSMA 2018) to produce sugar and other by-products. Beside this, it also provides direct and indirect employment to millions of people.

Climate change has become a major threat to agricultural productivity due to rise in temperature, altered rainfall pattern (intensity and frequency), emergence of new diseases and insect pests, introduction of new weeds and soil related problems like salinity and water logging (Zhao and Li 2015). Its effects have been reported extensively on cane yield and sugar recovery throughout the Punjab (Hussain *et al.* 2018). Due to inter and intra-annual variation in climatic conditions of the whole sugarcane growing area, a sugarcane variety exhibit good cane yield and sugar recovery pattern in a particular area whereas it loses its potential in other locality. The higher diurnal temperature has increased crop evapotranspiration losses causing rapid depletion of water from plant root zone. This condition is resulting in low crop germination, temporary wilting of crop plants, sun burning of leaves, poor crop ratooning and increased insect pests pressure (Hussain *et al.* 2018). Prolonged dry weather has become another serious problem affecting sugarcane productivity very badly. According to a study conducted by Pakistan Institute of Development Economics, rise of 1-2ºC in temperature could decrease sugarcane production by 14-40%, respectively (Siddiqui *et al.* 2012). Sugarcane productivity may have negative correlation and will continue to be considerably affected with increasing frequency and intensity of extreme environmental conditions due to climate change (Zhao and Li 2015).

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Temperature extremes along with heavy and unscheduled rains are creating escalated conditions of either drought or floods in sugarcane growing areas. This situation results in late planting of sugarcane crop, lodging, increased weed infestation, high incidence of red rot and attack of borers complex in those particular areas (Hussain *et al.* 2018). Adaptation and success of a sugarcane variety depends upon its adaptability to agro-climatic conditions of the area (Siddiqui *et al.* 2012). Therefore, a comprehensive research plan is required for sugarcane varietal development through fine tuning the process of adaptability testing to evolve new site-specific and climate resilient sugarcane varieties.

A strong variety development program for sugarcane is utmost important for countries like Pakistan where most of commercial sugarcane varieties released are developed from exotic fuzz or direct introduction (Nadeem *et al.* 2011; Afghan *et al.* 2013). Similarly, sugarcane cultivation is distributed across the county in various regions which differed from each other for climatic conditions, soil type and farming approach of growers. Selection of a proper variety to be planted in a particular agro-ecological zone is pre-requisite to explore its quantitative and qualitative characteristics (Hassan *et al.* 2017). The new candidate varieties/hybrids submitted by the public/private sugarcane research organization are tested for their yield potential, quality parameters, disease and insect pest resistance and other characteristics of economic importance under varied agro-ecological zones.

Red rot is one of the most recognized and notorious disease of sugarcane crop. It is a soil and seed transmissible disease (Khan *et al.* 2011). The disease is prevailing across the globe in all sugarcane growing areas but it is main problem of tropical and sub-tropical regions (Kumar *et al.* 2010). It is most serious threat to sugarcane crop (Duttamajumdar 2008) and causes decline in cane weight by 29 to 83%, juice extraction by 24 to 90% and sucrose contents reduces from 31 to 75% at different infection levels (Munir *et al.* 1986; Khan *et al.* 2011). The disease is responsible for failure of many popular varieties in different countries (Satyavir 2003; Khan *et al.* 2011). It is also major disease which is responsible for failure or elimination of several commercial varieties and elite clones of sugarcane from field (Viswanathan 2010).

In recent years, sugarcane insects particularly borers complex has emerged as one of main limiting factor for sugarcane productivity. The testing of promising sugarcane genotypes against borers complex is vital to find out resistant genotypes in variety releasing system. Sugarcane borers cause death of the shoots and stalks by blocking food supply to aerial parts of stem and leaves (Gul *et al.* 2008; Dinardo-Miranda *et al.* 2012). The type and intensity of insect pests varies in different cane growing areas of the country.

In the context of changing climatic patterns in our part of the world, there is a dire need of evaluating the new sugarcane germplasm against prevailing insect pest pressure in field conditions as a part of variety development program. It will also give insight of the future response of the genetic material lying with the prime public research and development organization in the country. Therefore, present study on adaptability of new candidate sugarcane varieties was carried out to evaluate their performance for biometric traits and genotypic resistance against red rot disease and borers complex in semi-arid conditions of Faisalabad.

