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Evaluation of Agronomic, Entomological and Breeding Aspects of Novel Sugarcane Clone under Climate Change Scenario

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Abstract. The increasing greenhouse gas emission and global warming during climate change result in sudden and extreme weather occasions. Climate change is affecting sugarcane production in the world, especially in the developing countries because of poor forecasting systems and mitigating strategies, sudden occurrence of pests and diseases. Varieties play an important role for sustainable sugarcane production. Varieties either lose their potential after few years release in field or become susceptible to pests and diseases under day by day changing climatic scenario. To combat climate changes and replace of exiting sugarcane varieties, different field experiments were planned at Sugarcane Research Institute, Faisalabad, Sugarcane Research Station, Khanpur and zonal testing of Sugarcane clone in adaptability trials at Progressive Sugarcane growers from 2002 to 2019 . All experiments were designed in randomized complete block design in three replications. Sugarcane clone S2003-US-127 were used in all experiments along with standards varieties HSF-240, CPF-249, SPF-234 and CPF-246. It is concluded from the study that sugarcane clone S2003-US-127 fetched higher cane yield (111.3 t/ha), sugar yield (14.1 t/ha), sugar recovery (12.72%) and higher economic Index than HSF-240, CPF-249, SPF-234 and CPF-246HSF. It is fast growing and matures earlier in 240-270 days. It has CPF 250 is resistant to red rot and smut.

Keywords: climate change, global warming, economic index, sugar recovery, maturity

Introduction

The climate change is a biggest threat to global agriculture causing significant decrease in its productivity. Likewise, sugarcane crop is facing implications of prevailing climate change scenario in all cane growing countries. Although, the sugarcane has wide range of adaptability for its cultivation but it requires optimum temperature range and other environmental characteristics for economic production of cane and sugar (Andrew *et al.*, 2020). Impacts of climate change on sugarcane production depend on its geographical location and degree of adaptation. Although some studies reveal that there are few positive impacts of changed environmental conditions like elevated CO_2 concentration may result in increasing photosynthesis, high water use efficiency due to reduced stomatal conductance and ultimately, helping in more sugarcane biomass and productivity. Similarly, most significant positive effect of climate change would be reduced incidence of frost, which is a major limitation for cane production in many sugarcane growing regions. Moreover, rise in temperature in tropical areas having cool winter may increase growth process and yield of sugarcane but its sugar content would decrease. Furthermore, frequency and distribution of rainfall at most demanding period of crop can increase cane yield (Zhao and Li, 2015).

Contrary to this, indirect negative impact of climate change on sugarcane production includes more pest pressure, high temperature increase smut incidence, dry weather excel ratoon stunting disease, storms can spread rust attack and farmers have to pay heavy cost to control weeds, insect pests and diseases. Climate change is effecting the dynamic of spread of sugarcane pests and diseases by influencing their population size, survival rate and geographical distribution which is reported by (Sengar *et al.*, 2015). In current scenario of climate change, sugarcane diseases like white leaf, orange rust, whip smut and red rot curtailed the cane and sugar yield drastically in various sugarcane growing countries, Kumar and Kumar (2017). Similarly, attack of sugarcane borers, leaf hopper, aphid, whitefly, white mite, mealy bug and locust not only threatened the cane crop but

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also resulted in significant yield loss (Sadam *et al*., 2018). Among climatic factors, temperature and rainfall are the main drivers of shifts in how and where sugarcane pests and diseases spread (Singh *et al*., 2016). Other adverse effect of climate change involve rise in sea level that make the sugarcane field difficult to farm, high temperature increase evapoutranspiration is resulting in more water demand and make plant difficult to survive. Similarly, water logging in some areas has restricted the sugarcane cultivation. Jones and Singels (2015) found that extreme temperature causes significant yield reduction in sugarcane by adversely affecting its physiology, biochemistry and quality. The impact of drought on sugarcane growth and development depends on plant growth stage, degree of water deficient stress and its duration (Zhao and Li, 2015). It observed that many resistant sugarcane varieties lose their potential and become susceptible to disease when they become under commercial cultivation. The reason behind this was the emergence of new strains of sugarcane disease due to mutation or climatic conditions in any particular cane growing area that act in breakdown of varietal resistance Malathi and Viswanthan (2012). Sugarcane yield relies on crop varieties, biotic and a biotic growth environment (weeds, insects, diseases and other climatic factors) and management practices. Thus, evolution of new sugarcane cultivar is the only solution to combat new diseases and pest under climate change (Singels *et al.*, 2014).

