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Climate Resilient, High Yielding and Stable Sugarcane Genotypes in India

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SUMMARY

Based on long term data analysis of advanced varietal trials of All India Coordinated Research Project (AICRP) on Sugarcane, identified nine genotypes which possess the qualities of high yield sustainability and low sensitivity towards adverse changes in environmental conditions during 2012 to 2018. Out of nine, two Co 10024 and Co 11001 from early group and two CoM 11086 and Co 08009 from mid late group of Peninsular Zone. In East Coast Zone, only one early maturing genotype, CoA 13322, was identified. Two mid-late genotypes, CoH 08262 and CoH 09264, were identified from North West Zone. Similarly two mid-late genotypes, CoSe 11454, CoP 12438, were identified from North Central and North Eastern Zone. Out of 163 genotypes, only CoSe 11454 was highly stable for all the three character, CCS (t/ha), cane yield (t/ha) and sucrose (%). Other eight were highly stable for CCS (t/ha) and cane yield (t/ha) only. These may be used as parents in crossing programme as possess the qualities of high yield sustainability and low sensitivity towards adverse changes in environmental conditions or having high stability and high yield criteria.

Keywords: Climate resilient, Sugarcane, Genotypes, Sustainability, Stability.

1. INTRODUCTION

About 38% districts (241 of 634) in India were found to be resilient to drought to dry condition (Annon., 2018). In fact, deficit monsoon has become chronic with 13 of the last 18 years witnessing below-normal rains. In recent years, country had continuously five deficit monsoon since 2014. Sugarcane is a high biomass crop which requires large amounts of water for good yields. Irrigation is necessary in order to produce sugarcane in almost all parts of the country, but water supplies are becoming increasingly limited (Gupta and Kumar, 2018). Most of the sugarcane area is resilient and slightly non-resilient to drought to dry condition and this crop shows better tolerance to water extreme than other crops. That is why the sugarcane yield in the country was not effected due to drought to dry condition and resulted sugarcane productivity in between 65 to 70 t/ha in last twenty years except 2002-03, 2015-16 and 2016-17. These three years were had either normal or little deficit monsoon. As sugarcane is highly sensitive to climatic and edaphic factors, location specific selection of varieties is important, as varietal requirement differs for every zone (Anon, 2014). This study was under taken to identify sugarcane genotypes which possess the qualities of high yield sustainability and low sensitivity towards adverse changes in environmental conditions.

2. MATERIAL AND METHODS

Genotype x Environment (GE) interaction continues to be a challenging issue among plant breeders, geneticists and agronomists in conducting varietal trials across diverse environments. Methods of partitioning GE interaction into components measure the contribution of each genotype in GE interaction. Whenever an interaction is significant, use of main effects e.g., overall genotype means across environments is often questionable. Stability performance of genotype is considered as an important aspect in varietal trials. Researchers need a statistics that provides a reliable measure of stability or consistency of performance of a

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genotype across a range of environments, particularly one that reflects the contribution of each genotype to the total GE interaction and helps in identifying the best genotype. For a successful breeding or genotype testing programme, both stability and yield (or any other trait) must be simultaneously considered. Also integration of stability of performance with yield through suitable measures will help in selecting genotypes in a more precise manner. In this study, it is proposed to use simultaneous selection indices using Additive Main Effects and Multiplicative Interaction (AMMI) model. This model is appropriate when main effects (genotypic, environmental) and genotype x environment interaction (GE) effects are both important in yield trials.

AMMI model offers a more appropriate statistical analysis to deal with such situations, compared to traditional methods like ANOVA, Principal Component Analysis (PCA) and linear regression. Currently, selection of sugarcane genotypes is based on the performance of cane yield across the location in a zone and ranking of genotypes is done on the basis of mean data. Ranking of genotypes based on simultaneous selection of high yielding and stable genotypes gives better and reliable picture in identifying a variety for release.

