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CLASSIFYING GENOTYPIC, PHENOTYPIC VARIABILITY, BROAD SENSE HERITABILITY AND PRINCIPAL COMPONENTS OF SUGARCANE (*Saccharum officinarum* L.) GENOTYPES FOR BETTER YIELD, QUALITY AND RESISTANCE AGAINST RED ROT

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ABSTRACT

Sugarcane is one of the important cash crops for Pakistan and it has been the primary source of sugar production. Sugarcane is used in our sugar mills and it's by products are used in making cattle feed, soil manure etc. Present research experiment was conducted to assess the 32 genotypes of sugarcane collected from different farms for cane yield through yield contributing traits in natural field conditions. Traits like Cane height, cane girth, area of leaf, no. of internodes, internode length, no. of tillers, weight of cane, brix percentage and red rot disease incidence and severity were considered for evaluation of sugarcane germplasm. Result showed that most of the traits showed significance amount of variability between the genotypes with respect to the considered plant parameters. XT910 genotype showed the highest cane height while SPF-237 showed highest cane diameter. MSH-2415 showed the largest area of leaf as compare to other genotypes. XT236 showed the highest number of tillers per stool. Highest sucrose value is ultimate goal of breeders and US 133 showed highest sucrose value with brix percentage mean of 22. This variety performed very well overall. Sugarcane genotypes US-133,US-633,US-127,CPF-247,MSH-2415 were found excellent for sugar recovery while SPF-213 and SPF-237 were observed as resistance/tolerant against Red Rot. Furthermore, SPF-213, US-133, US-633 and US-127were found genetically diverse genotypes for different calculated traits and would be useful in sugarcane breeding program to enhance sugar recovery and Red rot resistance/tolerance in advanced sugarcane genotypes. With the help of this experiment study, we have isolated the SPF-213 variety of sugarcane which showed minimum incidence of Red rot disease. This variety has potential to perform well under Red rot susceptible environment. Principle component analysis indicated that first five PCs had 78.59% of the total variation with eigenvalue more than 1. Biplot showed that lodging percentage and girth traits have least variability because they are close to the PC1 and PC2 while the other traits have considerable amount of contribution in variations among germplasm because they are far from the axes on table.

Keywords: Sugarcane, *Saccharum officinarum*, red rot, brix, component analysis

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a valuable sugar crop of tropical and subtropical regions of the world and inherent to South East Asia (JANGPROMMA et al., 2010). It is grown in varied climatic conditions from cool moist to hot dry environment about 609 meters altitude and latitude of 35^0 N and 35^0 S of the world. However, it thrives well at temperature above 20^0 C (ELAHI et al., 2001). Sugarcane is the most important sugar crop for production of sugar in tropical and subtropical nations. Sugarcane cultivars are crucial in the manufacturing of sugar. (KHAN et al., 2017). The sugarcane crop plays a critical part in Pakistan's economy and is essential for the country's massive sugar industry to function. It is a source of waste and raw materials for the paper and clipboard industries (AAMER et al. 2018).

Sugarcane is a cherished cash crop of Pakistan and major source of sugar production which lives up to 75 % of the requirements of sugar industry (BAHADAR et al., 2007). It added 0.7% in GDP and 3.6% in agriculture’s value addition (GOVERNMENT OF PAKISTAN, 2017). In Pakistan, the sucrose recovery (9.46%) and average cane yield is considerably lower than other cane growing countries of the world (ARAIN et al., 2011). There are innumerable yield limiting factors in sugarcane production like unsuitable cultural practices, improper use of fertilizers, competition of weeds, absence of planned irrigation, susceptibility of insects, pests and various etiological agents like fungi, bacteria, viruses and nematodes (BALOCH et. al., 2002, AHMAD et al., 2017). Five quantitative (germination percent, number of tillers, plant height, cane yield, and number of millable canes) and four qualitative (c. brix percent, pol percent, purity percent, and sugar recovery) variables were used to analyze morphological changes in sugarcane clones. For germination percent, number of tillers, plant height, number of millable canes, cane yield, purity percent, and sugar recovery, the ANOVA revealed significant (p0.05) variations among the clones. (KHALID et al., 2014). Mehareb et al. 2017 conducted an experiment to determine the genetic diversity of several sugarcane properties at various harvesting ages. Cluster analysis of sugarcane clones was found to be useful in predicting the results of future crossings and hybridization. The genotypes with high qualitative and quantitative attributes could be good candidates for use in Pakistan's sugarcane breeding and varietal improvement programmes (SEEMA et al., 2017).

