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Statistical Analysis of Certain Traits that Influence Sugar Recovery of Selected Sugarcane Varieties

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Abstract: Six exotic sugarcane varieties CP84-1198, CP85-1491, CP88-1165, CP89-846, TCP86-3368 and CP77-400 were included in the study. The study was conducted in order to determine the relationship between various agronomic traits as number of tillers, stalk height, stalk thickness, cane yield and brix value with sugar recovery. Genotypic and phenotypic correlation coefficient studies of each morphological character with sugar recovery showed negative and non-significant correlations with number of tillers, stalk height and cane yield. Positive but non-significant genotypic and phenotypic correlations were observed between sugar recovery and stalk girth. Only brix value showed positive and significant genotypic correlation with sugar recovery, while phenotypically this correlation was positive but non-significant. The results of the stepwise regression analysis indicated that on single factor basis the maximum R-square value of 0.594 was for brix value related to sugar recovery. The two variable model including the cane yield and brix value yielded highest R-square value of 0.699 with sugar recovery. When a three variable model was performed, out of all the combinations, the best one was for the stalk girth, cane yield and brix value with R-square 0.708. While in the four variable models, in the stepwise regression yielded the best one combination closely related to sugar recovery was stalk girth, stalk height and cane yield with R-square value 0.713. The R-square value was almost similar to four variable model i.e. 0.713 when five variable models were examined. The results of stepwise regression and correlation coefficients studies indicated that brix value (TSS %) and sugar recovery were closely related.

Key words: Sugarcane varieties, morphological traits, phenotypic correlation, genotypic correlation, stepwise regression

Introduction

Sugarcane is a large tropical grass with an unusual ability to store sucrose in stem cell vacuoles. In certain environments the plant can produce extremely high levels of biomass that can be used for the production of sugar, ethanol for fuel and many other by products. The ability to store sucrose, along with high biomass potential makes sugarcane one of the world's most productive agricultural crops. Sugarcane is grown in tropical and subtropical regions of the world in a range of climates from hot dry environments near sea level to cool, moist environment about 609 m elevation (Silva, 1984). Sugarcane is thought to have originated in Asia. East Indonesia/New Guinea is a particularly rich source of *Saccharum* germplasm (Berding and Roach, 1987). Southern Louisiana (lat.30°N) represents, the near northern limit of commercial sugarcane production (Burner *et al.*, 1997). It is one of the most important cash crop and therefore playing a vital role in improving the economy of the country.

Sugarcane has very specific photothermal requirement for flowering and viable seed setting (Clements and Awada, 1964). Due to unfavorable environmental conditions, sugarcane does not flower profusely in most of the cane growing areas in the world. This limitation in cane flowering and viable seed production has narrowed genetic base (Malik, 1989). The variety situation met within many countries reveal that variety evaluation programmes are mainly dependent on the import of germplasm from cane breeding stations abroad. The use of exotic germplasm of sugarcane is an excellent example of the contribution wild relatives have made towards the genetic improvement of economically important crop species (Martin, 1996). Almost all present commercial varieties of sugarcane in Pakistan are either a selection from seedlings growth from the imported fuzz or are direct introduction from imported exotic germplasm (Malik, 1989).

Commercial cane sugar, brix value and sugar contents are the most important characters for quality control and better sugar yield (Deswal and Sangwan, 1985; Battan and Chaudhary, 1986; Ho and Chang, 1987; Singh and Rai, 1989). Similarly high tillering ability of a variety is associated with both cane and sugar yield (Kadirvel and Devaraj, 1977). Adaptation of new varieties for better yield performance on the basis of number of millable canes, commercial cane sugar and stalk weight improves sugar production (Punia, 1981; Singh and Sharma, 1982; Nair and Somarajan, 1984, 1986; Hooda *et al.*, 1988; Hooda and Singh, 1989; Gravois and Milligan, 1992; Chaudhary and Singh, 1994; Redddy and Somarajan, 1994; Singh *et al.*, 1994). Stalk number, stalk height, stalk girth and brix percentage are the most important characters and joint distributions for each character in sugarcane crops indicated that selection of new varieties with these characters prove very useful for better yield (Reddy and Reddi, 1987; Nair and Sreenivasan, 1989; Xie *et al.*, 1989; Chen *et al.*, 1991; Madhavi *et al.*, 1991; Bangar *et al.*, 1992; Pillai and Ethirajan, 1993; Singh *et al.*, 1994; Singh and Khan, 1995).