Materials and Methods

Site description

This study was carried out during 2014–2015 and 2015–2016 at Sugarcane Research Institute (SRI), Ayub Agricultural Research Institute (A.A.R.I.), Faisalabad, Pakistan. Physico-chemical analysis of soil of experimental site was done before sowing. For this purpose, composite soil samples were collected from site at a depth of 15–30 cm. Soil analysis was carried out at the Soil and Water Testing Laboratory for Research, AARI, Faisalabad and is given in Table 1. Weather data of the experimental location for both crop seasons is presented in Table 2.

Experimental details

The study was comprised of five new sugarcane candidate varieties (Thatta-910, YTTh-236, S2006 SP-93, HoSG-31 and CSSG-32), belonging to different sugarcane research and development institutes of country and were tested against standard variety CPF 247. The trial was laid out in randomized complete block design with four replications. The crop was planted at 120 cm apart deep trenches in plots measuring size of 6.0 m × 4.8 m in autumn season (September 14, 2015 and September 18, 2016) during both years. The sugarcane seed was taken from healthy plant crop, cut and trashed manually. Seeding rate of 50,000 triple budded setts (billets) ha^{-1} was maintained at the time of planting.

Crop husbandry

Trenches were made with sugarcane ridger designed by the Sugarcane Research Institute, Faisalabad. The NPK fertilizers were applied at the recommended rate of 168-112-112 kg ha^{-1} by using urea, di-ammonium phosphate (DAP) and sulphate of potash (SOP) as source for nitrogen, phosphorus and potash, respectively. Full dose of phosphorus and potassium fertilizers were applied manually in trenches at the time of planting. Whereas nitrogen was applied in three equal splits at 45, 75 and 120 days after planting (DAP). Then, sugarcane billets (counted for each experimental unit to maintain equal seeding rate) were placed in two rows of each trench and afterward thin layer of soil were applied manually. Light irrigation was applied to ensure better sprouting of crop. One dose of herbicides;

Table 1: Physico-chemical analyses of soil during both years of sugarcane cultivation

Determination	2014–2015	2015–2016
Texture	Loam	Loam
Saturation (%)	37	35
pH	7.5	7.6
EC (dS m^{-1})	2.02	2.18
Organic matter (%)	0.89	0.97
Total N (g kg^{-1})	0.53	0.61
Available P (mg kg^{-1})	7.82	6.98
Available K (mg kg^{-1})	149	156

Table 2: Weather data during both years of sugarcane cultivation

Months	2014–2015			2015–2016		
	Mean temperature (C^o)	Mean relative humidity (%)	Total rainfall (mm)	Mean Temperature (C°)	Mean relative humidity (%)	Total rainfall (mm)
September	29.3	71.0	209	30.1	61.5	64.4
October	25.6	61.0	3.6	26.3	63.0	13.6
November	19.1	62.0	22.0	19.5	63.5	0.0
December	12.4	68.0	0.0	14.6	64.0	0.0
January	11.7	66.5	12.4	12.5	66.5	12.2
February	16.6	64.5	23.3	16.3	64.5	5.8
March	19.2	66.5	58.7	21.6	66.5	78.0
April	27.5	52.0	20.8	28.5	52.0	6.1
May	32.6	48.5	20.0	33.1	49.0	41.0
June	32.8	33.8	33.8	34.9	54.0	41.5
July	31.4	66.5	126.7	32.1	66.5	154.5
August	31.6	69.5	51.6	31.5	69.5	66.1
September	30.1	61.5	64.4	31.2	61.5	5.8
October	26.3	63.0	13.6	27.2	63.0	2.0
November	19.5	63.5	0.0	20.3	63.5	0.0
December	14.6	64.0	0.0	16.5	64.0	0.0

Source: Observatory of plant physiology section, Agronomic Research Institute-AARI, Faisalabad

atrazine + mesotrione at the rate of 2500 mL and ethoxysulforon (50 g ha^{-1}) was sprayed at 30 DAP to keep crop free from all types of weeds. Two interculturings with tractor were employed and earthing up was done after completing all fertilizer dose at 120 DAP. Overall, 19 irrigations (each of about 100 mm) were applied to crop in addition to rainfalls during entire cropping seasons.

Crop harvesting

The crop was harvested after achieving maturity in the month of December of each year under study. The whole plot was separately harvested, topped, trashed and tighten in bundles manually to record striped cane yield for each experimental unit using floor weighing balance.