Simultaneous selection approach proposed by Rao & Prabhakaran (2005) and Kumar & Sinha (2012 to & 2015) was used in this study which selects genotypes for both high yield and stability in multi-environmental trials using AMMI model by assigning 80% weight to yield and 20% to stability values of the genotype.

2.1 AMMI and simultaneous selection procedure

The AMMI method combines the traditional ANOVA and PCA into a single analysis with both additive and multiplicative parameters (Gauch, 1992). The first part of AMMI uses the normal ANOVA procedures to estimate the genotype and environment main effects. The second part involves the PCA of the interaction residuals (residuals after main effects are removed). The model formulation for AMMI shows its interaction part consists of summed orthogonal products. Because of this form the interaction lends itself to graphical display in the form of so-called bi-plots (Gabriel (1971)). Here, it is assumed that the first two PCA axes suffice for an adequate description of the GxE interaction. It is evident from earlier sections that the scope of bi-plots is very much limited. The inferences drawn from bi-plots will be valid only when the first two PCAs explain a large portion of interaction variation. In situations, where more than two PCA axes are needed to accumulate considerable portion of GEl variation, what should be the approach for identifying varieties which are high yielding as well as stable. Keeping this in mind, a new family of simultaneous selection indices was proposed by Rao and Prabhakaran (2005) which can select varieties for both yield and stability was applied in this study. The proposed selection indices (I_i) consists of (i) a yield component, measured as the ratio of the average performance ($\bar{Y}_{i.}$) of the i-th genotype to the overall mean performance of the genotypes under test, and (ii) a stability component, measured as the ratio of stability information (l/ $ASTAB_i$) of the i-th genotype to the mean stability information of all the genotypes under test. The simultaneous selection index is given as

$$I_i = \frac{\bar{Y}_{i.}}{\bar{Y}} + a\frac{\frac{1}{ASTAB_i}}{\frac{1}{T}\sum_{i=1}^{T}\frac{1}{ASTAB_i}}$$

Where $ASTAB_i$ is as stability measure of the i-th genotype under AMMI procedure and $\bar{Y}_{i.}$ is mean performance of i-th genotype. α is the ratio of the weights given to the stability components (w_2) and yield (w_1) with a restriction that $w_1 + w_2 = 1$.

Simultaneous selection criterion proposed by Rao and Prabhakaran (2005) was used in this study which selects genotypes for both high yield and stability in multi-environmental trials using AMMI model by assigning 80 % weight to yield and 20 % to stability value of the genotypes. Such weights were assigned because Hogart (1976) inferred that 75 % of the gains in cane yield in Australia were attributed to the varietal improvement and Edme *et al.* (2005) estimated that genetic improvement along contributed 69 % of the sugarcane yield.

This method was used for selection of high yielding and stable genotypes under Advance Varietal Trial of early and midlate maturity group in Plant I & II and ratoon crops conducted during (2012 to 2018) in Peninsular Zone, East Coast Zone, North West Zone and North Central Zone (Map 1) of All India Coordinated Project on Sugarcane. Advance Varietal Trials (Plant I) were conducted during first year and same crop was ratooned during second year of the crop. Advance Varietal Trials (Plant II) were conducted during second

year of the trial. Combination of two years of plant crops and one ratoon crop data were analyzed for stability analysis. AMMI analyses and simultaneous selection indices analyses were performed with the help of SAS 9.3 (SAS Institute, 2002-2010). Other statistical analysis was done using Ms-Excel (2014). In each zone, ranking of varieties was based on the above mentioned criterion for commercial cane sugar (CCS t/ha), cane yield (t/ha) and sucrose (%). Similar analysis was done for each identified genotype (Table 1) with other genotype of the trial for Simultaneous selection criterion proposed by Rao and Prabhakaran (2005).

