Research Article

Resistance to Artificial Infection of Smut and Genetic Variability in Sugarcane Clones

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Abstract | Improvement in sugarcane through breeding is limited due lack of diversity and disease infestation. One hundred and three clones of sugarcane were evaluated for two crop seasons through applying high inoculum conditions for smut incidence following RCBD during 2017-18. The analysis of variance revealed significant variations in cane weight, sugar recovery and smut incidence for both years. During the evaluation 84 and 80 clones were found resistant to smut in plant and ratoon crop respectively. Principal component analysis showed that first eigenvalue was equal to (1.78) and represented that (35.6%) of the total variation. The 2nd eigenvalue (1.077) and represented of the total variation (57.2%) for the crop plant. For the ratoon crop, the first eigenvalue was (1.83) and presented (36.6%) of the total variation while 2nd eigenvalue (1.15) and represented (59.7%) of total variation. Maximum sugar contents (13%) were recorded in CPF 250, weight/stalk (1.7 Kg) in S2011-SL-209 whereas S2003-US-618 was found highly affected by smut with 74% disease incidence rate among all the studied sugarcane lines/varieties. The correlation coefficients were significant ($p \leq 0.05$) for the traits such as cane weight, cane height, cane girth, and sugar recovery during plant and ratoon crop. Nevertheless, the smut was found significantly but negatively correlated with cane height and cane girth in both years. Estimations of broad sense heritability along with genetic advance was higher for cane weight, sugar recovery and smut incidence which indicated additive gene action and selection would be effective in later generations for the improvement using these traits.

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Introduction

Sugarcane (*Saccharum officinarum* L.) is globally cultivated to produce sugar, sugar related products and ethanol. It is a cash crop of Pakistan having 2.9% share in agriculture value addition and 0.5% in gross domestic production of the country. Sugarcane crop is severely affected by many diseases like red rot (major disease in Pakistan), smut, rust, pokhah boeng, red stripes and mosaic. The sugarcane yield losses have been estimated about 75% due to occurrence of these diseases (Sandhu *et al*., 1969). Amongst, smut disease is very important which causes not only a huge damage for yield but also disturbs the cane quality in susceptible varieties (Heinz, 2015; Hemaprabha *et al*., 2022). Smut is described as whip like sorus which is produced on apical meristem and lateral meristem of marked tillers and it was reported for the first time in south Africa in 1877 (Luthra *et al*., 1940). Smut is also known as culmicolous due to its capability to distress the cane stalk. The yield losses due to smut are ranged from 18-68% in different part of the world but losses in ratoon are more than plant crop (Steiner *et al*., 1975). Several workers have been involved in screening sugarcane clones for smut resistance (Alexander, 1982). The clone resistance depends on weather conditions such as temperature and humidity (Dean and Miller, 1977; Ahmed *et al*., 2019). High temperature and rainfall increase the inoculum and establishment of smut (Bock, 1964). Resistance in clones increases against the smut occurrence due to increase in age of cane, however dry weather increases smut teliospores (Sreeramulu and Vittal, 1972; Nzioki *et al*., 2010).

The aim of the study was to evaluate the resistance of germplasm clones against the smut prevalence under the artificial inoculum in prevailing agro-ecological conditions.

Materials and Methods

The experiment comprising of one hundred and three (103) sugarcane germplasm available at Sugarcane Research Institute, was carried out under artificial inoculation condition of whip smut pathogen at research farm of Sugarcane Research Institute, Faisalabad (31˚26′S, 73˚06′E) during autumn season 2017. Randomized complete block design with two replications having plot size of 8m×4.8m, row to row distance of 4 feet was used for plantation of the trial. Spore suspension of the disease @ 4gram spores per liter of water was prepared for the artificial inoculum and cane sets of tested sugarcane lines were dipped in the suspension for half an hour. The inoculated sets were also kept under moist chamber for 24 hours prior to sowing. Two observations on incidence were recorded during crop season, first at the completion of germination and at time of maturity of crops. Disease data was recorded on percentage basis by counting the total number of tillers and smutted tillers of each variety. The ratoon data was also recorded with same methodology (Rao *et al*., 1996). The data for different agronomic traits like cane height, cane girth, cane weight and sugar contents were also recorded. From each plot ten stalks were selected randomly and their mean values were calculated at the end of the year. Cane height was measured with meter rod and cane girth was measured with help of digital caliper in centimeters (cm). Sugar contents were calculated by using the formula as described by Kerr (1970) while data were analyzed by using the statistical software "Statistix 8.1 (McGraw-Hill, 2008).

