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# Genotype x environment interaction and stability in promising elite clones of yield potentiality in respect to cane and sugar yield

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**Abstract**
The present investigation was carried out to determine the relative performance of yield potential, stability and adaptability of promising sugarcane (*Saccharum officinarum* L.) varieties and identify promising once. Seven varieties were evaluated in randomized complete block design with three replications during spring season of 2015-16, 2016-17, 2017-18, 2018-19 & 2019-20 at Agricultural Research station, Ummedganj, Kota. The pooled analysis of variance showed highly significant ($p$<0.01) differences for genotypes (G), environments (E) and G x E interaction. The mean cane & sugar yield (t/ha.), regression coefficient (bi) and deviation from regression ($S^2d$) used to identify the stability and adaptability of popular varieties. Based on stability parameters and over all mean performance of cane & sugar yield, variety Co 0238 has high mean for both cane yield and sugar yield (83.05, 10.17) with bi =1.0 and non-significant $s^2d$ = 0, indicated that this varieties found better responsive to all the environments and were considered as stable varieties. Whereas the genotype Co 05009 produced high mean yield (79.64, 9.72), bi >1 with non significant $s^2d$, indicated below average stability, such genotypes tend to respond favorably to better environments but give poor yield in unfavourable environments. Hence, these genotypes were suitable for favorable environments. Variety CoS 8436 having low mean ((73.83, 8.70) for cane & sugar yield, bi < 1 with non significant $s^2d$ value, indicated that genotype suitable for poor environment.

**Keywords:** Stability parameters, G X E interaction, regression coefficient (bi), deviation from regression ($S^2d$), adaptability in popular varieties of sugarcane

## Introduction
Sugarcane is one of the major cash crops grown extensively in all over the world from tropical to subtropical region. India is the second largest producer in the sugarcane next to Brazil (FAO Data base 2004). In subtropical India variation in climatic conditions are wide in the period of its growth and maturity, here temperature ranges from 0 to 48 $^oC$, photoperiod ranges from 4 - 8 hr and humidity 8 - 100%. Climatic coefficient shifts a are variable factors during the crop growth period which affect the yield and other characters. Hence, the yield of sugarcane is generally low in the part of India. Sugarcane breeding is highly complex because of its highly heterozygous nature, combined with higher polyploidy (2n= 80 to 120) level. A commercial cane variety is selected on its stability to produce sucrose, its resistance to pest and diseases and its rationing ability. While other characteristics may not influence the selection procedure to any great extent, they may influence a grower's choice of variety. It is desirable to grow better varieties that produce more cane and higher sugar yield so that proper and effective varietal scheduling can be practiced to provide quality cane to factories during the crushing period. In any plant breeding programme, the genotypes x environment interactions are of major importance when testing of newly developed varieties. The relative performance of a variety differs due to the differences in genotype x environment interaction in different environments.
Genotype by environment interactions is important source of variation in any crop and the term stability can be used to characterize a genotype, which show a relatively constant yield, independent of changing environmental conditions. On the basis of this idea, genotype with a minimal variance for yield across different environments is considered stable (Sabaghnia *et al.* 2006) [8].
The analysis of adaptability and stability are therefore extremely important and necessary for the identification and recommendation of superior genotypes in different environments. Therefore, it is necessary to evaluate any genotype for G x E interaction for yield & its attributes and identify stability for these traits in sugarcane. Cane yield and its component traits are highly affected by the environments. Techniques for G x E analysis based on linear regression can be informative when G x E interaction has high linear association with the environmental index but when the non linear component is also significant. (Finley and Wilkinson 1963 [2], Eberhart and Russell (1966) [1]. The analysis based on Eberhart and Russell model being relatively simple and has been widely used for stability analysis. Regarding in stability parameters, sufficient information is not available in sugarcane which could be used in further breeding programme. Keeping above facts in view, the present investigation was under taken to focused on selection of high yielding varieties which are stable for cane and sugar yield.