2.2 New initiative of genotype ranking against high yield sustainability and low sensitivity towards adverse changes in environmental conditions under crop improvement programme of AICRP(S)

A successful evaluation of genotypes for stable performance under varying environmental conditions based on information on genotype × environment interaction for yield is an essential part of any sugarcane varietal development programme. The selection of sugarcane genotypes is based on the performance of cane yield across the location in a zone and ranking of genotypes was done on the basis of mean data. The same criterion was used in All India Coordinated Research Project (AICRP) on Sugarcane since 1971 and till 2011-12. A new approach involving simultaneous selection indices using Additive Main Effects and Multiplicative Interaction (AMMI) model for Advanced Varietal Trial of All India Coordinated Research Project on Sugarcane has been applied for simultaneous selection of high yielding and stable sugarcane genotypes. The approach involves three steps for selection of high yielding and stable genotype, in Advanced Varietal Trial of AICRP on sugarcane. In the first step, genotypes performing better than the best standards in the trial based on only yield performance are selected. In second step, the selected genotypes are ranked / judged on index values obtained on basis of both yield and stability. The third step involves the ranking of selected genotypes of step one on basis of their stability. Genotypes are considered best, high yielding and stable, if their respective ranks were found better than the ranks of best standard or at least one of the standards. If their ranks are inferior to the best standard, then we judged the top ranks among the tested genotypes based on index value.

3. RESULTS AND DISCUSSION

Based on the large data analysis of proposed above procedure, out of 163 genotypes tested in five zones at Advanced Varietal Trials under All India Coordinated Research Project (AICRP) on Sugarcane, identified nine genotypes which possess the qualities of high yield sustainability and low sensitivity towards adverse changes in environmental conditions during 2012 to 2018 (Table 1). Because these entries were found high yielding for cane yield (t/ha), CCS (t/ha) and Sucrose (%) and stable as per the procedure suggested by Rao & Prabhakaran (2005) except entry Co 13322 of East Coast Zone (Table 3, 4 and 5). These entries were also highly stable in respective zones if we consider only AMMI stability procedure proposed by Gauch (1992). Co 13322, an early maturing genotype, ranked second in the zone for cane yield (t/ha), CCS (t/ha) and Sucrose (%). But this entry recorded the highest cane yield of 117.91 t/ha among the nine entries. This entry had 13.57 t/ha CCS and 16.55 % sucrose.

Out of nine, two Co 10024 and Co 11001 from early group and two CoM 11086 and Co 08009 from midlate group were highly stable and high cane yielding of Peninsular Zone (Table 3, 4 and 5). These four entries recorded cane yield in between 94 to 106 t/ha. Similarly, these entries were highly stable and high yielding for CCS (t/ha). Among the nine entries, Co 08009 recorded the highest CCS (t/ha) of 14.07 t/ha and 19.35 % sucrose (Table 3, 4 and 5).

In North West Zone, out of nine, two CoH 08262, CoH 09264 from midlate group were highly stable and high cane yielding for cane yield (t/ha) and CCS (t/ha). Both these were developed from CCS HAU research centre, Uchani. These entries had low values of stability for CCS (t/ha) and sucrose (%) and had high rank for cane yield and CCS (t/ha).

In North Central and North Eastern Zone, mid-late entry CoSe 11454 was found to be the only entry during this period which showed the high stability for sucrose (%) along with cane yield (t/ha) and CCS (t/ha) among all the nine entries. Other eight entries had high stability for cane yield and CCS (t/ha) only. For Sucrose (%), these eight entries had very inferior rank and high value of stability among the nine entries. CoSe 11454 had lowest value of stability (2.48), which indicate that it is very stable genotype. This entry recorded cane yield (74.5 t/ha), CCS (9.14 t/ha) and Sucrose (17.6 %). This entry may be considered for release for commercial cultivation in North Central Zone of All

India Coordinated Research Project on Sugarcane. Similar performance were also observed for the mid-late entry, CoP 12438, in this zone.