It is well recognized that behavior of sugarcane genotypes in the field is principally based of its genetic potential and its yield can only be strengthened by genetic improvement of cultivars (PANHWAR & MEMON, 2004). In reaction to inoculation with *Colletotrichum falcatum* Went, the causal agent of red rot, sugarcane produces a complex variety of phytoalexins (MALATHI et al., 2018). Utilization of hybridization techniques can expand the genetics of sugarcane but defined climatic conditions essential for flowering are not present in Pakistan. Most of the cane breeding programs involve selection of superior genotypes with required characteristics from succeeding generations raised from fuzz and release as new variety. High cane and sugar contents are the vital objectives of development of superior genotypes (TERZI et al., 2009). In Pakistan, the current sugarcane breeding programme does not meet the variety evolution of desirable features. It is largely reliant on the introduction of exotic fuzz-seed sugarcane types, with little regard for varietal characteristics. As a result, characterising sugarcane germplasm is critical not just for resource conservation but also for identifying genetic linkages across breeding materials for overall sugarcane crop improvement (SHAHZAD et al., 2016). Taking into account foregoing research work, the present study was planned to evaluate sugarcane germplasm for yield traits in response to sugarcane red rot severity under natural filed condition with ultimate objective to search out sugarcane red rot free genotypes having high yield to secure sugarcane crop and their supplementary utilization in sugarcane breeding program.

MATERIALS AND METHODS

A field experiment was carried out during two consecutive years (2017-18 & 2018-2019) at the Research Area, College of Agriculture, University of Sargodha, Sargodha. Soil was sandy clay loam in texture with pH 7.82 (Table). Thirty two sugarcane genotypes were collected from government and private sectors. Sugarcane setts having three eye buds were planted in randomized complete block design (RCBD) in triplicate, keeping plant to plant and row to row distances at 30 and 75 cm, respectively. Irrigation and normal cultural practices were carried out during crop growth period each year. Each year the data were collected for plant parameters such as cane height (cm), cane diameter (cm), leaf area (cm2), tillers per stool, internodes per cane, internodal length (cm), single cane weight (g), and brix percentage. Scoring for Red rot incidence (%) and severity (%) under natural environmental conditions were also recorded. Red rot severity was estimated by the symptoms using the following scoring system suggested by (ADDY et al., 2018):

#	Location	Symptoms	Score
1.	Shoot	Green	0
		Yellow/dry	1
2.	Lesions	Very rare	1
		Lesions spreading but not covering whole cane area	2
		Lesions covering complete inner cane area	3
3.	White spots	Restricted	1
		Advanced	2
4.	Nodal indiscretion	One node intersected by fungus	1
		Two nodes intersected by fungus	2
		Three nodes intersected by fungus	3

Analysis of variance of all studied plant traits was computed to observe significant differences among sugarcane genotypes (STEEL et al. (1997). The year effect was non-significant so data were assembled. Principle component and biplot analyses (SNEATH & SOKAL, 1973) were done to determine inter relationship among characters and to categorize sugarcane genotypes for observed plant traits by using computerized software.

RESULTS AND DISCUSSION

Analysis of variance

Mean square values indicated the highly significant differences among sugarcane genotypes for given morphological parameters and red rot incidence and severity under natural environmental condition (Table 1). Mean comparison showed that for cane height genotype XT-910 showed maximum value 198.33 cm while the genotype Co-1148 present minimum value of 123.00 cm. Cane height is an important indicator of high quality juice in cane (KHALID et al.

2014). For cane diameter it was found that the genotype SPF-237 gave the highest mean diameter of 3.444 (cm) while on the other hand genotype CP-368 got the minimum mean of cane diameter 2.6556 (cm).

