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STUDIES ON MORPHOLOGICAL CHARACTERS FOR SELECTING FLOOD STRESS TOLERANT CLONES

By
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ABSTRACT

A pot experiment was conducted in concrete tank in the Bangladesh Sugarcane Research Institute (BSRI), Ishurdi, Pabna during 2003-2005 cropping seasons. The trial was conducted to screen flood stress tolerant clones. The clones I 137-96, I 82-98 and I 98-98 showed highly tolerant reaction having tolerance rating 1 against 30, 60, 90 and 120 d sustained flood stress condition, and maintained 70.5-79.2, 65.0-68.1, 56.4-58.6 and 45.0-49.1 per cent green leaf respectively. Besides, clones I 202-97, I 110-98, I 139-98, and I 142-98 showed tolerant reaction having tolerance rating 2 against 60, 90 and 120 d sustained flood stress condition and maintained 59.7-61.3, 45.4-55.7 and 39.4 – 40.8 per cent green leaf. The clone I 137-96 produced the highest fresh weight, dry weight and volume of primordial water roots (PWR) under flood stress condition. This screening programme will help the breeders for selecting suitable varieties for flood situation.

Key words: Morphological Characters, tolerant clones, flood stress, dry leaf, green leaf, PWR.

INTRODUCTION

In Bangladesh yield of sugarcane is very poor due to various reasons; among them vulnerability of sugarcane to water stress such as flood, water- logging and drought are most important. Due to higher demand of food, high and medium high lands are occupied by cereal and vegetable crops, and sugarcane is gradually being pushed to marginal and low lying 'char' lands often prone to seasonal inundation and flash flood which frequently hits by (1-5) Bangladesh Sugarcane research Institute, Ishurdi-6620, Pabna, Bangladesh.

unpredicted flood (Miah *et. al.,* 1993). In Bangladesh 1.2 million and 5.0 million hectares cultivable lands are severe and moderately severe flood prone respectively (Karim, 1992). Higher water table during active growth phase adversely affects stalk weight and plant population leading to the reduction of yield of about one ton per acre for each one inch increase in excess water (Carter and Floyed, 1974; Carter, 1976). The effect of excess water using temporary or continuous flooding has been studied extensively elsewhere (Jackson *et. al.,* 1978; Scott *et. al.,* 1989). Sugarcane roots are usually spreaded in the upper soil surfaces with 60% in the 0-30 cm depth, but may penetrate to 180 cm in well-drained soils (Paz-vergara *et. al.*1980; Gascho and Shih, 1983). One morphological change of sugarcane roots growing in high water table is a greater proportion of fibrous to thick roots in the soil layer above the water table (Eavis, 1972; Webster and Eavis, 1972). The reason is probably an adoption to lower O_2 levels. A thin root has a smaller path-length for O_2 diffusion to respiring tissue than a thicker root (Eavis, 1972).

Growth of roots is a heritable characteristic (Dillewijin, 1952). Rahman *et al.,* (1986) tested four sugarcane genotypes in flooded and drained pots. They found that genotypes more tolerant to flood had less reduction in root mass than non-tolerant genotypes. Sugarcane

genotypes usually show different tolerance to high water tables. Information of the relationship between plant shoot and root morphological characteristics under flood stress condition is limited, and results available are contradictory. A better understanding of those relationships should aid in finding ways to improve plant adaptability to high water tables. Therefore, this study was undertaken to find out morphological characters of promising clones of sugarcane grown under flood stress situation.

MATERIALS AND METHODS

An experiment was carried out to screen of flood stress tolerant clones during 2003-2005 cropping seasons. BSRI bred sugarcane seven clones viz. I 137-96, I 202-97, I 82-98, I 98-98, I 110-98, I 139-98 and I 142-98 were grown in plastic pots (10 pots per clone). One polybag settling was transplanted in each pot. Irrigations and all other cultural practices were done as and when required to all plant in pot for natural growth. After six months of transplanting five plants of each clone were placed in concrete tank and inundated in running water (30 cm deep above pot soil), while the remaining five plants per clone were kept as control. Green and dry leaf count was taken after 30, 60, 90 and 120 d of inundation. Data on fresh and dry weight of PWR (Primordial Water Root) as well as volume of PWR were taken at harvest. PWRs were collected and taken in paper bags of known weight, and oven dried at 85^0C until constant weight. Tolerance rating scale was recorded on greenness of leaves and other factors recorded.

RESULTS AND DISCUSSION

The results of the experiment have been presented in Figures 1 - 6. It is seen from the Figure 1 that the clones I 137-96, I 82-98, I 98-98 and I 139-98 showed highly tolerant reaction having tolerance rating scale 1 against 30 d sustained flood stress condition, and maintained above 70.0 per cent green leaf. Figure 2 shows that the clones I 137-96, I 82-98 and I 98-98 maintained above 65 per cent green leaf up to 60 d continuous flood water stress having tolerance rating scale 1, and rest clones showed tolerant reaction having tolerance rating scale 2. It is seen from the Figure 3 that clones I 137-96, I 82-98 and I 98-98 maintained above 55 per cent green leaf up to 90 d continuous flood stress having rating scale 1, and rest clones showed tolerant reaction. The Figure 4 shows that clones I 137-96, I 82-98 and I 98-98 showed above 45 per cent green leaf up to 120 d continuous flood water stress having tolerance rating scale 1.

The Figure 5 shows fresh and dry weight of primordial water roots, and it is seen from the Figure that highly tolerant clones maintained above 256 g fresh root weight and 34.5 g dry root weight. The Figure 6 shows that volume of PWR was also higher in these highly tolerant clones.

It is seen from Figure 1-4 that green leaf per cent of all clones was found to be decreased with the increase of stress period. It is reported earlier that decline in shoot dry yield with flooding might be because of decreased nutrient availability due to soil chemical changes or inhibitory effect of nutrient uptake mechanisms of root with low O_2 (Kozlowski and Pallardy, 1984). Generally, plant uptake of N, P and K decreases when grown in water logged soils (Glinski and Stepniewski, 1985). PWR and Green leaf percent were found to be different in different clones. Probably these are genetical character.

In species that are flood tolerant, aerenchyma formation is usually constitutive, meaning that it requires no external stimulus, such as flood (Drew, 1997). Glaze *et. al.,(*2004) observed that some genotype had constitutive stalk aerenchyma, but aerenchyma formed only

in stalks of some genotypes after they were exposed to flooding. Perhaps it was a delay in aerenchyma formation until after flooding the subsequently reduced photosynthesis rate that causes reduced green leaf per cent in some genotypes and finally they select as non tolerant genotypes for flood stress condition.

Running water (flood stress), which is rich in oxygen. Flood stress tolerant clones produce more water root probably because of flood stress mechanism. We also observed that tolerant clone I 137-96 produced more root in running water on flood stress. Rahman and Alam (1985) also reported that visual observations also indicated superior tolerance of these clones compared in the rest. The findings of the present study are in agreement with the report of Rahman and Alam (1985).