For sugarcane, if the simultaneous selection index value is around 1.45 then genotype is high yielding and highly stable across the zone for cane yield (t/ha) and CCS (t/ha). Similarly for sucrose (%) if it is around 1.20 then the genotype is high yielding and highly stable across the zone. As far as pest and diseases reaction of the genotypes is concern, the information of these nine genotypes is presented in Table 2, at an advance level of screening. Normally, genotypes are promoted to an advance level of testing which are resistant or moderately resistant to diseases at initial level of screening. Similar situation is for two important pest of sugarcane (Table 2). All are LS - Least susceptible to Early Shoot Borer and Top Borer.

CONCLUSION

Climate change induced changes in growth and development and adverse effects on sugarcane and sugar productivity invoke in urgency for climate – resilient varieties of sugarcane to mitigate such effects. Nine identified genotypes can also be considered as climate resilient genotypes of different zones (Table 1). These genotypes will be least effected by drought and water logging in different part of the country because yield fluctuations were minimum in the trails due to high stability in cane yield. Use of these nine genotypes, as parents, in sugarcane breeding programme may also be helpful in imparting multiple – stress tolerance and sustaining sugarcane production and productivity in different zones of AICRP(S) in the country under such conditions. These genotypes may be considered for release for commercial cultivation in different zone of All India Coordinated Research Project on Sugarcane.

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Table 1. Climate resilient high yielding and stable sugarcane genotypes in India

Zone	Early	Mid-late
Peninsular Zone	Co 10024, Co 11001,	CoM 11086, Co 08009
East Coast Zone	CoA 13322	
North West Zone		CoH 08262, CoH 09264,
North Central and North Eastern Zone		CoSe 11454, CoP 12438

Table 2. Details and performance and of climate resilient high yielding and stable sugarcane genotypes

Genotype	Zone name of the tested genotype	No. of Entries tested in trial	Maturity	Year	Trial Conducted	Disease reaction			Pest reaction	
						*Red rot	YLD	Smut	ESB	TB
Co 10024	Peninsular Zone	11	Early	2017	Plant I, Plant II and Ratoon	R or MR	R	S	LS	-
Co 11001	Peninsular Zone	8	Early	2018	Plant I, Plant II and Ratoon	R or MR	R or MR	R or MR	LS	-
CoM 11086	Peninsular Zone	8	Midlate	2018	Plant I, Plant II and Ratoon	R or MR	R or MR	R or MR	LS	-
Co 08009	Peninsular Zone	7	Midlate	2014	Plant I, Plant II and Ratoon	R or MR	-	R or MR	-	-
CoA 13322	East Coast Zone	7	Early	2018	Plant I, Plant II and Ratoon	R or MR	-	-	LS	-
CoH 08262	North West Zone	9	Midlate	2014	Plant I, Plant II and Ratoon	R or MR	-	S to MR	-	LS
CoH 09264	North West Zone	8	Midlate	2015	Plant I, Plant II and Ratoon	R or MR	R	MS to R	-	LS
CoSe 11454	North Central and North Eastern Zone	7	Midlate	2017	Plant I, Plant II and Ratoon	R or MR	-	R	MS	LS
CoP 12438	North Central and North Eastern Zone	6	Midlate	2018	Plant I, Plant II and Ratoon	R or MR	-	-	LS	LS

*Red rot reaction by plug and cotton swab method at least one centre of the zone

R – Resistant, MR - Moderately Resistant, LS - Least susceptible MS - Moderately susceptible

ESB – Early Shoot Borer and TB – Top Borer

Table 3. Ranking of genotypes of according to their (i) mean performance, (ii) stability and (iii) simultaneous index value in respect of cane yield (t/ha)