Observations on sprouting were recorded at 65 DAP by counting all germinants in plots to work out sprouting % and all tillers per plot were counted at 120 DAP to calculate tillers $plant^{-1}$ by using following formula:

$$\text{Tillers plant}^{-1} = (\text{total tillers} - \text{total sprouts})/\text{total sprouts}$$

Whereas, cane thickness was measured with Vernier caliper and cane length was recorded with meter rod from randomly taken 10 stalks form each experimental unit and then averaged. Millable canes and striped cane yield were recorded at harvesting of crop on whole plot basis. For this purpose each experimental unit was cut, all stalks were stripped, topped and then counted and weighed on floor balance to calculate data on plot basis. This data were then converted into ha basis.

Ten canes were randomly taken from bulk produced in each plot for qualitative juice analysis at the Sugarcane Technology Laboratory-SRI, Faisalabad. Each composite sample was subjected to extract juice by cane crusher having extraction capacity of ±70%. While brix were recorded by brix hydrometer standardized at 20°C and pol percent were determined by Horn's dry lead sub-acetate method of sucrose analysis (Anonymous 1970). The commercial cane sugar percentage (CCS%) was assessed by the Australian commercial cane sugar formula described by Meade and Chen (1977) as:

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

Where P stands for pol% of first expressed juice, B is brix% of first expressed juice and F is fiber% of cane.

Sugar yield was calculated by using the formula:

$$\text{Sugar yield} = \text{CCS\%} / 100 \times \text{stripped cane yield}$$

Screening against red rot disease

The candidate sugarcane genotypes were screened under artificial inoculated condition against red rot (*Collectorichum falcatum*) pathogen. Inoculation of standing canes of

sugarcane crop was carried out by inoculating lower internodes during July–August using plug technique @ 20–25 spores/microscopic in field. The inoculated stalks were harvested after two months of inoculation and disease spread with symptoms of internal lesions/spots were recorded on basis of reaction to variety on scale (0–9) given by Srinivasan and Bhat (1961) (Table 3).

Table 3: Criteria for screening of sugarcane genotypes against red rot disease

Reaction to disease	Disease score
Resistant (R)	0.0 – 2.0
Moderately resistant (MR)	2.1 – 4.0
Moderately susceptible (MS)	4.1 – 6.0
Susceptible (S)	6.1 – 8.0
Highly susceptible (HS)	Above 8.0

(Kalaimani, 2000)

Table 4: Criteria for screening of sugarcane genotypes against borers complex

Reaction	Inter-nodal damage (%)		
	Top borer	Stem borer	Root borer
Resistant (R)	0–10	0–10	0–10
Moderately Resistant (MR)	10.1–20	10.1–20	10.1–20
Susceptible (S)	20.1–40	20.1–40	20.1–40
Highly Susceptible (HS)	40.1 and above	40.1 and above	40.1 and above

Screening for resistance against sugarcane borers complex

For this purpose dead heart (%) was recorded twice during the months of April & May with one month interval by counting total number of tillers along with infested tillers from each plot. At harvesting, inter-node damage was recorded by collecting samples of ten randomly taken canes form each experimental unit. Then, all stalks were splitted longitudinally and closely observed for borer damage. Internode damage was recorded by counting total number of internodes along with attacked internodes for each borers separately. The assessment of reaction for resistance of different sugarcane borers was noticed as per grading given by Singh *et al.* (2002) given in Table 4.

Statistical analysis

The data collected were subjected to statistical analyses as described by Freed (1990) employing Statistix 8.1 and least significant difference test (LSD) was used to rank all sugarcane genotypes for their biometric performance (Steel *et al.* 1997).