Results and Discussion

The analysis of variance was performed for the data recorded in the filed for the 1^{st} year and results were significantly different for sugar recovery, cane weight and smut prevalence. The 2^{nd} year ratoon crop data also presented the similar results from the statistical analysis (Table 1).

Cane girth and cane height data showed non-significant results for both years. Genetic variability for cane weight, cane height, sugar recovery and high genotypic and phenotypic coefficient of variation have been reported which indicated that improvement can be proceeded through simple selection (Chaudhary, 2001). The response of cultivar to the pathogen attack depends on genetic make-up and its environment (Grisham and Hogarth, 2001).

Table 1: *Mean square value from analysis of variance for yield contributing traits and disease incidence for plant and ratoon crop.*

Source of variation	Degree of freedom	Morphological traits for plant and ratoon crop				Yield related traits for plant and ratoon crop				Disease incidence for plant and ratoon crop	
		Cane girthⓅ (cm)	Cane girth®	Cane heightⓅ (m)	Cane height® (m)	Sugar recoveryⓅ (%)	Sugar recovery® (%)	Cane weightⓅ (kg)	Cane weight® (kg)	Smut incidenceⓅ (%)	Smut incidence® (%)
Replication	1	1.723	2.526	5.248	3.979	3.814	6.553	3.066	0.996	162.515	126.8
Genotypes	102	0.174	0.208	0.183	0.216	4.273*	3.472*	8.396*	7.979*	230.162**	261.8**
Error	102	0.046	0.083	0.065	0.062	0.375	0.468	0.551	0.425	2.623	1.954

Ⓟ, Plant crop; ®, Ratoon crop

The LSD comparison based on ranking of 103 sugarcane clones for their performance against smut are shown in Table 2 for both years (plant and ratoon crop) of cultivation. This comparison of sugarcane clones for their performance against smut and yield traits will help cane breeders in revealing yield potential of these clones.

Sugarcane clones performance of plant crop

During the plant crop cultivation, resistant clones to smut were 84 while 5 only were susceptible to smut (Figure 1). The sugarcane clone SPSG-27 was found highly susceptible to smut with 61% disease incidence followed by S2003-US-618 with 53.5% disease incidence. The sugar contents were the highest in CPF 250 (13%) followed by CPF 249 (12.61%) while the clones S2008-FD-19 and S2008-AUS-190 exhibited the highest performance with respect to cane weight (1.7 kg). Two clones S2011-SL-813 and S2011-SL-209 were at the top with respect to their girth with mean value of 3.51 cm each. The mean values did not show significant different among 15 sugarcane clones for smut, thirty-six for sugar recovery and 45 for cane weight (Table 2).

Sugarcane clones performance for ratoon crop

Sugarcane clones performance for ratoon crop, 87 clones were selected as resistant against smut with 0-5% while only 16 clones were found susceptible to smut (Figure 1). Now S2003-US-618 and SPSG-27 both were noted susceptible smut against clones with 74% and 55% disease incidence rate, showing slight increase in disease incidence also. Sugar contents was again observed highest in CPF 250 (12.99%) followed by CPF 249 (12.11%). The sugarcane lines S.2011-SL-430 and S2011-SL-209 got top position with respect to weight stalk (1.7 kg). The means were not significantly different among 49 for cane weight, 41 for sugar contents and 20 for smut incidence (Table 2).

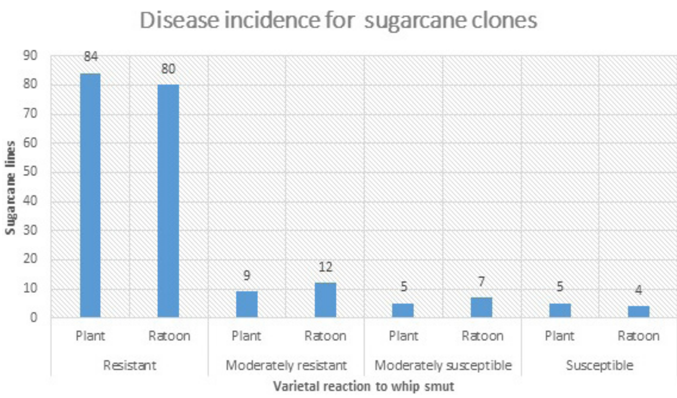

Figure 1: *Frequency of disease incidence.*

Table 2: *Mean comparison for smut incidence, cane weight and sugar contents in plant and ratoon crop.*