This trait contributes towards lodging resistance in sugarcane (MEHAREB et al. 2017). Leaf area has a direct influence on photosynthetic activity of crop plant (AAMER et al. 2018).

Mean comparison for leaf area showed that the maximum area of leaf for MSH-2415 genotype was 133.67 cm^2 and the minimum leaf area of 67.12 cm^2 was calculated for the Co-1148 genotype. Tillers per stool plays a significant role in sugarcane yield (SEEMA et al.,2017).

The highest mean value for tillers per stool was calculated in XT-236 genotype which showed mean of 6.00 and the lowest mean value of 1.3333 was calculated for CPSG-3481. Internodal length which is also a direct indicator of cane height showed the maximum mean value for genotype CPSG-2718 which was 15.100 (cm) while the genotype CPF-247 got minimum mean value of 6.450 (cm). The highest single cane weight of 1300.0 gram was calculated for the genotype XT-910 while the minimum single cane weight of 753.3 g was calculated for the genotype FST-19. The genetic variation among genotypes exhibited that selection would be possible to enhance cane yield in sugarcane. (MEHAREB et al. (2017) and AAMER et al. 2018).

Brix reading is a trustable index for measuring sugar content Khan et al. 2018. The maximum brix value of 22.26% was observed in the genotype US-133 while the minimum mean value of 18.889% was calculated for genotype SPF-220.

The results of Red Rot incidence in the studied sugarcane genotypes displayed that highly significant differences were present among reported genotypes for incidence of Red rot (MALATHI et al., 2008).

The highest scoring of 100% was observed for genotype Co-1148 while the minimum value is for SPF-213 which is 19.43% which mean that the SPF-213 was better performing in terms of resistance against red rot incidence. Co-1148 was very much prone to the red rot disease.

Table 1. Mean squares values of morphological parameters of sugarcane genotypes.

Plant traits	**Genotypes (g-1)31**	**Replications (r-1) 2**	**Error (g-1)(r-1) 62**
Cane height	998.75**	1161.03$^{N.S}$	308.42
Cane diameter	0.070**	0.045$^{N.S}$	0.038
Leaf area	713.47**	485.62$^{N.S}$	387.84
Weight per cane	52967.2**	7538.5$^{N.S}$	17382.6
Nº. of tillers per stool	4.05**	1.07$^{N.S}$	1.09
Nº. of internode	11.47**	3.12$^{N.S}$	5.23
Internode length	14.82**	0.25$^{N.S}$	2.34
Brix %	8.0359**	0.4009$^{N.S}$	2.6495
Red rot incidence %	1218.55**	86.19$^{N.S}$	64.69
Red rot severity %	1640.34**	6.76$^{N.S}$	46.24

** = Highly significant ($P \leq 0.01$) & NS = Non-Significant

Genotypic, phenotypic variability and broad sense heritability (h^2 BS)

Broad sense heritability, genotypic and phenotypic variations of the plant traits under consideration were presented in Table 2. The results presented that plant traits like weight per stool and single cane weight showed high broad sense heritability and sufficient genetic variability among sugarcane genotypes. Selection of genotypes based on the traits having high heritability (h^2) would be effective to improve cane production. Cane height, cane diameter and number of internodes also presented moderate broad sense heritability and genetic variation. These traits should be taken into account during selection of sugarcane genotypes for high yield. Our results get support from the findings of Khan et al. (2017), and Khaliq et al. (2018) who also reported high broad sense heritability for given plant traits.

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Table 2. Genotypic, phenotypic variability and broad sense heritability among different sugarcane genotypes.

Variables	**Vg**	**Vp**	**H^2bs %**
Cane height	586.21	1003.77	56.51
Cane diameter	0.28	0.54	57
Leaf area	1927.1	7813.9	24.69
Weight per cane	1.97	2.134	93
Nº. of tillers per stool	0.86	2.32	32
Nº. of internode	6.01	9.86	57
Internode length	1.38	4.29	31.61
Brix %	1.59	5.04	39

VG: Genotypic variance, VP: Phenotypic variance and HBS: Broad sense heritability

Principle Component and Bi-plot Analysis

Mean of all the traits was subjected to the principal component analysis to check for the groups (principal components) having desirable genotypes with respect to their performance. 9 principal components PC1 – PC9 were observed and data for the Eigenvalue has been shown in (Table 3). First four principal Components are showing the eigenvalue more than 1 which means they have high variability and it indicates their broad genetic base. The PC1 showed contribution of 29.263% to the total variation while PC2 share contribution of 21.778% similarly, PC3 share contribution of 14.799% of total variation and the PC4 share contribution of 11.915% of total variation. The remaining principal components have total of 20% contribution of the total variation.