It is seen from results that the clone I 82-98 showed highly tolerant reaction but produced less PWR, probably because roots of those clone is more efficient to absorb and utilize O_2 more effectively comparative other highly tolerant clones to those produced higher PWR. We know that Lack of root response to water table may be because of sugarcane roots have aerenchyma tissue. Ray and Sinclair (1999) examined more than 30 sugarcane genotypes and found that all had aerenchyma whether under hypoxic or non-hypoxic conditions. Arenchymous are air-filled tissues that allow transport of O_2 from shoots to the roots in many aquatic and flood tolerant plant species, such as rice (Drew, 1997). Our data confirmed report of Gosnell (1972), who grew one genotype of sugarcane in plastic containers at water table depths ranging from 25 to 125 cm. He did not observe any significant difference in root dry matter yields. The roots of all 40 sugarcane genotypes examined contained aerenchyma (Ray *et. al.,*1996; Van Der Heyden et. al., 1998). Presence of root aerenchyma is a key requisite for sustained root activity in flooded soil.

The clones, which are known as tolerant for flood stress condition looks fresh, produce more green leaf percentage, shoot yields. Characteristics of sugarcane with increased shoot yield associated with root morphology in the upper soil layer, based on significant correlation coefficients, were smaller average diameter roots and greater total root lengths (Morris *et. al.,* 2004)). Finer roots are associated with younger roots, which are most active in water and nutrient uptake that is needed for increased top growth (Barber and Silberbush, 1984; and Fageria *et al.,* 1997). Greater root length along with small root diameter is associated with greater nutrient uptake by roots and increased shoot yield (Barber and Silberbush, 1984; and Mengel, 1985). Consequently, smaller (finer) average diameter of roots and greater total root lengths would indicate greater capacity for nutrient uptake and increased shoot yield compared to larger diameter roots and lower total root lengths (Fageria *et. al.,* 1997). It is also reported smaller diameter roots in sugarcane under water-logged compared with drained soil (Eavis, 1972; and Webster and Eavis, 1972). Eavis (1972) suggested that smaller diameter root production was an adaptive mechanism to low O_2 contents in the soil. He indicated that a smaller diameter root would have less O_2 demand and a lower diffusive path length for O_2 compared with a larger diameter root. Another desirable root morphological characteristic detected in the upper soil layer for increased sugarcane yield was lower quantities of root lengths in the 2.5 - 4.5 mm root diameter classes (medium to older aged roots) (Morris *et. al.,* 2004)). These larger diameter roots (older roots) may be less active in nutrient uptake compared with smaller diameter (younger roots) (Baver *et. al.,* 1963).

It may be recommended that clone which bear comparatively greener leaves and visually looks fresh may be selected as tolerant clones for flood stress. It may also

be stated that this information would increase further our understanding regarding physiologic responses of sugarcane to high water table and periodic floods so that strategies could be developed in Bangladesh to identify those clones whose survival mechanisms are not compromised by PWR formation. Another option would be develop to identify those clones that form constitutive stalk aerenchyma.

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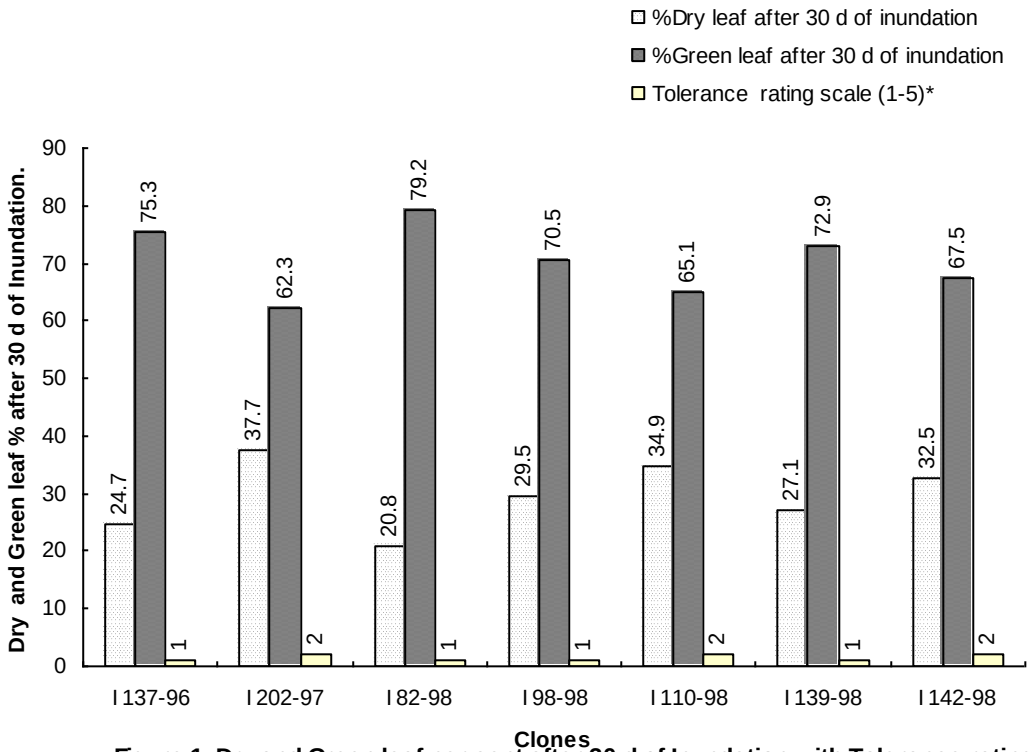


Figure 1. Dry and Green leaf per cent after 30 d of Inundation with Tolerance rating scale(Mean of two seasons).