Results

Biometric performance of sugarcane genotypes

Promising sugarcane varieties indicated significant difference for all growth related traits, cane yield, yield attributes and qualitative characteristics for both years of experimentation. Data given in Table 5 showed that during first year (2014–2015) sprouting potential of all sugarcane genotypes varied significantly and was maximum (49.4%) for S2006 SP-93 and lowest (29.7%) for CSSG-32. The highest number of tillers plant^{-1} (2.47) was noticed for check variety (CPF 247) but it was at par with S2006 SP-93 (2.41); whereas the lowest (1.86) were noticed for CSSG-32 (Table 5). The maximum cane thickness of 3.10 cm was observed for clone S2006 SP-93 while the minimum thickness (2.25 cm) was noticed for CSSG-32. Tallest canes (245 cm) were produced by genotype S2006 SP-93 against shortest (159 cm) by CSSG-32 (Table 5). In case of millalbe canes, clone S2006 SP-93 was on top with maximum value of 119 (10^3 canes ha^{-1}), while minimum number of millable canes of 67.7 (10^3 ha^{-1}) was observed in CSSG-32 (Table 5). The data also revealed that the highest stripped cane yield of 130.2 TCH was recorded for S2006 SP-93 and lowest (72.8 TCH) was for CSSG-32 (Table 5). On an average, S2006 SP-93 exhibited 15% higher cane yield than local check whereas CSSG-32 could not surpass local check for cane yield which was lowered by 35%. Maximum sucrose contents (13.14%) were noticed for S2006 SP-93 which was closely followed by Thatta-910 (12.9%), CPF 247 (12.82%) and YTTh-236 (12.44%), while it was minimum (10.03%) for clone CSSG-32 (Table 5). The highest sugar yield (17.11 t ha^{-1}) was exhibited by clone S2006-SP-93 against lowest (7.29 t ha^{-1}) by CSSG-32 (Table 5).

During 2nd year of crop (2015–2016), sugarcane genotypes were also differed significantly for agronomic and qualitative characteristics. Likewise 1st year, genotype S2006 SP-93 exhibited better sprouting than all others with an average value of 50.4% against lowest (31.9%) for CSSG-32 (Table 5). The check variety CPF 247 remained on top with maximum number of tillers plant^{-1} (2.47) and was closely followed by S2006 SP-93 (2.45 tillers plant^{-1}) however, minimum value (1.90) was associated with CSSG-32 (Table 5). The data presented in Table 5 indicated that thickest stalks (3.15 cm) were yielded by genotype S2006 SP-93 against thinnest (2.28 cm) by CSSG-32. Maximum cane length (243 cm) was recorded for S2006 SP-93 while it was minimum (161 cm) for CSSG-32 (Table 5). The clone S2006 SP-93 surpassed all other genotypes by producing maximum millalbe canes (117 10^3 ha^{-1}) against the lowest (70 10^3 ha^{-1}) by CSSG-32. It is also evident from the data (Table 5) that clone S2006 SP-93 again exhibited good performance during 2nd year of study than others and was proved to be better with highest cane yield of 129 TCH followed by HoSG-31 with 120.6 TCH than the lowest (74.3 TCH) for CSSG-32. Maximum sucrose contents (12.77%) was recorded for YTTh-236 but this difference could not reached to the level of significance over Thatta-910 (12.41%), CSSG-32 (12.31%), CPF 247 (12.17%) and S2006 SP-93 (11.88%) against lowest (10.92%) was noticed for HoSG-31 (Table 5). In case of sugar yield, it was found highest (16.29 t ha^{-1}) for genotype S2006 SP-93 while lowest was recorded for CSSG-32 having sugar yield of

Table 5: Effect of sugarcane genotypes on agronomic and qulaitative traits of sugarcane crop

Sugarcane genotype	Sprouting (%)	Tillers plant^{-1}	Stalk diameter (cm)	Stalk length (cm)	Millable cane yield ($\times 10^3$ ha^{-1})	TCH	Sucrose contents (%)	Sugar yield (t ha^{-1})
Crop Season 2014–2015								
S2006 SP-93	49.4 a	2.41 a	3.10 a	245 a	119 a	130.2 a	13.14 a	17.11 a
HoSG-31	46.2 b	2.34 b	2.92 b	230 b	109 b	122.7 b	11.90 b	12.61 b
CSSG-32	29.7 f	1.86 e	2.25 f	159 f	67.7 f	72.8 f	10.03 c	7.29 e
Thatta-910	40.2 d	2.20 c	2.60 d	197 d	86.5 d	102.7 d	12.90 a	13.26 c
YTTh-236	35.5 e	2.10 d	2.46 e	174 e	77.0 e	90.2 e	12.44 ab	11.23 d
CPF 247 (Check)	43.8 c	2.47 a	2.75 c	217 c	96.5 c	112.7 c	12.82 a	14.46 bc
LSD value at 5%	1.36	0.06	0.06	8.59	5.76	5.74	0.82	1.33
Crop Season 2015–2016								
S2006 SP-93	50.4 a	2.45 ab	3.15 a	243 a	117 a	129.0 a	11.88 ab	16.29 a
HoSG-31	46.0 b	2.36 b	2.94 b	237 a	107 b	120.6 ab	10.92 b	14.02 bc
CSSG-32	31.9 d	1.90 e	2.28 f	161 d	70.0 e	74.3 e	12.31 a	9.71 d
Thatta-910	40.3 c	2.26 c	2.63 d	199 c	88.9 c	102.4 c	12.41 a	13.53 bc
YTTh-236	37.6 c	2.13 d	2.46 e	172 d	79.9 d	90.2 d	12.77 a	12.27 c
CPF 247 (Check)	45.5 b	2.47 a	2.77 c	221 b	96.8 c	113.4 b	12.17 a	14.70 ab
LSD value at 5%	2.85	0.09	0.06	13.0	8.29	8.76	0.97	1.81