Sr. No.	Plant crop				Ratoon crop			
	Clone name	Disease incidence	Yield related traits		Clone name	Disease incidence	Yield related traits	
		Smut incidence %	Sugar contents (%)	Weight/ stalk (Kg)		Smut %	Sugar contents (%)	weight/ stalk (Kg)
1	CPF 250	1.5	13	1.5	CPF 250	1	12.99	1.5
2	CPF 249	0	12.61	1.6	CPF 249	0.5	12.11	1.6
3	CPF-246	0	12.5	1.4	CPF-246	1	10.99	1.4
4	YTTh-55	3.75	12.495	1.3	YTTh-55	1.5	12.16	1.3
5	S.2008-AUS-195	1.5	12.49	1.4	S.2008-AUS-195	2.39	11.69	1.4
6	CPF 252	1.5	12.48	1.5	CPF 252	0	11.65	1.5
7	CPF-247	2	12.35	1.3	CPF-247	0	11.7	1.2
8	S.2008-FD-17	0	12.23	1.4	S.2008-FD-17	0	11.17	1.5
9	S.2003-US-618	53.5	3.65	1.0	S.2003-US-618	74	12.91	1.0
10	S.2011-SL-593	1.5	10.505	1.2	S.2011-SL-593	1	12.81	1.2
11	S.2009-SA-111	1	12.35	1.4	S.2009-SA-111	16.5	12.61	1.4
12	S.2008-M-34	31.7	10.95	1.4	S.2008-M-34	42.5	12.4	1.3
13	S.2008-M-42	1	11.95	1.3	S.2008-M-42	0	12.28	1.4
14	S.2008-AUS-130	1	11.815	1.3	S.2008-AUS-130	0	12.21	1.4
15	S.2006-US-469	26	11.225	1.1	S.2006-US-469	23.96	12.21	1.1