Keeping in view the above information, the present study was conducted in order to determine the relationship between various agronomic traits as number of tillers, stalk height, stalk thickness, cane yield and brix value with sugar recovery.

The information obtained from the present study may help to formulate the appropriate selection strategy to select the varieties of best merit, suitable for cultivation in different ecological regions of the world.

Materials and Methods

Present study was carried out at the experimental field area of the National Agricultural Research Centre (NARC), Islamabad during the crop season 1998-99. The experiment was planted during September 1998 and harvested during December, 1999. Six exotic varieties of sugarcane i.e. CP84-1198, CP85-1491, CP88-1165, CP77-400, CP89-846 and TCP86-3368 were planted in a randomized complete block design with three replicates. Ten rows, measuring 10 m each, were planted for each variety in three replicates. Two budded double sets were planted end to end with a raw spacing of 90 cm. Total area for data recording from these three rows, leaving 1 m boarder on each end of the rows was 21.6 m^2. All the varieties were treated with the similar agronomic practices, 115 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} /K_2O were applied at the time of planting. Nitrogen was applied @ 230 kg ha^{-1} in five splits. First dose of nitrogen was applied at the time of planting. Rest of the four nitrogen doses were applied during March, April, May and 2nd week of June. Weeds were initially controlled with pre-emergence application of a weedicide Gesapax Combi (80 wp) @ 3.75 kg ha^{-1}. At later stages weeds were controlled by hoeing and earthing up. Similar levels of irrigation were given to all the varieties. Data on various agronomic characters were collected at harvest.

Number of tillers at harvest: Data on number of tillers were recorded from an area of 21.6 m^2. Total number of tillers were counted from the harvested area and number of tillers per hectare was calculated on the basis of the collected data.

Stalk height and girth: Ten representative stalks were taken out of the harvested stalks. Stalk height was measured from base of the stalk to the topmost node, exposed by removing all the leaves. Then the height of these ten stalks was averaged. Stalk girth was measured from the same ten stalks with the help of digital caliper. Stalk girth was measured 25 cm above the base of the stalk; 25 cm below the topmost node of the stalk and from the center of the stalk and then averaged.

Cane yield: Cane yield was recorded from an area of 21.6 m^2 and on the basis of cane weight from harvested area, cane yield tons per hectare was calculated.

Brix value and sugar recovery: Five stalks were taken from each plot for quality analysis. These samples were taken to sugarcane quality laboratory at Sugarcane Research Institute, AARI, Faisalabad. These stalks were crushed with power cane crusher to extract the juice. Brix reading was taken by brix hydrometer. Juice was used for the determination of sucrose percentage with the help of Horn's dry lead acetate method of sugar analysis (Spencer and Meade, 1959). Purity of the juice was also calculated. These values were used to calculate the sugar recovery, using Australian fiber constant (12.5%) on the basis of Winter-Crap formula (Geerlings, 1904).

Sugar recovery (SR) = [Pol in juice - (Brix - Pol in juice) x 0.4] x 0.63

Statistical analysis: Genotypic and phenotypic correlation of each morphological character with sugar recovery was determined (Kwon and Torrie, 1964).

The collected data on morphological traits were further subjected to stepwise regression analysis (Gomez and Gomez, 1984) to measure the more precise relationship and effects of the parameters (under study) on the sugar recovery.