The mitigations strategies for sustainable sugarcane production in current climate change scenario should focus on planting of drought tolerant and heat resistant varieties, investing on irrigation infrastructure, improving irrigation efficiency and drainage system and improving culture/management practices for efficient soil and water conservation (Zhao and Li, 2015).

Sugarcane is an important crop that is grown in 115 countries globally (FAO, 2016). Being an vital industrial and high value cash crop, it contribute significantly in the uplift of socio-economic conditions of farming community in Pakistan. It accounts for 3.4% in agriculture value addition and 0.7% in overall GDP of Pakistan (GOP, 2019). The role of sugarcane in national economy is so important that at the time of independence, it was cultivated on 189.4 thousand hectares and its area expanded upto 1217 thousand hectares in 2017, reflecting about six times rise. Similarly, at that time, sugarcane production was 5.5 million tons at national level by yielding 29.19 tons of canes/hectare, which is later documented as 73.6 million tons with an average cane yield of 60.4 tons/hectare (PSMA, 2016). Correspondingly, sugar industry has also grown at fast pace as there was only two sugar mills in the country at the time of independence and this number reached to 90 by now with current annual crushing capacity of over 6.1 million tons (Tabassum *et al*., 2018). Nevertheless, Pakistan is ranked at important position in sugar world but there is enough potential in current sugarcane varieties, soil and climatic conditions to increase cane and sugar yield. The presently available sugarcane varieties in field is threatening by climate change in the form of adverse climatic extremes and appearance of new races of weeds, insects and disease that are adversely affecting their potential with time (Khan *et al.*, 2017).

Punjab is at top in varietal evolution program among all three cane growing provinces of the country. In same way, the Sugarcane Research Institute, Faisalabad has developed and released 28 sugarcane varieties for commercial cultivation in Punjab since its inception. The newly developed cane varieties play an important role in increasing cane and sugar yield on sustainable basis (Tabassum *et al*., 2018). The CP 77-400, SPF 213, SPF 234, CPF 237, HSF 240, CPF 246, CPF 247, CPF 248, CPF 249, CPF 250, CPF 251, CPF 252 and CPF 253 are presently under cultivation varieties in all cane growing districts of the province. The sugarcane varieties of SRI, Faisalabad have significant impacts in national economy. In 2015-16, SPF 234 was found highest contributor among all cane varieties having economic impact of Rs. 16958.68 million in economy of the Punjab. Whereas, HSF 240 and CP 77-400 contributed Rs. 12531.13 million and 2638.41 million, respectively in provincial economy (Tabassum *et al*., 2018).

In view of above, the following research experiments were conducted to develop and evolve new sugarcane varieties for commercial cultivation in Punjab. This may be able to replace the existing cultivars being infected by various insect pests and diseases due continuous and repaid changes in temperature and rainfall pattern in the Punjab, Pakistan.

Materials and Methods

Release of a new cane variety started from sowing of Fuzz imported during 2002 from Sugarcane Breeding Research Station, Canal Point, USA. The seedling number assigned in 2003 as S2003-US-127 and put in the preliminary varietal trial for comparison with other

standard sugarcane cultivars. Therefore, it was promoted and tested under semifinal and final varietal trials. The variety also tested in different zones at farmers' fields and National Uniform Sugarcane Yield Trials (NUSYT) to test the adaptability of variety before release as commercial variety. The candidate variety was evaluated by spot examination committee and case was submitted to expert sub-committee and then finally to Punjab Seed Council (PSC) for approval during 2019. All the experiments were laid out under randomized complete block design with three to five replications.

Results and Discussion

The test variety has good germination and tillering potential. It is tolerant to lodging and its tiller mortality is less. The said variety is early in maturity and maintains its quality throughout the season. The ratooning potential of the variety is very good. The test variety CPF 250 exhibited better number of canes per unit area and cane weight than standard varieties HSF 240 & CPF 246 (Table 1). These results are in line with the results of Andrew *et al*. (2020).

The cane yield performance of candidate sugarcane variety CPF 250 in comparison with standard variety HSF 240 from 2008 to 2012 is given in Table 2. The data showed that the test variety CPF 250 gave 13% more stripped cane yield than standard variety HSF 240, whereas, it showed 5.93% more sugar recovery than HSF-240. Similar results were reported by Jones and Singels (2015).

The candidate variety was tested with standard varieties SPF 234 and CPF 246 for four years at Sugarcane Research Station (SRS), Khanpur (Table 3). The data revealed that the candidate variety CPF 250 gave 1.46% more stripped cane yield and 6.03% more sugar recovery than the standard varieties SPF 234/CPF 246.