Means sharing different letters in a column, statistically differ from each other
TCH = Tons of canes hectare^{-1}

Table 6: Resistance of sugarcane genotypes against red rot disease

Genotype	Reaction against red rot disease	
	Crop Season 2014–2015	Crop Season 2015–2016
S2006 SP-93	MR	MR
HoSG-31	S	S
CSSG-32	S	S
Thatta-910	S	S
YTTh-236	S	S
CPF 247 (Check)	S	S

MR = Moderately resistant; S = Susceptible

9.71 t ha^{-1} (Table 5).

Screening of promising sugarcane genotypes against red disease

Disease reaction to red rot of all genotypes under study indicated relative response of clones during both crop seasons in terms of red rot resistance (Table 6). During both years of study, none of clones showed resistant reaction to red rot on disease rating scale except S2006 SP-93 which exhibited moderate resistant reaction against the disease in field conditions.

Screening against insect pests (borers complex) Tolerance

The results presented in Table 7 revealed that during first year of study, out of six varieties including check, minimum tiller infestation (4.08%) was recorded on CPF 247 against maximum (6.74%) in CSSG-32, whereas values for rest of clones were ranging between 5.91 and 6.55%. All sugarcane genotypes were found resistant against top borer and root borer and their inter-node damage was ranged from 0.00 to 3.03% and 1.68 to 4.99%, respectively. However, minimum inter-node damage (4.53%) by stem borer was recorded on CPF 247 and maximum (13.52%) on HoSG-31, hence three clones were found resistant and three moderately resistant to stem borer. The cumulative inter-node was recorded minimum (7.21%) on CPF 247 and maximum (17.85%) on HoSG-31 followed by Thatta-910 (17.36%). Out of five promising clones tested against CPF 247, three were moderately resistant and two moderately susceptible against sugarcane cane borers. No attack of Gurdaspur borer was observed during first crop season.

During second year, minimum tiller infestation (5.95%) was recorded on check variety (CPF 247) while maximum (10.48%) on CSSG-32 and values of remaining four clones were ranged from 6.70 to 8.25%. Inter-node damage by top borer was ranging from 0.00 to 0.73% and all clones were again found resistant against top borer. Lowest value of 8.23% for inter-node damage by stem borer was recorded on YTTh-236 followed by HoSG-31 (9.43%), S2006 SP-93 (10.04%) and highest (14.04%) was noticed on CSSG-32. Overall, three clones were ranked as resistant and three moderately susceptible against stem borer. In case of inter-node damage by root borer, it was ranging from 3.19 to 10.69% and all clones were found resistant except CSSG-32 which was moderately resistant to root borer. Minimum cumulative inter-node damage (12.10%) was noticed on YTTh-236 and maximum (25.05%) on clone CSSG-32. Out of six, two were found resistant, three moderately resistant and one moderately susceptible against sugarcane borers. Again in second year, none of sugarcane genotype was affected by Gurdaspur borer.

Discussion

The present study indicated the variation in adaptability of sugarcane genotypes belonging to various origin. This difference among genotypes for their plant growth attributes, cane yield, sugar contents, resistance against red rot disease and borers complex was mainly due to their different genetic makeup and prevailing climatic conditions. The genetically improved sugarcane clones may have ability to give better results for cane yield and sugar

Table 7: Resistance of sugarcane genotypes against borers complex on the basis of average borer infestation (%)