In the first principal component PC1 (Table 4), cane height, weight per cane, internode length, red rot incidence and leaf area are most important traits in contribution to variability which is calculated as 29.263%.

In second principal component PC2 in (Table 4) the main traits which contributes in variations among genotypes are red rot incidence, area of leaf, brix percentage and number of tillers. The variation is calculated by second principal component about 51.042%.

Table 3. Eigenvalue and total variance % of principle components for sugarcane genotypes.

Principal Components	Eigenvalue	Variability %	Cumulative %
PC1	2.926	29.263	29.263
PC2	2.178	21.778	51.042
PC3	1.480	14.799	65.841
PC4	1.192	11.915	77.756
PC5	0.702	7.015	84.771
PC6	0.582	5.824	90.595
PC7	0.515	5.154	95.749
PC8	0.386	3.857	99.606
PC9	0.039	0.394	100.00

In the third principal component PC3 it can be observed from (Table 4) that number of tillers, cane girth and brix percentage plays a great role in creating variation among genotypes with the cumulative variation percentage of 65.841%

In PC4 (Table 4) it can be seen that the traits which contributed more for variation among all genotypes are lodging, number of tillers and number of internodes which gives the cumulative value of 77.756%.

Similarly, the PC5 shows the 84.771% of the total variation and PC6, PC7, PC8 and PC9 shows the more than 90% of total variation (Table 4).Our findings are in conformity with Shahzad et al. (2016), Ahmed and Gardezi, (2017), Aamer et al. (2018) and Khan et al. (2019).

Biplot showed that lodging percentage and girth traits have least variability because they are close to the PC1 and PC2 while the other traits have considerable amount of contribution in

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variations among germplasm because they are far from the axes on table (Figure 1 and 2). PC1 and PC2 scatter plot showed that sugarcane genotypes XT-910, SPF-220, SPF-234, SPF-213, Co1148, CPF-247 and FST-19 are scattered throughout the plot (Figure 1 and 2).

Table 4. Principal components for 10 morphological and quality traits in 32 genotypes of sugarcane.

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**PC9**
Height	0.490	-0.227	0.043	-0.239	-0.166	0.312	-0.185	-0.039	-0.699
Weight per cane	0.477	-0.249	0.142	-0.258	-0.134	0.244	-0.135	-0.196	0.700
Girth	0.101	-0.232	0.511	0.381	-0.358	-0.509	0.066	-0.359	-0.093
Nº. of tillers	0.097	0.146	0.654	0.268	0.194	0.228	-0.181	0.588	0.040
Nº. of internode	0.293	-0.202	-0.428	0.268	-0.428	-0.210	0.113	0.608	0.097
Internode length	0.371	-0.223	0.038	-0.037	0.598	-0.170	0.648	0.039	-0.044
Area of leaf	0.368	0.487	-0.090	0.009	0.099	-0.277	-0.198	-0.072	0.001
Lodging	0.146	0.091	-0.223	0.736	0.062	0.510	0.100	-0.323	0.012
Brix	0.013	0.472	0.200	-0.209	-0.479	0.242	0.635	0.013	-0.008
Red rot incidence	0.363	0.503	-0.080	0.007	0.072	-0.251	-0.158	-0.074	0.001