## Material and Methods
The present investigation was carried out with seven release varieties of sugarcane (*viz*, CoJ 64, Co 0238, Co 05009, CoS 767, CoS 8436 Co Pant 97222 and Co 05011) in different environment to test stability. The experiment were laid out in complete randomized block design with three replications with row to row spacing of 90 cm. in each environment during spring season of five years (2015-16, 2016-17, 2017-18, 2018-19 & 2019-20) at Agricultural Research Station, Ummedganj, Kota,

Rajasthan and recommended agronomic practices were followed during the entire cropping season to raise good crop. The stability of genotypes was estimated by using the method of Eberhart & Russell (1966) [1]. In this analysis sum of square due to G x E were portioned into individual genotype mean, regression of environmental mean (bi) and deviation from regression ($S^2d$). The regression coefficient (bi) and mean square deviation from regression ($S^2d$) were used to define genotype stability. The pooled error was used to test the hypothesis that the mean square deviation did not differ significantly from 0.05 and 0.01% probability levels. The t- test employing the standard error of regression coefficient against the hypothesis that it did not differ from 1.0. It was assumed that genotype effects were fixed and the year effects were random. The data on cane and sugar yield were recorded on plot basis and estimated in t/ha. The stability parameters were calculated by Eberhart & Russell's (1966) [1] joint regression model

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

**Where**

Yij = is the mean of the $i_{th}$ variety at the $j_{th}$ environment,
$\mu_{I=}$ is the mean of the $j_{th}$ variety over all environments,
$\beta_i$ = is the regression coefficient that measures the response of the $j_{th}$ variety to varying environments,
$I_j$ = is the environmental index obtained as the mean of all varieties at the $j_{th}$ environment minus the grand mean and
$\delta_{ij}$ = is the deviation from regression of the $i_{th}$ variety at the $j_{th}$ environment.

The stability parameters, regression coefficient and mean square deviation were estimated as described below.

The regression coefficient ($\beta_i$): $bi = \frac{\sum j Y ijtj}{\sum j I2 j}$

Where,
$\sum_j Yij\ Ij$ = is the sum of the product.
$\sum_j I^2{}_j$ = is the sum of squares

The mean square deviation ($\delta^2 d_i$): $\frac{\sum j \delta 2\ ij}{s} - \frac{e}{r}$

Where, $\delta 2\ ij$ = is the deviation from regression of the $i^{th}$ genotype at the $j^{th}$ environments
s = number of location,
t = number of varieties &
e = estimate of pooled error and
r = is the number of replications.

Environment Index ($I_j$) = $\frac{\sum j Yij}{t} - \frac{\sum i \sum j Yij}{ts}$

Where
$\sum_j Yij$ = is the total of all the varieties at $j^{th}$ locations.
$\sum_i \sum_j Yij$ = is the sum of squares

Eberhart & Russell defined a stable genotype as the one which produced high mean yield with regression coefficient *(bi)* around unity and deviation from regression residual variance ($S^2\ d_i$) near to zero. The estimate of deviations from regression suggests the degree of reliance that should be put to linear regression in interpretation of the data. If these values are significantly deviation from zero, the expected genotype cannot be predicted confidently or reliably. When deviations are not significant, the conclusion may be drawn by jointly considering the mean yield and regression values proposed by Finlay and Wilkinson (1963) [2] and Eberhart and Russell (1966) [1] that are summarized in table 1.