The out-field trials were conducted at 29 locations of Punjab province during three years from 2017 to 2019. The progressive farmers were selected randomly for zonal trials of candidate variety against check HSF-240 and CPF- 249. These trials are very important to conduct in various locations of the province, minimizing the chance of failure of the variety in a region. The candidate variety CPF 250 exhibited 9.70 & 7.0% higher cane yield than check varieties CPF 249 and HSF 240 (Table 4). In addition, it showed 6.20 and 11.4% more sugar recovery against standard varieties. These results are in line with the results of Kumar and Kumar (2017).

The performance of candidate variety was also tested in national uniform sugarcane yield trial (NUSYT) and was evaluated at 13 locations during 2016-17 and 2017-18 and results are given in Table 5. The results showed that CPF-250 produced 25.35% and 9.93% higher cane yield and sugar recovery over check variety. These results are in line with the findings of Khan *et al*. (2017).

The study of economics of coming variety is of the importance because farmers see the economic benefits before adopting the new variety. The economic data showed that on an average CPF 250 produced 1.75 t/ha more sugar yield than standard variety HSF 240, CPF

Table 1. Performance of CPF 250 in comparison with HSF 240 and CPF 246

Variety	Germination (%)	Tillers/ plant	Millable canes (000/ha)	Per cane weight (Kg)
CPF 250	40.2	1.72	122.9	0.90
HSF 240	42.8	2.24	126.8	0.77
CPF 246	37.3	1.52	73.9	0.92

Table 2. Performance of CPF 250 at Sugarcane Research Institute (SRI), Faisalabad

Year	CPF 250		Check variety HSF 240		Percent increase/ decrease over check	
	Cane yield (t/ha)	S. Rec. (%)	Cane yield (t/ha)	S. Rec. (%)	Cane yield (%)	S. Rec. (%)
2008-09	149.6	12.89	129.9	12.42	15.1	3.78
2009-10	98.0	12.94	90.7	12.08	8.07	7.12
2010-11	101.9	13.39	88.1	12.80	15.6	4.61
2011-12	92.7	13.62	82.6	12.60	12.2	8.09
Avg.	110.6	13.21	97.8	12.47	13.0	5.93

Table 3. Performance of CPF 250 at SRS, Khanpur

Year	CPF 250		Check variety SPF 234/ CPF 246		Percent increase/ decrease over check	
	Cane yield (t/ha)	S. Rec. (%)	Cane yield (t/ha)	S. Rec. (%)	Cane yield (%)	S. Rec. (%)
2009-10	102.3	11.97	101.5	11.48	0.83	4.27
2010-11	120.9	12.86	117.8	11.11	2.67	15.7
2011-12	101.3	12.12	102.3	12.04	-0.99	0.66
2012-13	106.4	12.12	103.1	11.65	3.14	4.03
Avg.	107.7	12.27	106.2	11.57	1.46	6.03

249, SPF 234 and CPF 246. On an average, CPF-250 gave an additional benefit of Rs. 105000 over standard varieties HSF 240, CPF 249, SPF 234 and CPF 246 (Table 6). These results are in line with the results of Andrew *et al*. (2020).

Impacts of climate change on sugarcane production depend on its geographical location and degree of adaptation. Although some studies reveal that there are few positive impacts of changed environmental conditions like elevated CO_2 concentration may result in increasing photosynthesis, high water use efficiency due to reduced stomatal conductance and ultimately, helping in more sugarcane biomass and productivity. Similarly, most significant positive effect of climate change would be reduced incidence of frost, which is a major limitation for cane production in many sugarcane growing regions. Moreover, rise in temperature in tropical areas having cool winter may increase growth process and yield of sugarcane but its sugar contents would decrease. Furthermore, frequency and distribution of rainfall at most demanding period of crop can increase cane yield (Zhao and Li, 2015).

Sugarcane growers prefer the variety giving more ratoons. Ratooning ability of candidate variety CPF 250 was studied at SRI, Faisalabad (Table 7). It was depicted from the data mentioned below that in ratoon crop, candidate variety produced 6 t/ha more cane yield over HSF-240 and these results are in line with the results of Khan *et al*. (2017).