Genotype	Maturity	Estimated value			Rank based on estimated value		
		Index Value	Cane Yield (t/ha) value	Stability value	Index value based rank	Cane Yield (t/ha) based rank	Stability based rank
Peninsular Zone							
Co 10024	Early	1.56	98.07	1366.91	1	4	1
Co 11001	Early	1.45	94.51	1275.3	1	2	1
CoM 11086	Midlate	1.52	101.26	681.61	1	2	1
Co 08009	Midlate	1.5	102.06	993.65	1	3	1
East Coast Zone							
CoA 13322	Early	1.37	117.91	238.15	2	1	3
North West Zone							
CoH 08262	Midlate	1.55	81.85	171.71	1	2	1
CoH 09264	Midlate	1.56	85.28	275.66	1	1	1
North Central and North Eastern Zone							
CoSe 11454	Midlate	1.71	74.50	95.88	1	4	1
CoP 12438	Midlate	1.52	76.59	95.96	1	1	1

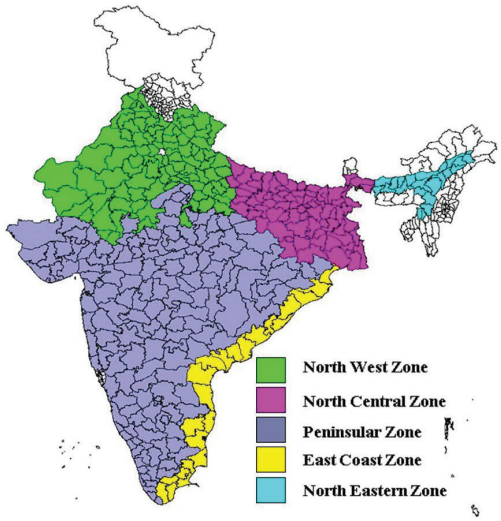
Table 4. Ranking of genotypes of according to their (i) mean performance, (ii) stability and (iii) simultaneous index value in respect of CCS (t/ha)

Genotype	Maturity	Estimated value			Rank based on estimated value		
		Index Value	CCS (t/ha) value	Stability value	Index value based rank	CCS (t/ha) based rank	Stability based rank
Peninsular Zone							
Co 10024	Early	1.51	12.18	25.86	1	5	1
Co 11001	Early	1.37	11.29	22.42	1	3	1

Genotype	Maturity	Estimated value			Rank based on estimated value		
		Index Value	CCS (t/ha) value	Stability value	Index value based rank	CCS (t/ha) based rank	Stability based rank
CoM 11086	Midlate	1.4	13.19	19.22	1	4	1
Co 08009	Midlate	1.43	14.07	20.28	1	3	1
East Coast Zone							
CoA 13322	Early	1.35	13.57	6.41	2	2	3
North West Zone							
CoH 08262	Midlate	1.44	9.65	3.15	1	5	1
CoH 09264	Midlate	1.46	9.62	5.16	1	2	1
North Central and North Eastern Zone							
CoSe 11454	Midlate	1.51	9.14	3.37	1	2	1
CoP 12438	Midlate	1.45	9.09	2.00	1	3	1

Table 5. Ranking of genotypes of according to their (i) mean performance, (ii) stability and (iii) simultaneous index value in respect of Sucrose (%)

Genotype	Maturity	Estimated value			Rank based on estimated value		
		Index Value	Sucrose(%) value	Stability value	Index value based rank	Sucrose (%) based rank	Stability based rank
Peninsular Zone							
Co 10024	Early	1.23	17.56	7.35	7	8	8
Co 11001	Early	1.11	17.02	7.03	8	8	8
CoM 11086	Midlate	1.26	18.53	7.33	3	6	3
Co 08009	Midlate	1.23	19.35	3.98	4	3	4
East Coast Zone							
CoA 13322	Early	1.21	16.55	3.73	7	8	5
North West Zone							
CoH 08262	Midlate	1.26	16.90	2.81	5	7	3
CoH 09264	Midlate	1.11	16.57	5.82	8	8	8
North Central and North Eastern Zone							
CoSe 11454	Midlate	1.33	17.6	2.48	1	2	1
CoP 12438	Midlate	1.32	17.06	2.2	2	4	2



Map 1: Zones of All India Coordinated Research Project on Sugarcane