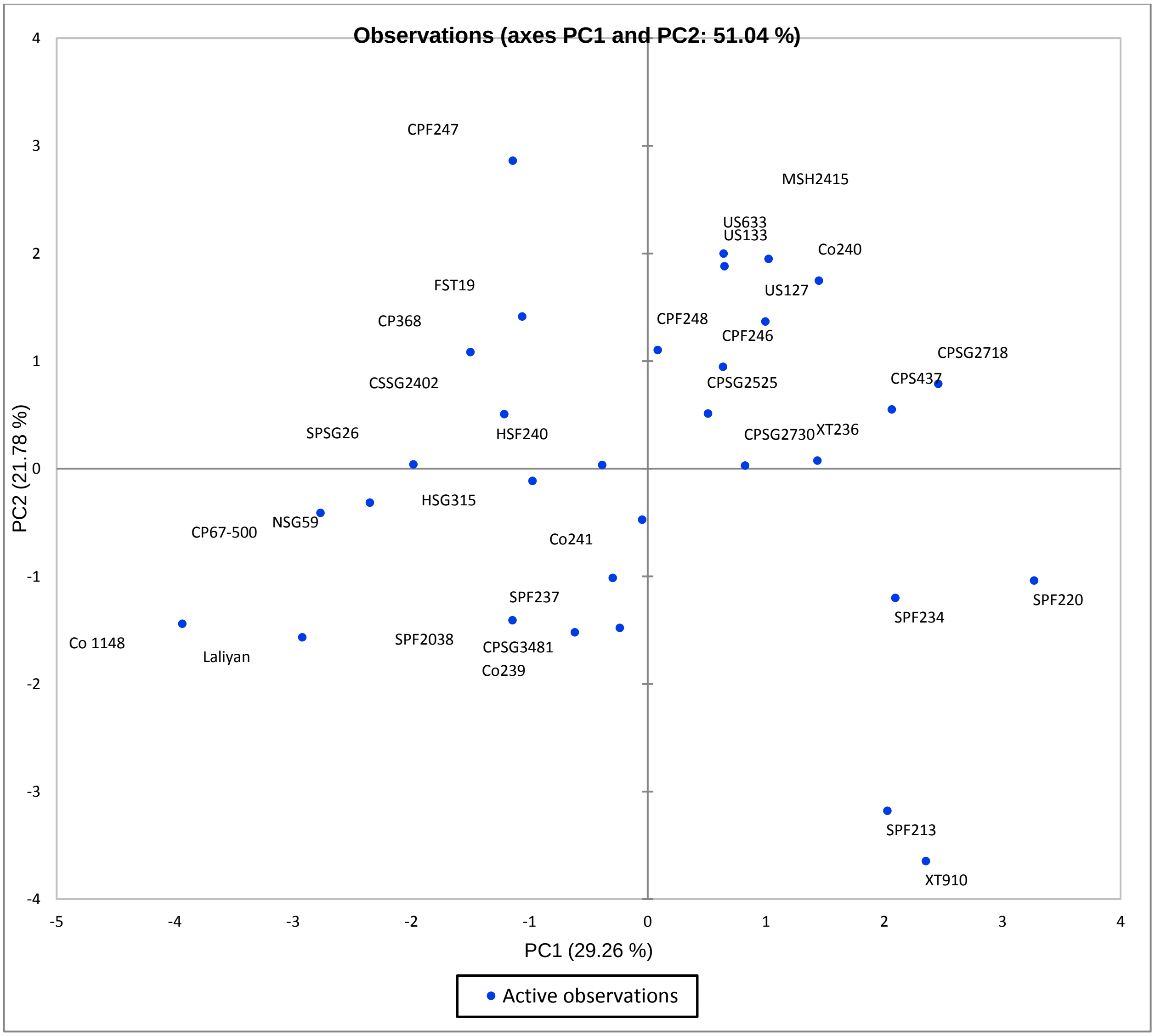

Figure 1. Two dimensional orientations of 32 genotypes of sugarcane on principal component axis 1 and 2.