Results

Correlation analysis: Genotypic and phenotypic correlation coefficient studies were made on the various agronomic characters as number of tillers, stalk height, stalk girth, cane yield and brix value with the sugar recovery. Sugar recovery showed negative and non-significant genotypic correlation with stalk number, stalk height and cane yield (Table 1). A positive but non-significant genotypic correlation was noted between

Table 1: Phenotypic and genotypic correlation coefficients of various components traits with sugar recovery

Traits	Sugar recovery (%)
Number of tillers ('000' ha^{-1})	-0.1949^{NS}, $(-0.2044)^{NS}$
Stalk girth (mm)	0.322^{NS}, $(0.606)^{NS}$
Stalk height (cm)	-0.2609^{NS}, $(-0.4187)^{NS}$
Cane yield (t ha^{-1})	-0.6372^{NS}, $(-0.6994)^{NS}$
Brix value	0.7738^{NS}, $(0.8415)^{*}$

Values within parentheses represent genotypic correlation coefficients and other values represent phenotypic correlation coefficient, NS = Non-significant
* = Significant $P \leq 0.05$

sugar recovery and stalk girth (Table 1).

Only brix value showed positive and significant genotypic correlation with sugar recovery. It was noted that phenotypic correlation coefficients had the same trend. Phenotypically sugar recovery was negatively and non-significantly correlated with number of tillers, stalk height and cane yield. Sugar recovery showed positive but non-significant phenotypic correlation with stalk girth and brix value (Table 1).

Stepwise regression analysis: Stepwise regression analysis was performed for the characters under study i.e. number of tillers ('000' ha^{-1}), stalk height (cm), stalk girth (mm), cane yield (t ha^{-1}), brix value and sugar recovery (%). Regression models with R-square values for the dependent variable sugar recovery are presented in Table 2.

It is evident from the data that on single factor basis the maximum R-square value of 0.594 was for brix value related to sugar recovery (Table 2). Other variable closely related with sugar recovery was cane yield with R-square value of 0.382. On a single factor basis the minimum coefficient of determination was 0.03 for number of tillers (Table 2).

The two variable model including the cane yield and brix value yielded R-square value of 0.699 with sugar recovery. Other two variables closely related to sugar recovery were number of tillers and brix values with R-square value 0.692. The two variable models, including the stalk girth and brix value yielded R-square value of 0.598 and stalk height and brix value yielded R-square value of 0.596 with sugar recovery.

When a three variable model was performed, out of all the combinations, the best two were for the stalk girth, cane yield and brix value with R-square 0.708 and stalk height, cane yield and brix value with R-square value 0.703. While number of tillers, cane yield and brix value had R-square values of 0.702 with sugar recovery.

Four variable model in the stepwise regression yielded the two combinations closely related to sugar recovery were stalk girth, stalk height, cane yield, and brix value and number of tillers, stalk girth, cane yield, and brix value with R-square values 0.713 and 0.710, respectively.

The R-square value was almost similar to four variable model i.e. 0.713 when five variable model was examined (Table 2).

Discussion

Assessment of adaptation, performance of various sugarcane varieties in different ecologies and evaluation of agronomic characters of exotic cane varieties is necessary before a variety is introduced for commercial cultivation.

Stooling or tillering in cane varieties resembles other grasses (Barber, 1919). At early developmental stages, tillers grow erectly or spreading and bend upward afterward. Different varieties of sugarcane differ in their trend of tillering and ultimate tillers at harvest (van Dillewijn, 1952).

In this study a negative but non-significant association was found between number of tillers and sugar recovery. Balasundaram and Bhagyalakshmi (1978) and Nagatomi *et al.* (1982) found that number of tillers were positively correlated with sucrose contents. Similarly Bakshi (1994) found that number of canes were strongly associated with sugar yield. Singh *et al.* (1983), Reddy and Khan (1984) and Zhou (1990) found a close and positive association between tillers and sucrose percentage. Ortega *et al.* (1991) also observed that number of tillers was closely associated with sugar yield in sugarcane.

Tillering is influenced by various internal and external factors. Some varieties have early rapid tillering capabilities while others are slow in tillering at commencement and tillering in these varieties increase gradually. Light intensity, its duration, plant nutrition, temperature, spacing and earthing up are some of the external factors those affect tillering of a sugarcane variety (van Dillewijn, 1952).