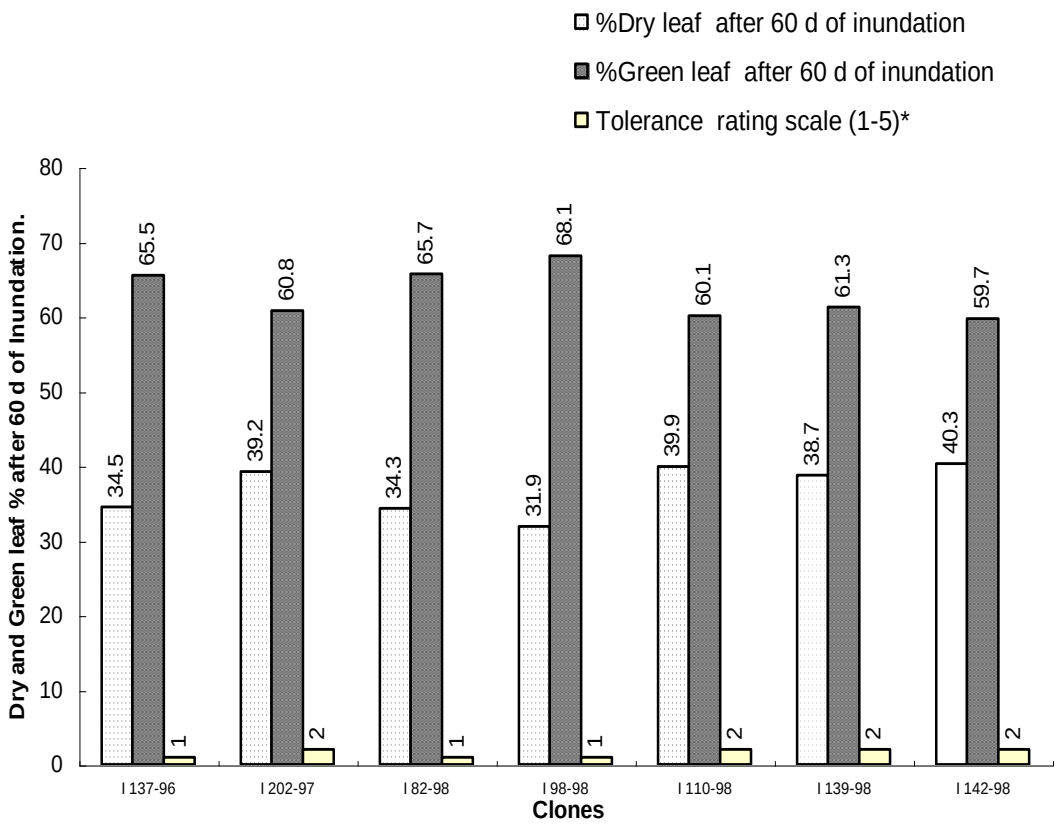


Figure 2. Dry and Green leaf per cent after 60 d of Inundation withTolerance rating scale (Mean of two seasons).

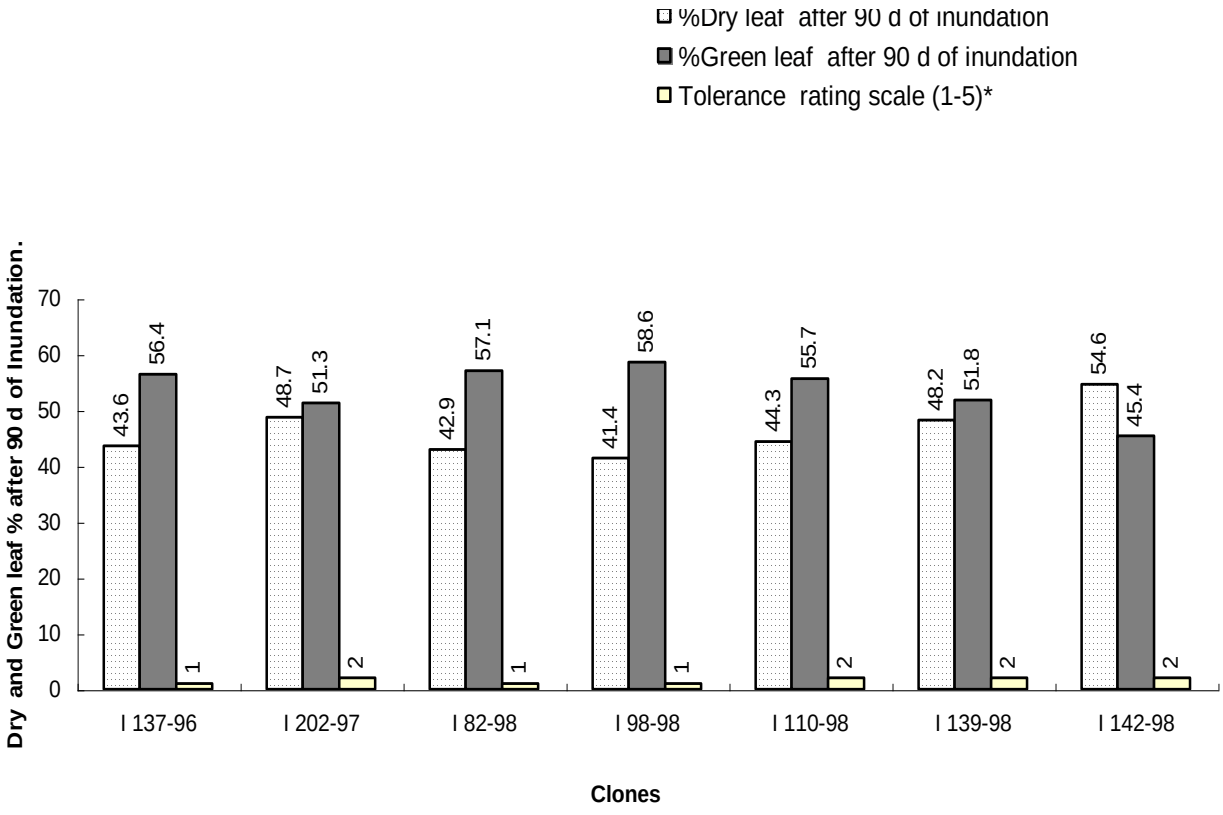
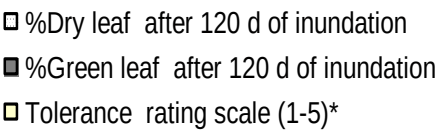


Figure 3. Dry and Green leaf per cent after 90 d of Inundation with Tolerance rating scale (Mean of two seasons)