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Sr. No.	Plant crop				Ratoon crop			
	Clone name	Disease incidence	Yield related traits		Clone name	Disease incidence	Yield related traits	
		Smut incidence %	Sugar contents (%)	Weight/ stalk (Kg)		Smut %	Sugar contents (%)	weight/ stalk (Kg)
16	S.2008-AUS-134	44.5	12.2	1.3	S.2008-AUS-134	18.66	10.96	1.4
17	CPF-248	1	12.115	0.6	CPF-248	0	12.1	1.5
18	HOSG-31	1	12.095	1.3	HOSG-31	1.5	12.1	1.2
19	VMC-95-09	1	10.68	1.3	VMC-95-09	0	12.09	1.3
20	S.2011-SL-781	0	10.96	1.3	S.2011-SL-781	0	12.05	1.5
21	S.2009-SA-171	0.5	12.165	1.1	S.2009-SA-171	0.5	11.85	1.2
22	S.2009-SA-57	0.5	12.085	1.1	S.2009-SA-57	1	11.92	1.2
23	S.2008-AUS-184	3.95	11.18	1.5	S.2008-AUS-184	3.36	11.95	1.4
24	S.2008-AUS-138	4	11.55	1.4	S.2008-AUS-138	17	11.91	1.3
25	S.2008-AUS-129	3.5	11.585	1.6	S.2008-AUS-129	10.62	11.91	1.5
26	S.2011-SL-359	0	8.335	1.4	S.2011-SL-359	0.5	10.75	1.2
27	S.2011-SL-62	1	11.97	1.4	S.2011-SL-62	1	11.26	1.3
28	S.2008-AUS-107	1	11.95	0.9	S.2008-AUS-107	2	11.7	0.8
29	S.2011-SL-39	0	11.9	1.3	S.2011-SL-39	2.5	11.6	1.2
30	S.2006-US-272	14.5	11.855	1.4	S.2006-US-272	14.13	11.8	1.3
31	S.2008-AUS-172	7	11.805	1.4	S.2008-AUS-172	13.62	11.9	1.5
32	S.2009-SA-79	1.5	11.75	1.5	S.2009-SA-79	0	11.05	1.4
33	S.2011-SL-430	1.5	11.7	1.7	S.2011-SL-430	0.5	10.8	1.6
34	S.2008-FD-19	3.5	11.66	1.7	S.2008-FD-19	4.67	11.1	1.6
35	HSF-240	36	11.65	1.1	HSF-240	41.5	9.75	1.1
36	S.2008-AUS-178	17	11.6	1.6	S.2008-AUS-178	15.29	11.86	1.5
37	SL-96-234	10	11.055	0.3	SL-96-234	12.68	11.7	1.3
38	S.2006-SP-93	12	11.535	1.5	S.2006-SP-93	8.15	11.1	1.5
39	S.2005-US-54	1.5	11.535	1.4	S.2005-US-54	0.5	11.7	1.3
40	S.2008-AUS-190	2.5	11.29	1.5	S.2008-AUS-190	1	11.44	1.5
41	S.2009-SA-8	1	11.15	1.1	S.2009-SA-8	1.5	11.5	1.2
42	S.2011-SL-701	0	11.265	1.1	S.2011-SL-701	0	10.09	1.1
43	S.2011-SL-1845	0	10.175	1.2	S.2011-SL-1845	1	11.4	1.2
44	S.2011-SL-35	0	10.6	1.2	S.2011-SL-35	1	11.4	1.2
45	SL-96-278	2.5	10.8	1.1	SL-96-278	14.14	11.36	1.0
46	S.2011-SL-543	0.5	10.14	1.0	S.2011-SL-543	0.5	11.3	1.0
47	S.2011-FD-16	1	11.2	1.3	S.2011-FD-16	1.5	10.99	1.4
48	S.2011-SL-517	0	9.66	1.0	S.2011-SL-517	0	11.26	1.0
49	S.2009-SA-169	0	11.215	1.5	S.2009-SA-169	4.86	11.19	1.5
50	S.2008-AUS-133	1	11.125	1.6	S.2008-AUS-133	1.5	11.96	1.5
51	S.2011-SL-158	0	11.125	1.5	S.2011-SL-158	0.5	9.53	1.4
52	S.2008-M-79	3	11.115	1.3	S.2008-M-79	7.4	11.05	1.2
53	S.2011-FD-26	0	8.21	0.9	S.2011-FD-26	1.5	10.86	0.9
54	S.2011-FD-18	0	11.05	1.3	S.2011-FD-18	1	9.8	1.3
55	S.2009-SA-67	27	11.035	1.2	S.2009-SA-67	2.63	11.91	1.3
56	BPTH-804	3.35	11.025	1.4	BPTh-804	4.9	11.09	1.4
57	S.2011-SL-597	0.5	10.03	1.1	S.2011-SL-597	0	11.05	1.0
58	CSSG-32	11	11.225	1.6	CSSG-32	13.8	11.05	1.5
59	S.2011-SL-454	10.7	10.95	1.0	S.2011-SL-454	11.5	10.31	1.1