It has been observed and reported by different researchers that various varieties of sugarcane differ genetically in their tillering, stalk height, stalk girth, cane yield and sugar contents (Habib *et al.*, 1991).

A positive but non-significant correlation was found between stalk girth and sugar recovery. Genotypic correlation coefficients were higher than the phenotypic correlation coefficients, which showed that genetic association was stronger than phenotypic association with sugar recovery.

Singh and Gill (1988) reported closely related results; they found that cane thickness was positively correlated with sucrose percentage. Sharma and Singh (1984) found stalk

Table 2: Stepwise regression models for the dependent variable sugar recovery

Number in model	R^2	Variables in models
1	0.030	Number of tillers
1	0.061	Stalk girth
1	0.067	Stalk height
1	0.382	Cane yield
1	0.594	Brix value
2	0.692	No. of tillers, brix value
2	0.598	Stalk girth, brix value
2	0.596	Stalk height, brix value
2	0.699	Cane yield, brix value
3	0.702	Number of tillers, cane yield, brix value
3	0.708	Stalk girth, cane yield, brix value
3	0.703	Stalk height, cane yield, brix value
4	0.710	Number of tillers, stalk girth, cane yield, brix value
4	0.713	Stalk girth, stalk height, cane yield, brix value
5	0.713	Number of tillers, stalk girth, stalk height, cane yield, brix value

circumference have direct effect on sugar contents. In another study the stalk diameter had showed highest correlation coefficient with sugar recovery (Bakshi *et al.*, 1996).

Stalk girth play important role in improving cane yield per unit area. Storage capacity for sugar also increases as the stalk girth increases hence not only cane yield but also sugar yield per unit area is increased with increased stalk girth. Singh and Sharma (1982) regarded stalk diameter as very important character contributing cane yield.

It is also proved by the present statistical data that stalk height was negatively and non-significantly correlated with sugar recovery. Only cane height is not an important character in selecting the canes for better sugar recovery (Sangwan and Singh, 1983).

In the present study cane yield was negatively correlated with sugar recovery, which shows that only cane yield is also not an important criteria for the selection of new varieties because we do not need to increase the tonnage per hectare with low sugar recovery.

Difference in climate, particularly light intensity plays important role in improving cane yield. Light intensity is rather one of the most influential factor improving cane and sugar yields. Favorable climate and proper management factors ensure better cane and sugar yields in cane crop (van Dillewijn, 1952).

Many authors have reported the similar findings, which are evident in the present study. As negative association between stalk number and stalk thickness, sugar contents and cane yield (Kang *et al.*, 1983; Milligan *et al.*, 1990).

Positively and highly significant correlations were found between brix value and sugar recovery. This revealed much more stronger genotypic and phenotypic relationship between these two traits. So brix value is an important character to be kept in mind while selecting a variety for higher sugar contents. The selection of clones with better levels of brix will be helpful to have the new cane variety with improved sugar recovery (Richard, 1975; Miller, 1977; Kanwar *et al.*, 1980; Rao and Ethirajan, 1984; Battan *et al.*, 1985).

When stepwise regression models for the dependent variable sugar recovery were studied it was noted that on a single factor basis brix value was the only character, which was found to be very closely related to sugar recovery having the maximum R-square value of 0.594.

The observations of Miller's regression analysis and path coefficient (1977) also confirmed these results. He also noticed that brix value is an important character for the selection of new varieties.

A two variable model using cane yield and brix value factors accounted for a high value of variability in sugar recovery with R-square value of 0.69. The results suggest that two factors model showed improvement with the greater R-square value than the one variable model.

It is concluded from the present study, that brix value and sugar recovery are quality characters, which are closely associated. These observations are supported by the earlier findings of Hogarth (1971) who also carried out multiple regression analysis of data from different crosses of sugarcane and reported that brix value was the only character, which had the greatest influence on the selection of new clones with improved sucrose percentage. He also suggested that more emphasis should be given to brix value than any other character at the stage of selection. Similarly Gravois *et al.* (1991) and Chang (1996) conducted path coefficient analysis observing that purity and brix value were the main factor responsible for increasing sugar contents in sugarcane.

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