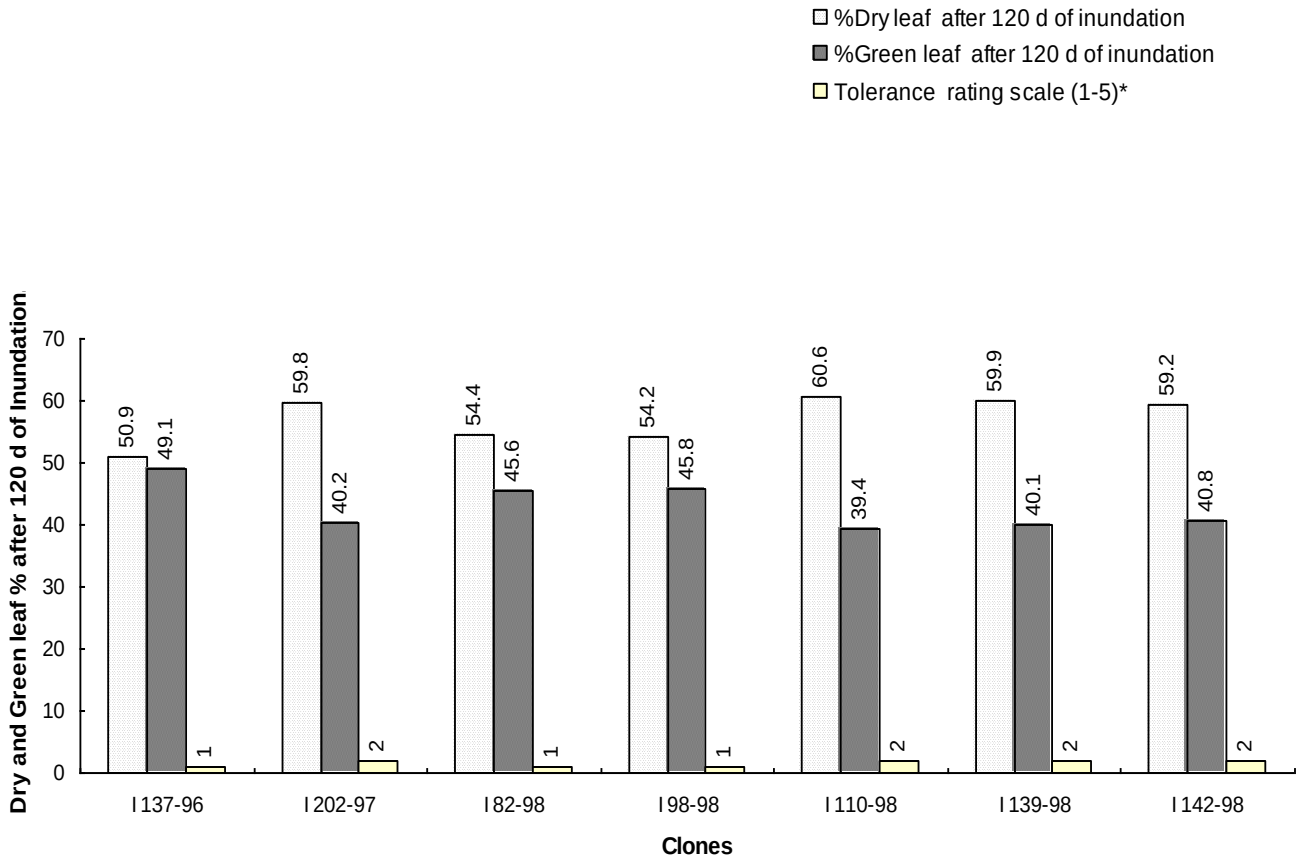


Figure 4. Dry and Green leaf per cent after 120 d of Inundation with Tolerance rating scale (Mean of two seasons).

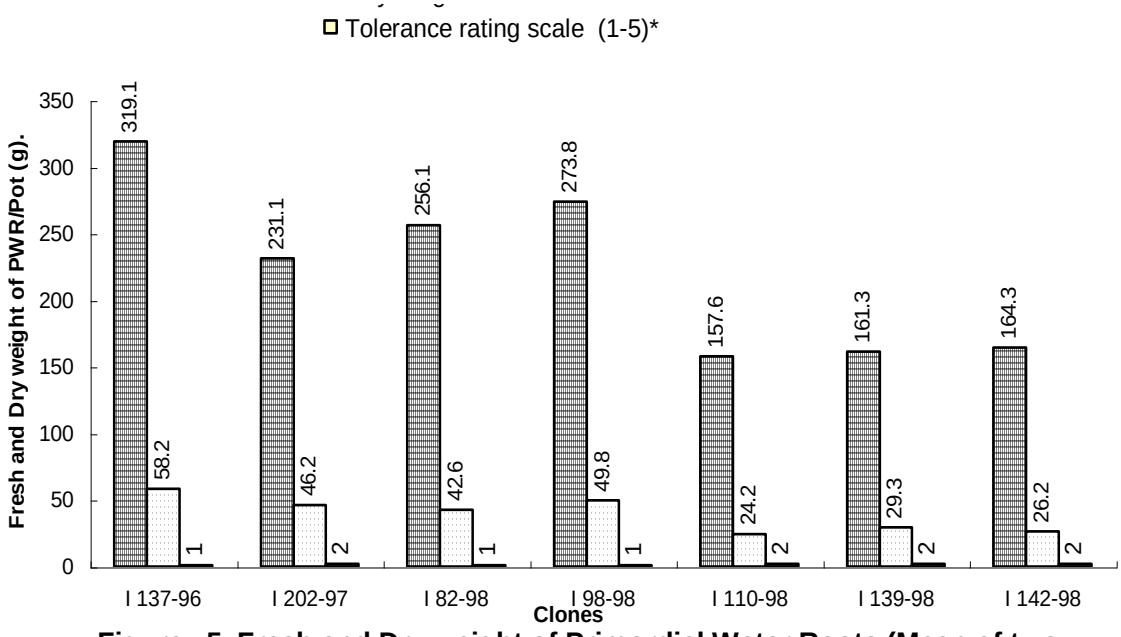


Figure 5. Fresh and Dry weight of Primordial Water Roots (Mean of two seasons) with tolerance rating scale.

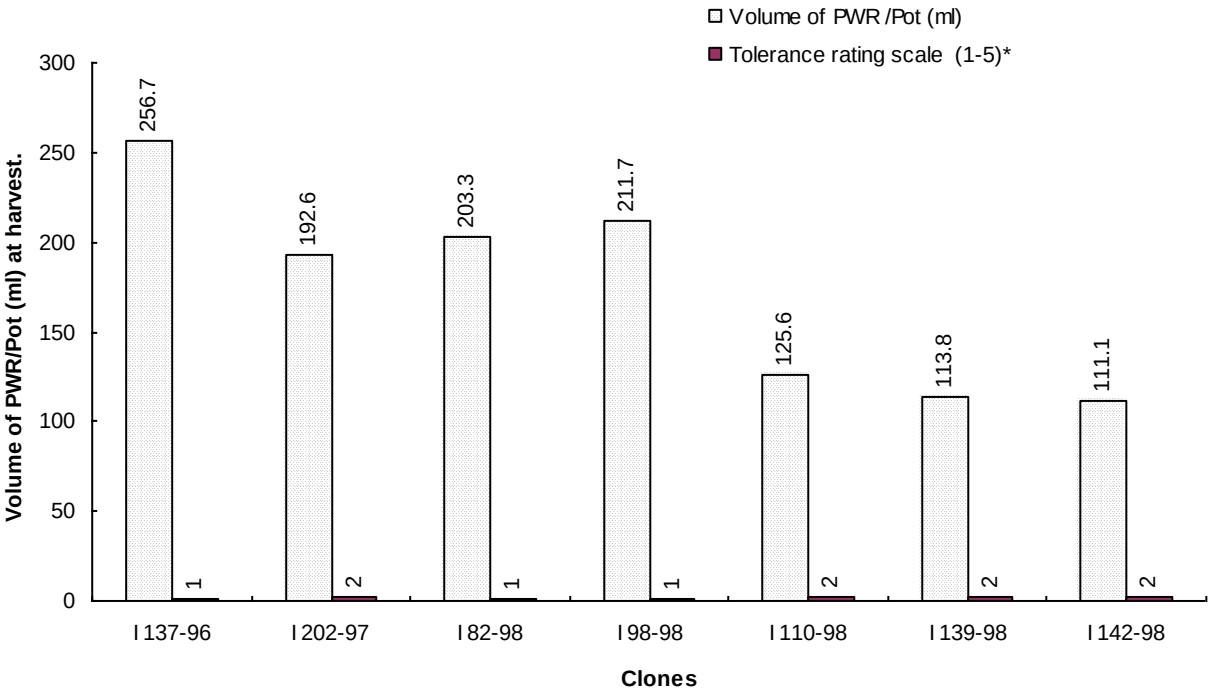


Figure 6. Volume of Primordial Water roots (Mean of two seasons) with Tolerance rating scale

***Tolerance rating scale (1-5), 1= highly tolerant, 2= tolerant, 3= moderately tolerant, 4= Intolerant, 5= highly intolerant**

EVALUATION OF YIELD AND YIELD CONTRIBUTING PARAMETERS OF DIFFERENT SUGARCANE (SACCHARUM OFFICINARUM L.) VARIETIES UNDER NATIONAL UNIFORM VARIETAL YIELD TRIAL

By

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ABSTRACT

A comparative study trial was conducted on the suitability of thirteen (13) sugarcane varieties at the field of Quaid-e-Awam Agriculture Research Institute, Larkana, Sindh during the year 2005-06. Among these varieties L-116 considered as check. It was found that all of tested varieties except one (S2001-US-400) produced significantly higher cane yield as compared to check variety. Variety LRK-2004 produced the highest cane yield (186.21) followed by variety Ganj Bakhsh with mean cane yield of (135.91) tones ha^{-1}. Varieties NIA-2004 and Chandka also gave good results with cane yield of 129.23 and 128.39 tones ha^{-1} respectively. Therefore, there is a great increase in production of cane by using these varieties at farmers' field in upper Sindh.