**Table 1:** Regression values, stability type in relation to relation to mean yield.

| Regression | Stability | Mean yield | Remarks |
|---|---|---|---|
| $\beta_i = 1$ | Average | High | Well adapted to all environments or Desirable |
| $\beta_i = 1$ | Average | Low | Poorly adapted to all environments |
| $\beta_i > 1$ | Below average | High | Specifically adapted to favourable environments |
| $\beta_i < 1$ | Above average | High | Specifically adapted to unfavourable environments |

**Results and Discussion**

Pooled analysis of variance (Table-2) revealed that genotype, environment and genotype x environment interaction (G x E) were highly significant for both cane yield (t/ha) and sugar yield (t/ha). Significant mean squares due to genotype x environment interactions indicated differential response of genotypes in different environments. It means a particular variety may not exhibit the same phenotypic performance under different environments or different varieties may respond differently to a specific environment. Similar findings were earlier reported by Koli *et al.* 2016 [6] and Naidu *et al.* 2017 [7] in sugarcane. Both linear and non-linear components of G x E interactions were also found significant for cane and sugar yield showing the importance of both linear (predictable) and non-linear (unpredictable) components in the expression of the traits. The linear component was significant as against the nonlinear components (Pooled deviation), which revealed that a large portion of G x E interaction was accounted for by linear regression although pooled deviation was significant. These results were in confirmation to those reported by Kimbeng *et al.* 2009 [5], Tiwari *et al.* 2011 [9] and Koli *et al.* 2016 [6] in sugarcane.

Table -3 showed that, the higher average cane and sugar yield was found in Co 0238 (83.05, 10.17) followed by Co 05009 (79.64, 9.72) and CoS 767 (79.44, 9.05) respectively. Whereas, minimum cane and sugar yield was recorded in CoS 8436 (73.83, 8.70). This implies that the effect of genotype on the yield is not all same. The standard deviation calculated for the different traits provide a basis for assessing the adaptation of potential genotypes to the different environments. Genotypes with low standard deviation are adaptable to a wide range of environment as compared to varieties with standard deviation that are adaptable to specific environments. The standard deviations calculated for both cane and sugar yield are presented in Table-3. The standard deviation for cane yield ranged from 0.86 to 2.91. The broad interval range of standard deviation for cane yield indicated that the environment had an effect on cane yield of all the genotype. Similarly, the standard deviation for sugar yield ranged from 1.08 to 4.26**.** Whereas, minimum sugar yield was recorded in CoS 8436 (73.83, 8.70) indicates that the genotype has low yielding potential across all locations. Similar findings were earlier reported by Imtiaz *et al.* (2013) [4], Naidu *et al.* (2017) [7] and Guddadamath *et al.* (2014) [3] in sugarcane.

The estimates of mean performance (x), regression coefficient (bi) and deviation from regression (($S^2$di) are presented in Table-4. Considering the stability of a genotype, the three parameters *viz*, grand mean over the environments (x), unit

regression coefficient (bi=1) and squared deviation from the regression ($S^2di = 0$) were considered stable in performance.

Eberhart and Russell (1966) [1] defined a stable genotype which showed high mean yield, regression coefficient (bi) around unity and deviation from regression near to zero. Accordingly, the mean and deviation from regression of each variety were considered for stability and linear regression was used for testing the varietal response.

a. Genotypes with high mean, bi = 1 with non-significant $s^2d$ are suitable for general adaption, *i.e.* suitable over all environmental conditions and they are considered as stable genotype.
b. Genotypes with high mean, bi >1 with non-significant $s^2d$ are considered as below average in stability. Such genotypes tend to respond favorably to better environments but give poor yield in unfavourable environments. Hence, they are suitable for favorable environments.
c. Genotypes with low mean, bi<1 with non-significant $s^2d$ do not respond favorably to improved environmental conditions and hence, it could be regarded as specifically adapted to poor environments.
d. Genotypes with any bi value with significant $s^2d$ are unstable.