The disease reaction was started to check from third stage of nursery in varietal development programme and continues to final selection stage. The candidate variety is resistant to diseases in sugarcane growing areas of Punjab other than river belt (Table 8). In four years as mentioned in table, reaction of candidate variety

Table 4. Performance of CPF 250 in zonal field trials at 29 locations of Punjab

Year	No. of sites	CPF 250		Check varieties				Percent increase/ decrease over CPF 249		Percent increase/ decrease over HSF 240	
				CPF 249		HSF 240					
		Cane yield (t/ha)	S. Rec. (%)	Cane yield (t/ha)	S. Rec. (%)	Cane yield (t/ha)	S. Rec. (%)	Cane yield (%)	S. Rec. (%)	Cane yield (%)	S. Rec. (%)
2016-17	9	116.0	12.8	102.7	11.8	109.3	11.5	13.0	9.00	6.10	11.5
2017-18	11	121.2	12.5	104.5	11.4	104.5	11.2	15.9	9.30	15.9	11.3
2018-19	9	110.0	12.7	109.3	12.6	110.6	11.4	0.60	0.80	-0.50	11.4
Avg.		115.7	12.7	105.5	11.9	108.1	11.4	9.70	6.20	7.00	11.4

Table 5. Performance of CPF 250 in NUSYT at 13 locations

Year	Locations	CPF 250		Check variety(s) check		Percent increase/decrease over	
		Cane yield (t/ha)	S. Rec. (%)	Cane yield (t/ha)	S. Rec. (%)	Cane yield (%)	S. Rec. (%)
2016-17	06	118.92	12.32	90.22	10.93	32.68	13.19
2017-18	07	112.84	2.67	96.46	11.93	18.39	6.67
Avg.		115.88	12.49	93.34	11.43	25.53	9.93

Table 6. Economic benefits of CPF 250 over reference varieties

Locations	Variety	Cane yield (t/ha)	S. Rec. (%)	Sugar Cane yield (t/ha)	Difference (t/ha)	Increased over local checks (Rs./ha)
SRI, Faisalabad, SRS, Khan Pur and 29 zonal / out field trials	CPF 250	111.3	12.72	14.15	-	-
	HSF 240, CPF 249, SPF 234, CPF 246	104.9	11.8	12.4	1.75	105000

Sugar @ Rs. 60000/t

against red rot and mosaic is mild resistant and against other diseases it is resistant. These results are in line with the results of Kumar and Kumar (2017).

The candidate variety CPF 250 is resistant to all the borers on dead heart and cumulative internode damage basis under field conditions (Table 9). These results are in line with the results of Andrew *et al*. (2020) and Khan *et al*. (2017).

Table 7. Ratooning ability of CPF 250 (2009-10)

Cane yield (t/ha)	Difference (t/ha) with HSF 240		Percent variation over HSF 240
	CPF 250	HSF 240	
95.0	89.0	6.0	6.7

Table 8. Reaction against different diseases in CPF 250

Year	Variety	Reaction to diseases					
		Red rot	Whip Smut	Pokkah Boeng	Red stripe	Rust	Mosaic virus
2015-16	CPF 250	MR	R	R	R	R	MR
2016-17	CPF 250	MR	R	R	R	R	MR
2017-18	CPF 250	MR	R	R	R	R	MR
2018-19	CPF 250	MR	R	R	R	R	MR

Grading scale for red rot disease (0-9) 0: I (Immune), 1:HR, 2: R, 3-4: MR, 5-6: MS, 7-8: S, 9: HS: Whip smut/ Red stripe:0-5%: R, 5.1-15%: MR, 15.1-30%: MS, Above 30%: S: Rust 1 R, 2 MR, 3 MS, 4 S: Mosaic 0.1-2.5% HR, 2.6-5 R, 5.1-10 MR, 10.1-20 MR, 20.1-35 MS, 35.1-50 S, 50.1-75 HS, 75.1-100 HS

Table 9. Borer infestation of CPF 250 and HSF 240

Year	CPF 250		HSF 240	
	Dead heart (%)	Cumulative internode damage (%)	Dead heart (%)	Cumulative internode damage (%)
2014-2015	0.31	7.19	5.06	8.47
2015-2016	5.2	7.3	4.01	5.95
2016-2017	5.7	7.4	3.76	6.72
2017-2018	6.4	8.6	5.88	7.45
Avg.	3.24	8.48	4.73	7.05
Reaction	R	R	R	R

Criteria for Resistance: 1-10: R, 10.1-20: MR, 20.1-30: MS, 30.1-40: S, Above 40: HS

Conclusion

The candidate variety CPF 250 is a cross of CP 89-879 X CP 90-956 was tested in preliminary and semi-final trials and then in medium and late final varietal trials for 4 years from 2008-09 to 2011-12. It is an early maturing variety with high tonnage and more recovery as compared with medium maturing variety HSF 240. It is a disease and insect resistant variety and will prove to be a good substitute of SPF 245, SPF 234 and HSF 240. CPF-250 gave higher economic index of Rs. 105000 over standards.

Recommendations

CPF-250 is recommended for general cultivation for the growers in sugarcane areas other than river belt of Punjab province. Other cultivars in field may be replaced with it being resistant to borers, red rot and smut under changing climatic conditions in Punjab province.

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