Keywords: Sugarcane, National Uniform Varietal Yield Trial, Girth, Brix %, Cane yield.

INTRODUCTION

Sugarcane is a crop of great agro-economic importance. In Pakistan it is planted on an area of 1.056 million hectares with a total annual cane production of 53.104 million tones. It plays a remarkable role in the uplift of the growers and the country by earning foreign exchange (Rehman, *et al*., 1992) and providing employment to numerous farm workers throughout the year (Hussain, *et al*., 2003). The average cane yield in our country (50.28 t ha^{-1}) is far below than the yield obtained in many other cane growing countries of the world like Peru (136.51 t ha^{-1}), Egypt (110.80 t ha^{-1}), Australia (100.35 t ha^{-1}) and Kenya (84.48 t ha^{-1}) (Anonymous, 1998).

Among the various factors responsible for low yield of sugarcane, the use of low yielding varieties is considered the major one (Ahmad, 1988). It is fact that development of new sugarcane varieties is not feasible in our country due to insufficient breeding facilities or lack of infrastructure for cross breeding under artificial conditions. Therefore, sugarcane varietal development is dependent on import of germplasm and also through exotic or locally collected fuzz (Panhwar, *et a*l., 2003). The use of exotic germplasm for the improvement of sugarcane is an excellent example in genetic improvement. Our agricultural breeders have evolved high yielding varieties since last many years. Such varieties have a large range of adaptability than others and are grown more widely throughout the area (Majeedano, *et al*., 2003). On other side majority of the growers are unaware of new high potential varieties, their maintenance and replacement after a definite time. While, most of the superior varieties deteriorate after some time, which surely needs its replacement with new ones (Bahadar, *et al*., 2000).

For obtaining above-mentioned goals a research programme for the development of sugarcane varieties was started on co-

operative basis among three provinces of the country. During the year 2002-2003, sixteen (16) approved promising lines were tested at the experimental field of Quaid-e-Awam Agriculture Research Institute, Larkana to compare quantitative and qualitative performances to develop most suitable and promising varieties for the area. The variety LRK-2001 proved good response of environmental reaction for Brix % and cane yield and its inclusion as approved variety was recommended for general cultivation in upper Sindh province (Naich, *et al*., 2006). The present study was conducted by keeping in view the major objective of varietal improvement under agro-ecological conditions of Larkana, Sindh.

MATERIALS AND METHODS

Investigations to evaluate the most suitable varieties for the area, were carried out through varietal trial including twelve varieties with one check (L-116) viz. Chandka, LRK-2003, LRK-2004, HoLRK-3-19, Ganj Bakhash, NIA-2004, S 2001-US-400, CP-92-1167, S 98-SP-108, S 96-SP-1215, CSSG 668 and CSSG 676 during the year 2005-06 at Quaid-e-Awam Agriculture Research Institute (QAARI) Larkana, Sindh. The trial was laid out in randomized complete block design having four replications in a net plot size of $3x9m^2$. The ridges/furrows were made at the distance of 90 cm. The seed setts were placed at depth of 6-8 inches, covered with soil and irrigated. The sowing was done on 8^{th} of October, 2005.The recommended dose of NPK fertilizers was applied @ 275-150-150 kg ha^{-1}. Whole doses of P and K and 1/3 of N fertilizers were applied as basal dose at the time of land preparation. Remaining N fertilizer was applied in two equal split doses, at the time of first and second earthing. Weedicide Gexapex Combi was sprayed @ 4-5 kg ha^{-1} as pre-emergence herbicide to control the weeds. Further weeding was done by cultural operations and earthing up. Furadon 3G was applied @ 20 kg ha^{-1} in two half split doses for the control of borer attack. All agronomic practices like earthing, irrigation were carried out uniformly as per requirements of the crop. The crop was harvested in last week of December 2006.The observations on germination (%), cane length (m), cane girth (cm), tillers/stool, internodes/cane, brix (%) and yield (tones ha^{-1}) were recorded on monthly basis and at the time of harvest from each variety including check.

RESULTS AND DISCUSSION

Data on germination parentage (%) of all promising lines are given in Table 1 that show that this parameter ranged from 67.75 to 89.00 (%). The variety S98-SP-108 produced higher germination percentage (89.00) followed by varieties HoLRK-3-19, Chandka and CP-92-1167 having 86.25, 80.50 and 79.75 mean germination percentage respectively. However, the minimum germination percentage (67.75) was recorded for the variety S2001-US-400. The differences in germination character between all the varieties might be due to their different genetic potential (Naich, *et al*., 2006). The results regarding cane length (m) reveals that highest cane length (4.10) recorded in case of variety LRK-2004 followed by Chandka and S96-SP-1215 with 3.67 and 3.17 respectively. While the minimum cane length (1.99) recorded for the variety L-116 (Check). The higher cane length of the varieties might be due to the genetic make up of the parent materials of these varieties. These results are partially supported with the findings of Buriro, *et al*., (2003) and Baloch, *et al*., (2004) who reported different response of yield component in different sugarcane cultivars.

Stalk diameter is an important yield contributing character and large stalk diameter would enhance the acceptability

of varieties from commercial point of view (Ramdoyal, 1999). The results regarding cane girth (cm) revealed that variety Gang Bakhsh had significantly maximum girth (3.39) followed by Chandka with an average cane girth of 3.28 cm. The minimum cane girth (1.88) was recorded for L-116 (Check). Data regarding number of tillers/stool (Table 1) revealed that variety LRK-2004 produced significantly maximum number of tillers/stool (10.43) followed by variety LRK-2003 with (8.58) average number of tillers/stool. Varieties Chandka and S98-SP-108 also produced good number of tillers/stool with 7.43 and 6.93 respectively. Minimum number of tillers/stool (5.22) was recorded in case of variety Gang Bakhsh. The higher values for number of tillers/stool obtained in case of variety LRK-2004 might have genetically associated to have greater tillering capacity. These results are further supported by the findings of Singh and Singh (2004) who studied considerable numbers of sugarcane varieties and found significantly varying trend of effectiveness in all varieties, regarding number of tillers/stool.

It can be inferred from the data presented in Table 3 that highest number of (28.99 and 28.32) internodes/cane were recorded from varieties Chandka and LRK-2004 respectively, followed by varieties LRK-2003 and CSSG-676 with mean values of 27.74 and 27.58 internodes/cane respectively. Lowest number of (20.33) internodes/cane was recorded for variety L-116 (Check). These results are in line with Khan, *et al*., (2003) who pointed out that different varieties had different trend for number of internodes/cane.