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Sr. No.	Plant crop				Ratoon crop			
	Clone name	Disease incidence	Yield related traits		Clone name	Disease incidence	Yield related traits	
		Smut incidence %	Sugar contents (%)	Weight/ stalk (Kg)		Smut %	Sugar contents (%)	weight/ stalk (Kg)
60	S.2011-SL-847	1.5	10.93	1.5	S.2011-SL-847	1	7.9	1.5
61	S.2011-SL-402	1.5	10.825	1.0	S.2011-SL-402	0.5	9.65	1.1
62	S.2008-M-69	0.5	11.15	1.5	S.2008-M-69	7.13	10.85	1.5
63	S.2011-SL-353	2	10.78	1.0	S.2011-SL-353	0.5	8.31	0.9
64	S.2009-SA-41	2	10.815	1.2	S.2009-SA-41	2.5	10.96	1.2
65	S.2011-SL-71	1	7.05	1.1	S.2011-SL-71	0	10.09	1.1
66	SPSG-27	61	10.465	1.0	SPSG-27	55.5	10.75	1.0
67	S.2011-SL-420	0	10.7	1.4	S.2011-SL-420	0	8	1.4
68	S.2008-M-55	17	11.205	1.6	S.2008-M-55	23.78	10.6	1.6
69	S.2011-FD-22	0	10.865	1.1	S.2011-FD-22	3	10.6	1.2
70	S.2011-SL-392	0.5	10.605	1.4	S.2011-SL-392	1.5	8.65	1.3
71	S.2011-SL-637	1	10.6	1.1	S.2011-SL-637	1	9.41	1.1
72	M1861-89	0.5	11.05	1.4	M1861-89	0	10.41	1.3
73	SL-96-128	4	10.585	1.7	SL-96-128	1.67	10.41	1.6
74	VMC-84-947	0	10.1	1.1	VMC-84-947	0	10.4	1.1
75	M.2238-89	6.5	10.555	1.3	M.2238-89	4.5	9.81	1.3
76	S.2011-SL-51	2	7.995	1.2	S.2011-SL-51	1.5	10.31	1.2
77	S.2011-SL-768	2	9.65	0.9	S.2011-SL-768	0	10.19	0.9
78	M70-89	0.5	10.265	1.6	M70-89	0	9.45	1.4
79	S.2006-US-384	11.3	10.96	1.2	S.2006-US-384	14	10.17	1.3
80	SPSG-24	1.5	10.365	1.4	SPSG-24	0	10.15	1.4
81	S.2011-SL-209	1.5	9.375	1.7	S.2011-SL-209	0.5	10.1	1.7
82	VMC-86-550	0	10.66	1.4	VMC-86-550	2.5	10.09	1.3
83	S.2011-SL-156	0.5	10.075	1.0	S.2011-SL-156	1	10.5	1.1
84	VMC-88-354	1.5	7.985	1.4	VMC-88-354	0	10.06	1.4
85	CPSG-33	0	10.195	1.3	CPSG-33	1.5	10	1.3
86	PSR 97-41	1.5	9.985	1.3	PSR 97-41	0.5	8.98	1.2
87	SPSG-29	15.5	9.985	1.3	SPSG-29	18.25	9.91	1.2
88	S.2011-SL-702	2	9.975	1.5	S.2011-SL-702	0.5	10.95	1.4
89	S.2011-SL-415	0	9.95	1.4	S.2011-SL-415	2	11.16	1.3
90	S.2011-SL-813	1	9.81	1.4	S.2011-SL-813	1.5	8.86	1.1
91	S.2011-SL-145	0.5	10.99	1.2	S.2011-SL-145	1	9.62	1.2
92	S.2011-SL-615	0	9.655	0.8	S.2011-SL-615	0.5	9.32	0.9
93	S.2011-SL-360	0	8.98	0.9	S.2011-SL-360	1	8.45	1.0
94	S.2011-SL-537	1	8.75	1.0	S.2011-SL-537	1.5	10.21	1.0
95	S.2011-SL-797	0	9.455	1.1	S.2011-SL-797	0	8.8	1.1
96	S.2011-SL-169	0	9.31	0.7	S.2011-SL-169	1	8.38	0.8
97	S.2011-SL-642	0.5	7.945	1.5	S.2011-SL-642	1	11.07	1.4
98	S.2011-SL-873	1.5	7.655	1.1	S.2011-SL-873	0.5	10.47	1.1
99	S.2008-M-76	11	7.95	1.2	S.2008-M-76	3.21	7.91	1.2
100	S.2008-M-80	2.5	7.615	1.2	S.2008-M-80	5.67	10.65	1.2
101	S.2011-SL-714	1	9.12	0.8	S.2011-SL-714	0	10.82	0.7
102	S.2011-SL-638	0.5	7.23	1.1	S.2011-SL-638	0	7.71	1.2
103	S.2011-SL-106	1.5	10.02	1.4	S.2011-SL-106	2	7.3	1.4
		1.62	0.61	0.74		1.40	0.68	0.65
		3.21	1.22	1.47		2.77	1.36	1.29

Table 3: *Correlation coefficients for yield related traits and smut resistance in plant crop.*

Traits	Cane weight	Cane height	Cane girth	Sugar recovery		
Cane height	0.275**					
Cane girth	0.094	0.256**				
Sugar recovery	0.284**	0.209**	0.246**			
Smut incidence	-0.034	-0.168*	-0.291**	-0.105		
Traits		**Cane girth**		**Cane height**	**Sugar recovery**	**Smut incidence**
Cane height		0.275**				
Sugar recovery		0.092		0.143*		
Smut incidence		-0.122		-0.1716*	0.0934	
Cane weight		0.038		0.331**	0.284**	-0.081