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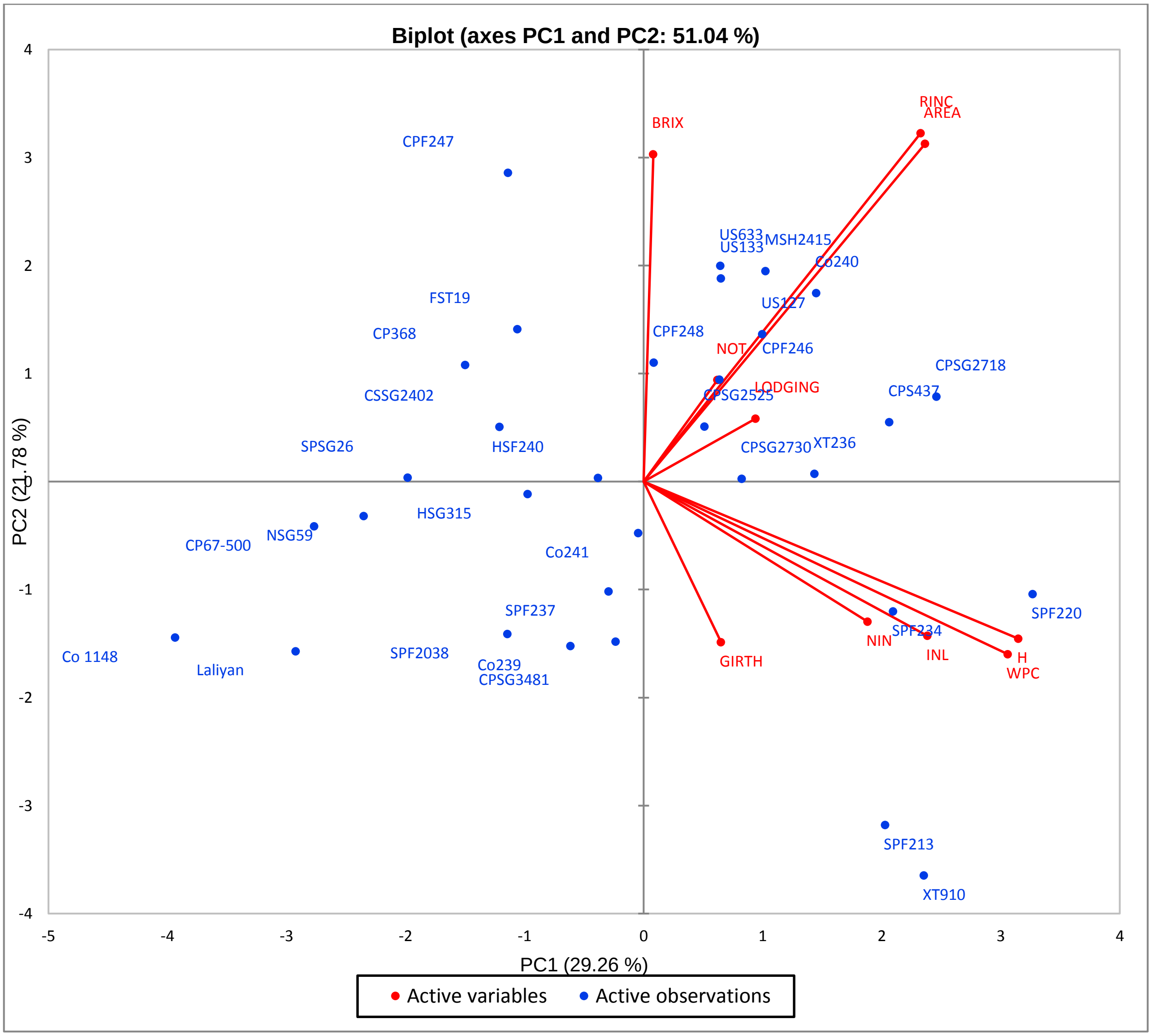

Figure 2. PC1 and PC2 bi-plot showing relationship of plant traits with sugarcane genotypes.

CONCLUSION

High level of genetic variation prevailed in studied sugarcane genotypes for different morphological traits, sugar recovery and Red rot tolerance. Sugarcane genotypes US-133,US-633,US-127,CPF-247,MSH-2415 were found excellent for sugar recovery while SPF-213 and SPF-237 were observed as resistance/tolerant against Red Rot. Furthermore, SPF-213, US-133,US-633 and US-127were found genetically diverse genotypes for different calculated traits and would be useful in sugarcane breeding program to enhance sugar recovery and Red rot resistance/tolerance in advanced sugarcane genotypes.

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