Field brix is a good estimation of the sugar content in sugarcane (Ramdoyal, 1999) and is used as a criterion for evaluation of maturity and quality of sugarcane under field conditions (Habib, *et al*., 1992). It is evident from the results presented in Table 1 that variety LRK-2003 exhibited highest brix percentage (21.45), closely followed by variety LRK-2004.While, Chandka variety exhibited the least performance of brix percentage i.e. 17.80. The varieties that had high brix percentage might be due to their good response of environmental reaction and association with the genetic make up of the parent material of these varieties. These results are in agreement with the findings of Panhwar, *et al*., (2003), Memon, *et al*., (2004) and Naich, *et al*., (2006) who studied a number of sugarcane varieties and found different levels of brix percentage.

The results regarding cane yield revealed that the mean cane yield of the varieties differed significantly from one another. Variety LRK-2004 produced the highest cane yield (186.21) followed by variety Ganj Bakhsh with mean cane yield of (135.91) tones ha^{-1}. Varieties NIA-2004 and Chandka also gave good results with cane yield of 129.23 and 128.39 tones ha^{-1} respectively. While, varieties HoLRK-3-19 and S98-SP-108 had cane yield of 113.12 and 112.28 tones ha^{-1}, respectively. The lowest cane yield of 75.32 tones ha^{-1} was produced by variety S-2001-US-400. High cane yielding varieties showed best environmental response and hence revealed good performance of cane yield as compared to the other varieties. This higher cane yield of variety LRK-2004 was mainly associated with higher cane length, more number of tillers $plant^{-1}$, and better values regarding germination percentage and cane girth. The results are in agreement with those of Keerio, *et al*., (2003), Buriro, *et al*., (2003), Baloch, *et al*., (2004) and Naich, *et al*., (2006), who carried out studies on different sugarcane varieties and found different trend for cane yield per unit area.

Table-1: Yield and yield parameters of different sugarcane varieties planted at Quaid-e- Awam Agriculture Research Institute, Larkana

Varieties	Germination (%)	Plant height (m)	Tillers stool^{-1}	Internodes/ cane	Cane girth (cm)	Brix (%)	Yield Mt ha^{-1}
Chandka	80.50	3.67	7.43	28.99	3.28	17.80	128.39
LRK-2003	74.25	2.93	8.58	27.74	2.73	21.45	106.72
LRK-2004	70.25	4.10	10.43	28.32	2.92	21.30	186.21
HoLRK-3-19	86.25	2.85	6.15	27.49	2.38	18.90	113.12
Ganj Bakhsh	69.00	2.75	5.22	27.32	3.39	18.95	159.1
NIA-2004	75.50	3.07	5.28	27.08	2.35	18.85	129.23
S2001-US-400	67.75	2.78	5.47	24.58	2.26	19.35	75.32
CP-92-1167	79.75	2.41	5.74	24.16	2.86	18.00	78.11
S98-SP-108	89.00	2.77	6.93	25.46	2.51	18.50	112.28
S96-SP-1215	72.00	3.17	6.12	25.83	2.39	18.50	81.72
CSSG-668	77.50	2.89	5.98	25.08	2.56	18.65	79.76
CSSG-676	73.00	2.87	5.48	27.58	2.44	18.35	89.77
L-116 (Check)	78.75	1.99	6.68	20.33	1.88	18.30	79.49
Minimum	**67.75**	**1.99**	**5.22**	**20.33**	**1.88**	**17.80**	**75.32**
Maximum	**89.00**	**4.10**	**10.43**	**28.99**	**3.39**	**21.30**	**186.21**
Average	**76.42**	**2.94**	**6.58**	**26.15**	**2.61**	**18.99**	**107.39**

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RELATIVE CANE YIELD AND QUALITY APPRAISAL OF DIVERGENT SUGARCANE CLONES IN 4TH CYCLE UNDER THATTA CLIMATIC CONDITIONS

By

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ABSTRACT

The experiment was conducted at National Sugar Crops Research Institute; farm Thatta to investigate the cane yield and quality performance of thirteen sugarcane clones in 4th cycle during 2003-04. The experiment was laid out under randomized complete block design with three replications. Thirteen sugarcane clones viz. HoTh-301, HoTh-307, HoTh-309, HoTh-313, HoTh-316, HoTh-318, HoTh-325, HoTh-332, HoTh-334, HoTh-337, HoTh-340, HoTh-344, HoTh-349 along with Thatta-10 as check were planted in plant crop during October 2003. The results showed that there were highly significant differences amongst the clones for the traits under study. Six sugarcane clones HoTh-318, HoTh-316, HoTh-307, HoTh-344, HoTh-349 and HoTh-332 gave out standing performance by producing highest average cane yield of 119.26, 118.0, 117.68, 116.38, 114.95 and 114.81 t/ha respectively against the check variety Thatta-10 (114.0 t/ha). While, in case of sugar yield the clones HoTh-318, HoTh-307, HoTh-316, HoTh-344, HoTh-349 and HoTh-332 remained superior by producing maximum sugar yield of 15.46, 15.16, 15.13, 15.01, 14.77 and 14.50 t/ha respectively against the check variety Thatta-10, which gave sugar yield of 14.19 t/ha. Contrary to this, the other clones in the trial could not exceed check variety in terms of cane and sugar yield. Thus on account of maximum cane and sugar yield the clones HoTh-307, HoTh-316, HoTh-318, HoTh-332, HoTh-344 and HoTh-349 were advanced to next selection stage for further progression and testing.

INTRODUCTION

Sugarcane (*Saccharum officinarum* , L.) bears a great impact on the economic uplift of the growers. It provides raw material to the sugar industry for the manufacture of sugar and many other by –products and play a distinct role in the economy of Pakistan. Survival of sugarcane industry in Pakistan is at the mercy of sugarcane cultivation. Therefore, evolution of sugarcane varieties higher in cane and sugar yield is need of the time for improving the efficiency of sugar mills. It is generally recognized that sugarcane has a relatively a high average production efficiency, there being limited potential for increasing yields in response to increased agronomic inputs such as irrigation, fertilization and pest controls. Therefore, investment in breeding effort remains the best approach for maximizing cane and sugar productivity in the long run.

Improvement of sugarcane through genetic manipulation has been a direct, on going process following observation that sugarcane produced viable seed. Sugarcane hybrid fuzz is obtained from the flowering parents through planned crosses between parent varieties by conventional breeding methods. Sugarcane is hard to flower under natural environment until some specific temperature; humidity and

photoperiod requirements are fulfilled. Many sugarcane varieties flower and produce viable seed up to 20^0 N or S latitude, where photo thermal environment is favourable. In Pakistan, photo thermal climate is favourable in coastal areas, where many sugarcane varieties flower but only few produce viable fuzz (Keerio and Memon 2004). This potential can be utilized with the provision of artificial photo thermal conditions where synchronized flowering in desired varieties can be induced to run a systemic cross breeding program in Pakistan.