Pearson association analysis for yield contributing traits and smut prevalence

Correlation studies for yield contributing traits and smut prevalence ($p \leq 0.05$) showed that cane height had positive and significant correlation with cane weight while cane girth and sugar recovery were also highly significantly correlated with cane height. Smut occurrence also displayed key negative correlation with cane height. Sugar recovery and smut prevalence were significantly and positively correlated with cane girth for the period of plant crop (Table 3). However, for the duration of ratoon crop cane height indicated positive and substantial correlation with cane girth. Sugar recovery was also positively and significantly correlated with cane height, conversely smut occurrence showed significant but negative correlation. Cane weight had positive and significant correlation with cane height and sugar recovery (Table 4). Similar results were also reported for cane weight and cane length (Banerjee *et al.*, 2015). None-significant correlation have been reported between smut grade and stalk length and there should be not any difficulty to select smut-resistance and high yielding clones (Wu *et al.*, 1983).

Table 4: *Correlation coefficients for yield related traits and smut resistance in ratoon crop.*

Traits	Cane girth	Cane height	Sugar recovery	Smut incidence
Cane height	0.275**			
Sugar recovery	0.092	0.143*		
Smut incidence	-0.122	-0.1716*	0.0934	
Cane weight	0.038	0.331**	0.284**	-0.081

Principal component analysis for variation

Principal component analysis showed high variation amongst the genotypes for the yield traits. Three major components showed 35.6% PC1, 21.5% PC2, 15.7% PC3 variation with main proportions of PC1 and PC2 for plant crop (Table 5). The Ratoon crop also showed also three major p components 36.7% PC1, 23% PC2, 17.1% PC3, respectively. The PC1 and PC2 revealed higher variations (Table 6). The best performing clones were S2008-FD-17, CPF 250, CPF 249 and S2008-FD-19 while S2003-US-618, and SPSG-27 showed less performance for all the traits studied. The poor performance of S2003-US-618, and SPSG-27 might be due to attack of their whip smut. Tahir et al. (2013) estimated the principal component analysis and accounted for the 88% of the total variation and 93.64 % for the first 7.36% and for the 2nd component of the variation in yield.

Table 5: *Principal component analysis for cane yield characteristics and smut resistance in crop plant.*

Variables	PC1	PC2	PC3	PC4
Eigenvalue	1.781	1.077	0.785	0.73
Proportion%	35.6	21.5	15.7	14.6
Cumulative%	35.6	57.2	72.9	87.5
Weight	0.390	-0.610	-0.1021	-0.5271
Height	0.485	-0.060	-0.752	0.322
Can girth	0.401	0.383	0.210	0.410
Sugar recovery	0.480	-0.319	0.620	0.182
Smut	-0.370	-0.620	-0.016	0.64

Table 6: *Principal component analysis for can yield characteristics and smut resistance in ratoon crop.*

Eigenvalue	1.8326	1.1510	0.8542	0.6679
Proportion %	36.7	23.0	17.1	13.4
Cumulative%	36.7	59.7	76.8	90.1
Traits	PC1	PC2	PC3	PC4
Cane weight	0.540	-0.290	0.383	0.206
Cane height	0.581	0.113	0.201	0.200
Cane girth	0.392	0.290	-0.700	0.313
Sugar recovery	0.380	-0.561	-0.304	-0.650
Smut incidence	-0.270	-0.713	-0.189	0.500

Table 7: *Genetic variability and some direct selection indices for smut resistance in plant and ratoon crop.*

Traits	Crop type	Components of variability						Direct selection indices	
		GV	GCV %	PV	PCV %	EV	ECV %	h2bs%	GA%
Cane girth	Plant crop	0.04	12.06	0.09	17.38	0.05	12.51	48.15	8.56
	Ratoon crop	0.04	11.92	0.12	20.66	0.08	16.88	33.26	7.06
Cane height	Plant crop	0.04	11.69	0.11	19.09	0.07	15.09	37.49	7.41
	Ratoon crop	0.05	13.47	0.11	19.98	0.06	14.76	45.41	9.46
Sugar recovery	Plant crop	1.30	34.94	1.68	39.67	0.38	18.78	77.58	16.56
	Ratoon crop	1.00	30.64	1.47	37.10	0.47	20.93	68.17	13.59
Smut	Plant crop	75.85	38.40	78.47	39.07	2.62	72.41	96.66	30.41
	Ratoon crop	2.52	44.53	2.94	48.14	0.42	18.29	85.56	20.29
Weight	Plant crop	2.62	45.27	3.17	49.81	0.55	20.78	82.61	20.22
	Ratoon crop	86.61	39.98	88.56	400.43	1.95	59.48	97.79	29.42

GV, genotypic variance; PV, phenotypic variance; EV, environmental variance; GCV%, genotypic coefficient of variance; PCV%, phenotypic coefficient variance, ECV%, environmental coefficient variance; h2bs%, Broad sense heritability, GA, genetic advance.