Genotypes	Tiller infestation (%)	Inter-nodal damage by						Cumulative internode damage	
		T.B.		S.B.		R.B.			
		%	Reaction	%	Reaction	%	Reaction	%	Reaction
Crop Season 2014–2015									
S2006 SP-93	5.94	0.00	R	10.26	MR	4.47	R	14.48	MR
HoSG-31	5.91	1.18	R	13.52	MR	4.33	R	17.85	MS
CSSG-32	6.74	0.00	R	8.19	R	2.65	R	10.84	MR
Thatta-910	6.36	0.00	R	12.37	MR	4.99	R	17.36	MS
YTTh-236	6.55	3.03	R	9.38	R	5.09	R	12.62	MR
CPF 247 (Check)	4.08	0.00	R	4.53	R	1.68	R	7.21	R
Crop Season 2015–2016									
S2006 SP-93	8.25	0.00	R	10.04	R	4.38	R	13.10	R
HoSG-31	6.79	0.38	R	9.43	R	5.54	R	15.36	MR
CSSG-32	10.48	0.32	R	14.04	MR	10.69	MR	25.05	MS
Thatta-910	6.72	0.73	R	12.46	MR	3.98	R	16.37	MR
YTTh-236	6.70	0.00	R	8.23	R	3.84	R	12.10	R
CPF 247 (Check)	5.95	0.00	R	14.02	MR	3.18	R	17.21	MR

T.B. = Top Borer, S.B.= Stem Borer, R.B. = Root Borer, R = Resistant & MR = Moderately resistant

contents under available set of environmental conditions (El-Geddaway *et al.* 2002; Keerio *et al.* 2003; Arain *et al.* 2011). The better results for yield contributing traits, cane and sugar yield in genotype S2006 SP-93 may be attributed to its improved genetic makeup over other competing genotypes and its better adaptability potential in field evaluation under the agro-ecological conditions of Faisalabad. These better results may be coupled with more availability of favorable climatic conditions for crop growth and maturity during both crop years (Afghan *et al.* 2013).

In addition, the higher cane and sugar yield for S2006 SP-93 was not only due to its resistant genotypic reaction against red rot and borers complex but also its better field performance (Sajjad *et al.* 2013). The results of this study showed strong relationship between yield contributing traits and cane yield of sugarcane (Habib *et al.* 1991). The better genotypic potential with relation to sprouting and tillers at early growth stage and more number of mature canes with desirable characteristic at lateral part of the growth may also be correlated with better performance of S2006 SP-93 in this study (Javed *et al.* 2002; Khan *et al.* 2003; Arain *et al.* 2011). Whereas genotypes having lower values of yield related traits showed poor cane yield (Arain *et al.* 2011). Nonetheless sugar contents are mainly dependent on the genetic makeup of sugarcane genotypes and have mere variation with changing agro-ecological conditions (Nazir *et al.* 1997). Hence, sugarcane genotype having higher cane yield and sugar contents coupled with resistance to disease and insects pests attack in a particular set of environment is a great blessing for sugarcane researchers. Keeping in view of these findings, it may be stated that research for new promising lines may guide us towards better future cane and sugar production than present due to their inherent upheld potential.

Resistance to red rot disease of sugarcane is apparently complex and is affected by morphological and physiological factors (Singh and Singh 1989). Infection may occur through wounds or nodal tissues (Singh and Singh 1989). Rind penetration and internode damage caused by sugarcane borers, provide an important avenue for red rot infection of planted stalks in any climatic conditions (Ogunwolu *et al.* 1991). Red rot resistance evaluation indicated the presence of genotype-environment interaction which was also verified by stalk inoculation technique which is a regular feature of variety development program at SRI, Faisalabad (Khan *et al.* 2011). Clones were classified as resistant when disease symptoms did not progress beyond the inoculated internode.

Results of this study indicated that resistance to borers complex in promising sugarcane genotypes was almost constant for both years under study except some inconsistency occurred for few clones which might be due to variation in genetic inheritance of the genotypes and was merely affected by the growing conditions. The present study also confirmed the negative correlation between borers infestation index and qualitative traits of sugarcane (Parez-Gonzalez *et al.* 1977). Moreover, the favorable environment for incidence of insect pests and genotypic reaction also affect sugarcane yield in the field (Zhao and Li, 2015). The favorable environment for borers complex is very necessary which prevails before monsoon season characterized by drought conditions and high temperature in the Punjab, Pakistan. Therefore, genotypes having resistance against sugarcane borers is a biggest tool for sustainable sugarcane production in all sugarcane growing zones of the Punjab, Pakistan.

Conclusion

Results unveiled that sugarcane genotype S2006 SP-93 had better adaptability under agro-climatic conditions of Faisalabad as evident by higher cane and sugar yield along with better resistance against red rot disease and borers complex compared to all other genotypes including check variety. Hence, this genotype may be preceded further for variety development studies.

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