The varietal development program at National Sugar Crops Research Institute, Thatta is being carried out through locally collected fuzz (wind pollinated) and exotic fuzz (artificially crossed), received from different foreign breeding stations. New seedlings of sugarcane are produced from the fuzz. Subsequent selection of the seedlings (clones) is done in different selection stages. After careful examination of these clones in several tests, high cane and sugar yielding ones having resistance to insect pest and disease are selected and issued for commercial cultivation.

According to Glaz, *et al.,* (2000) clonal selection at pre commercial stages helps in the identification of improved genotypes for commercial production of sugarcane. Careful selection of the clones in early stages may lead to the development of superior varieties (Panhwar *et al.*,2003). Balagtas and Laptian (1983) studied 24 foreign clones and stated that the Chinese clone F-148 and Coimbatore variety Co-449 gave better performance over the check. Poltronieri *et al,.* (1982), reported that clones B-4362, CP 49-260 and Co-1007 gave highest stripped cane yields of 175.5,174.8 and 170.3 t/ha compared a new clone CoS-776 with Co-1158. The former did better in respect of tillering, cane formation, ratoonability and juice quality but the differences in cane yield were not significant. Javed, *et al.,* (2001) reported that clone AEC 82-1026 produced significantly higher cane and sugar yield than commercial varieties BL-4 and L-116 under agro-climatic condition of Tando Jam. The other two clones AEC 86-328 and AEC 86-329 were superior to all entries in quality traits. Similarly Khan, *et al.*,(2002) evaluated two sugarcane clones AEC 81-8415 and AEC 80-2046 along with 4 commercial varieties viz. BL-4, PR-1000, BF-129 and L-116 at three location in the province of Sindh and reported that clone AEC 81-8415 was superior to all entries except BL-4 for cane and sugar yield but at par with them in CCS%.

The productive behavior of old sugarcane varieties is deteriorating with the passage of time. Therefore constant replacement of old varieties with new one's is need of the time. Keeping in view this objective present study was conducted to find out the potential sugarcane clones to release them as new commercial varieties in future.

MATERIALS AND METHODS

Large number s of seedling was grown in nursery from exotic fuzz of USA origin. These seedlings (clones) were shifted the main field and year wise tested in several selection stage by rejecting undesirable clones, selections in the course of screenings were as follows:

Year	Selection stage	Clones tested
1999-2000	Single clone trial	1765
2000-2001	First cycle	1624
2001-2002	Second cycle	527
2002-2003	Third cycle	138
2003-2004	Fourth cycle	13

The study was conducted at National Sugar Crops Research Institute, farm, Thatta. Thirteen sugarcane clones viz. HoTh-301, HoTh-307, HoTh-309, HoTh-313, HoTh-316, HoTh-318, HoTh-325, HoTh-332, HoTh-334, HoTh-337, HoTh-340, HoTh-344, HoTh-349 along with Thatta-10 as check were planted in

October 2003 by overlapping method using two budded sets. Plot size was 18 m^2; three rows of each genotype in six meters long furrows at one- meter row spacing were sown. The crop was fertilized @ 275-112-175 Kg NPK t/ha. All P, K and 1/3 N was applied at the time of sowing while remaining 2/3 N was applied in two equal splits, first at the completion of germination and second at the time of earthling up. Uniform management and cultural operations, insect pest and disease control measures were adopted at appropriate stage. The data observations pertaining to cane yield and its parameters, commercial cane sugar percentage (CCS%) and sugar yield were recorded and was subjected to statistical analysis using MSTAT-C statistical programme (MSTAT-C Manual, 1991).

RESULTS AND DISCUSSION

Analysis of variance reveals that highly significant differences were existed among the sugarcane clones for cane yield and yield components (table-1). The results regarding mean performance of different sugarcane clones for quantitative parameters are presented in table-2, which reveals that maximum average cane thickness was observed in clone HoTh-307 (26.0 mm) closely followed by HoTh-332 (25.93 mm), HoTh-344 (25.90 mm) and HoTh-301 (25.86 mm). While, minimum average cane thickness was exhibited in HoTh-340 (21.80 mm) followed by HoTh-334 (23.49 mm) and HoTh-325 (23.96 mm) against check variety Thatta-10 (25.56 mm). As regards the number of internodes per plant, the clone HoTh-318 was at top with 26.69 average internodes/plant followed by HoTh-340, HoTh-332, and HoTh-316, which produced 24.66, 24.33 and 24.18 average number of internodes/plant respectively. Highest average cane height was observed in clone HoTh-340 (207.49 cm), which was closely followed by HoTh-316 (206.10 cm) and HoTh-307 (202.49 cm) and the lowest average cane height was recorded in clone HoTh-334 (148.66 cm), HoTh-301 (155.33 cm) and HoTh-337 (155.66 cm) against the check variety Thatta-10 (200.33 cm). The variable cane height of the clones may be attributed to their variable inherent growth and development potential. A perusal of data in table-2 indicates that average millable canes were highest in HoTh-340 (166.66 canes 000/ha) followed by HoTh-325 and HoTh-301, which produced 133.33 and 123.33 millable canes thousand /ha respectively. While, the clones HoTh-316, HoTh-332 and HoTh-349 were at par by producing 113.33 millable canes thousand/ha. In contrast, the clones like HoTh-337, HoTh-334, HoTh-313 and HoTh-309 produced minimum 83.33, 86.66, 90.00 and 93.33 average millable canes thousand/ha respectively against the check variety Thatta-10 (110.00 canes 000/ha). The differences in number of millable canes among the clones might be due to their variable inherent tillering potential. The data in table-2 further reveals that all the clones in the trial showed varying trend of effectiveness for cane yield. Highest average cane yield was recorded in clones HoTh-318 (119.26 t/ha) followed by HoTh-316 (118.0 t/ha), HoTh-307 (117.68 t/ha), HoTh-344 (116.38 t/ha), HoTh-349 (114.95 t/ha) and HoTh-332 (114.81 t/ha) against the check variety Thatta (114.0 t/ha). On the contrary, the clones HoTh-309 and HoTh-337 were at par and produced minimum average cane yield of 65.0 t/ha followed by HoTh-334 (67.50 t/ha) and HoTh-313 (72.50 t/ha). It is well known that sugarcane varieties are greatly affected by genetic make up (Geddway, *et al.,* 2002). The variation in cane yields and yield components among the varieties may be attributed due to their differences in genetic make up (Verghese *et al.*, 1985; Mali and Singh, 1995). Nazir, *et al,* (1997) reported that higher cane yield is the function of high potential variety. Khan *et al,* (2002) reported that increase in cane yield might be due to

maximum plant height, weight per stool and cane girth.

Month wise quality analysis data is present in table-3, which reveals that maximum mean CCS of 12.97% was recorded from HoTh-318 closely followed by HoTh-344, HoTh-307, HoTh-349, HoTh-316 and HoTh-332 which produced mean CCS of 12.90, 12.89, 12.85, 12.83 and 12.63% respectively against the check variety Thatta-10 (12.45% CCS). While rest of the clones in the trial produced mean CCS% less than that of check variety Thatta-10. Maximum sugar content in the clones might be due to their inherent genetic potential of the parent material. Khan *et al*., (2003) and Memon *et al.*, (2004) in their studies reported variable behavior among newly developed Thatta varieties for cane yield and yield components.