Heritability and genetic advance analysis

The impact of smut incidence on yield and its contributing traits was defined by prevalence of phenotypic variance, heritability and genetic advance (Table 7). The phenotypic variance of these traits was divided into genotypic and environmental variance. The values for genotypic and phenotypic variances indicated that yield contributing traits and impact of smut was genetically controlled because the values due genotypic variance were higher than environmental variance that indicated less affect by the environment. GCV and PCV were moderate (12.06% and 17.38%) for cane girth in plant crop. Similar behaviour was also presented in ratoon crop. The PCV and GCV were also moderate for plant and ratoon crop for cane height. Sugar recovery showed high PCV and GCV (34.94% and 39.67%) for plant crop while for ratoon crop the performance for GCV and PCV was also high. The smut incidence and cane weight also displayed the high PCV and GCV for both plant and ratoon crop. Cane weight also revealed the highest estimation of heritability (97.79%) along with high genetic advance (29.42) for ratoon crop followed by smut incidence the highest heritability (96.66%) along with high genetic advance (30.41%) for plant crop. The evidence on genetic variability existing in breeding material is important for a breeder to start any breeding programme. The coefficient of variation, heritability and genetic advance are essential for improving the desirable traits in sugarcane because it helps whether the objective can be achieved or not from existing material (Somu and Nagaraja, 2020). The high genotypic and Phenotypic variation was reported for single cane weight in plant crop while for sugar recovery in ratoon crop (Sanghera *et al*., 2014). Hapase and Hapase (1990) also revealed the higher magnitude of genotypic and phenotypic coefficient of variation for single cane weight and sugar recovery. The information for genetic variation will not be enough unless the estimation of heritability of the character being improved is not provided because it measures the value of that character which provides the heritable portion of the total variation.

The high phenotypic and genotypic coefficient of variation were observed for single cane weight in plant crop and pooled analysis respectively, while, in ratoon crop for CCS t/ha. The high phenotypic and genotypic coefficient of variation were observed for single cane weight in plant crop and pooled analysis respectively, while, in ratoon crop for CCS t/ha. Prediction for the reliable selection heritability is more effective along with genetic advance than alone the heritability value (Johnson *et al*., 1955) and the trait having low genetic advance do not respond the simple selection (Pant and Singh, 2001). Hiremath and Nagaraja (2016) revealed that clones were significant different for the characters studied. Genotypic and phenotypic coefficient of variations were also higher along with high heritability and genetic advance for cane weight and sugar recovery. Additive gene action controls these traits and selection in early generation may be fruitful. Heritability for cane weight/ha, stalk length and smut resistance were relatively high indicating that effective selection would be possible on a family basis (Li *et al*., 2003). Ratooning ability is a composite trait and is controlled by genetic and environmental factors (Wang *et al*., 2020). Narrow-sense heritability estimates for first crop season and second crop season has also been reported from moderate to low along with genetic advance also from moderate to low in plant cane (Chao *et al*., 1990).

Conclusions and Recommendations

The improvement in sugarcane through breeding is limited due to disease attack. The resistance of sugarcane clones was checked against the smut through artificial inoculum. The crop indicated 5 clones were susceptible to smut. In ratoon crop 80 genotypes were resistance to smut disease. The heritability and genetic advance showed that traits studied were controlled through additive gene action and selection will be effective in lateral generations.

Novelty Statement

This evaluatation study for resistance of germplasm clones against the smut prevalence will help sugarcane farmers in prevailing agro-ecological conditions.

Author's Contribution

Hafiz Muhammad Walayat Ali and Zaheer Ahmad Nazar: Collected smut data.
Hafiz Basheer Ahmad: Analysed the data and wrote the manuscript.
Muhammad Akhlaq Mudassir and Mahmood-Ul-Hasan: Edited and corrected the manuscript.
Abdul Khaliq: Wrote the manuscript.
Muhammad Shahzad Afzal: Analysed the data.

Conflict of interest

The authors have declared no conflict of interest.

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