In the present study, promising variety Co 0238 has high mean for both cane yield and sugar yield (83.05, 10.17) with bi =1.0 and non-significant $s^2d = 0$ (Table 4), indicated that this varieties found better responsive to all the environments and were considered as stable varieties. Whereas the genotype Co 05009 produced high mean yield (79.64, 9.72), bi >1 with non-significant $s^2d$, indicated below average stability, such genotypes tend to respond favorably to better environments but give poor yield in unfavourable environments. Hence, these genotypes were suitable for favorable environments. Variety CoS 8436 having low mean ((73.83, 8.70) for cane & sugar yield, bi < 1 with non-significant $s^2d$ value, indicated that genotype suitable for poor environment.

In general, Eberhart & Russell model found more robust for predicting the stable genotypes. The stable genotype with respect to the cane and sugar yield under variable environments may be useful in breeding programme for evolving high yielding genotypes adapted in this zone.

**Table 2:** Pooled analysis of variance for cane yield (t/ha) and sugar yield (t/ha) in seven popular varieties of sugarcane.

| Source of Variation | Degree of Freedom | Mean sum of squares | |
|---|---|---|---|
| | | Cane yield (t/ha) | Sugar yield (t/ha) |
| Total | 34 | 51.616** | 1.352** |
| Genotype | 6 | 154.221** | 4.364** |
| Environment | 4 | 28.611** | 6.405** |
| GXE | 24 | 8.681** | 4.163** |
| E + (G X E) | 28 | 4.191* | 0.081* |
| E linear | 1 | 5.450* | 0.077* |
| G X E Linear | 6 | 7.092* | 0.103* |
| Pooled Deviation | 21 | 3.302** | 0.075** |
| Pooled Error | 60 | 0.170** | 0.003** |

*,** Significant at 0.05 & 0.01 level of probability.

**Table 3:** Mean and Standard deviation for the cane and sugar yield among seven varieties of sugarcane.

| S. No. | Name of Varieties | Cane yield (t/ha) | | Sugar yield (t/ha) | |
|---|---|---|---|---|---|
| | | Mean | Std. deviation | Mean | Std. deviation |
| 1. | CoJ 64 | 76.38 | 2.86 | 8.90 | 2.99 |
| 2. | Co 0238 | 83.05 | 1.96 | 10.17 | 3.03 |
| 3. | Co 05009 | 79.64 | 2.91 | 9.72 | 2.37 |
| 4. | CoS 767 | 79.44 | 0.86 | 9.05 | 4.26 |
| 5. | CoS 8436 | 73.83 | 1.74 | 8.70 | 1.71 |
| 6. | Co Pant 97222 | 75.91 | 1.60 | 9.08 | 1.08 |
| 7. | Co 05011 | 75.17 | 1.60 | 9.73 | 3.21 |
| | Average | 76.94 | 2.50 | 9.34 | 2.67 |

**Table 4:** Stability parameter for grain yield (t/ha) of popular sugarcane varieties in Zone V$^{th}$ of Rajasthan.

| S. No. | Name of Varieties | Cane Yield (t/ha.) | | | Sugar Yield (t/ha.) | | |
|---|---|---|---|---|---|---|---|
| | | Mean | bi | $S^{-2}di$ | Mean | bi | $S^{-2}di$ |
| 1. | CoJ 64 | 76.38 | 1.72 | 2.08 | 8.90 | 0.59 | 0.04 |
| 2. | Co 0238 | 83.05 | 1.02 | 0.17 | 10.17 | 1.01 | 0.02 |
| 3. | Co 05009 | 79.64 | 1.69 | 2.65 | 9.72 | 1.30 | -0.03 |
| 4. | CoS 767 | 79.44 | 0.34 | -2.64 | 9.05 | 2.08 | 0.06 |
| 5. | CoS 8436 | 73.83 | 0.91 | -0.90 | 8.70 | 0.47 | -0.03 |
| 6. | Co Pant 97222 | 75.91 | 0.90 | -1.45 | 9.08 | 0.45 | -0.06 |
| 7. | Co 05011 | 75.17 | 0.39 | -0.28 | 9.73 | 1.09 | 0.04 |

*, ** Significant at 0.05 & 0.01 level of probability.

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