Sugar yield data presented in table-3 reveals that the clones HoTh-318, HoTh-307, HoTh-316 and HoTh-344 were on top by producing maximum sugar yield of 15.46, 15.16, 15.13 and 15.01 t/ha respectively. Moreover, the clones HoTh-349 and HoTh-332 displayed next good performance by producing sugar yield of 14.77 and 14.50 t/ha respectively against the check variety Thatta-10, which produced sugar yield of 14.19 t/ha. In contrast, the other clones like HoTh-309, HoTh-313, HoTh-334 and HoTh-337 exhibited minimum results in terms of sugar yield against the check. The highest sugar yield in clones may be attributed to relatively more average cane yield and subsequent recoverable sugar percentage.

Table-1 Mean square values and their significance from analysis of variance for cane yield and yield components of different sugarcane clones during 2003-04

Source of variation	df	Cane thickness	Cane height	Internodes /plant	Millable canes 000/ha	Cane yield
Replication	2	0.005	11.174	125.625	92.857	103.595
Factor A	13	4.549**	25.720**	1049.00**	1378.755**	1435.172**
Error	26	1.166	2.069	221.663	51.832	21.749

Table-2 Performance of different sugarcane clones for cane yield and yield contributing traits in 4th cycle at NSCRI, farm Thatta during 2003-04

Genotypes	Cane thick-ness (mm)	Cane ht. (cm)	Internodes/ Plant	Millable canes 000/ha	Cane Yield (t/ha)
HoTh-301	25.86	155.33	19.83	123.33	95.00
HoTh-307	26.00	202.49	23.31	116.66	117.68
HoTh-309	24.60	184.63	21.58	93.33	65.00
HoTh-313	24.80	172.83	17.99	90.00	72.50
HoTh-316	25.10	206.10	24.18	113.33	118.00
HoTh-318	25.37	212.42	26.69	120.00	119.26
HoTh-325	23.96	182.66	22.16	133.33	92.50
HoTh-332	25.93	199.94	24.33	113.33	114.81
HoTh-334	23.49	148.66	19.16	86.66	67.50
HoTh-337	25.22	155.66	20.50	83.33	65.00
HoTh-340	21.80	207.49	24.66	166.66	97.50
HoTh-344	25.90	200.16	23.70	116.66	116.38
HoTh-349	25.60	192.00	23.25	113.33	114.95
Thatta-10	25.56	200.33	23.92	110.00	114.00
CV%	4.43	8.33	6.60	6.38	4.78
LSD 0.5%	1.81	24.99	2.41	12.08	7.82
LSD 0.1%	2.45	33.78	3.26	16.33	10.58

Table-3 Quality performance of different sugarcane clones in 4th cycle At NSCRI, Farm Thatta during 2003-04

Genotypes	Month wise Commercial Cane Sugar Percent (CCS%)			Mean CCS %	Sugar Yield (t/ha)
	October	November	December		
HoTh-301	11.43	11.59	11.86	11.62	11.03
HoTh-307	12.68	12.82	13.17	12.89	15.16
HoTh-309	11.39	11.56	11.85	11.60	7.54
HoTh-313	11.26	11.47	11.65	11.46	8.30
HoTh-316	12.64	12.82	13.04	12.83	15.13
HoTh-318	12.80	12.92	13.21	12.97	15.46
HoTh-325	11.41	11.61	11.97	11.66	10.78
HoTh-332	12.31	12.69	12.90	12.63	14.50
HoTh-334	10.69	11.02	11.97	11.22	7.57
HoTh-337	11.34	11.54	12.00	11.62	7.55
HoTh-340	11.22	11.51	11.93	11.55	11.26
HoTh-344	12.57	12.96	13.19	12.90	15.01
HoTh-349	12.63	12.83	13.11	12.85	14.77
Thatta-10	12.30	12.46	12.60	12.45	14.19

Appendix-1 Summary of meteorological data recorded at Meteorological Station of National Sugar Crops Research Institute, Thatta during 2003-04

Year	Month	Temperature ^{0}C		Humidity %	Rainfall (mm)
		Minimum	Maximum		
2003	October	20.45	36.32	51.61	-
2003	November	16.32	30.68	51.24	-
2003	December	11.58	26.01	37.76	-
2004	January	11.98	25.12	50.16	13
2004	February	15.37	29.03	48.72	-
2004	March	18.29	35.83	46.74	-
2004	April	23.56	36.20	56.46	2
2004	May	25.67	39.00	54.58	-
2004	June	28.63	36.95	68.60	-
2004	July	26.64	32.64	72.29	-
2004	August	26.41	31.30	76.00	5
2004	September	24.40	32.35	76.10	-
2004	October	21.00	32.70	69.67	36
2004	November	17.47	32.26	59.73	-
2004	December	14.19	26.77	65.48	-

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EFFECT OF SOWING DEPTH AND EARTHING UP ON LODGING IN PRESOWN SUGARCANE

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ABSTRACT

The field studies on management strategies for controlling lodging in presown sugarcane were carried out at Sugarcane Research Station, Khanpur during 2004-05 and 2005-06. The management practices included two sowing techniques i.e., shallow furrows, deep trenches and three earthing up treatments i.e., no earthing, earthing up with spade and earthing up with ridger. The results indicated non-significant cane yield improvement due to trench sowing and significant due to earthing up. Spade earthing increased cane yield by 19.20 % and earthing up with ridger increased by 18.00% over no earthing control in pool analysis. A measurable increase in commercial cane sugar was recorded owing to earthing up as a result of reduced lodging.

INTRODUCTION

Lodging exerts a potential threat to economic harvests in sugarcane. A lodged sugarcane crop is more liable to damage by rodents. Its axillary buds sprout or may be damaged by rotting and false tillering starts which reduces cane weight and sugar recovery. Besides yield and quality losses, cane remains no more fit for seed purpose. Moreover, a lodged sugarcane crop is more susceptible to insect pest attack and frost injury. Von and Lin (8) concluded in Taiwan that earthing up to a height of 30 cm leads to 12% increase in millable cane yield over non earthed plot. Both the increase in cane yield and average length of millable canes were statistically significant. About 30% reduction in cane yield and 8.63% in commercial cane sugar due to 1odging has been reported by Ahmad (2). In a field study under Faisalabad conditions earthing up gave significantly more cane yield than no earthing. Commercial cane sugar was also improved (3). Sarwar *et al*., (6) reported 27.50% increase in cane yield while 5.54% in commercial cane sugar due to earthing up with cane ridger. Bashir and Saeed (4) found that by increasing seed rate of sugarcane lodging was enhanced. Minhas *et al*., (5) noticed that earthing up increased cane yield significantly through cane height, girth and tillers. Afzal and Chattha (1) observed that earthing up helps in reducing lodging and to give anchorage to cane crop. Earthing up should be done at the completion of tiller formation, in the month of March for autumn planting and May-June for spring planting.

Keeping in view the drastic decline in cane yield and recovery due to lodging, the present studies were undertaken to chalk out strategy for reducing lodging in sugarcane.

MATERIALS AND METHODS

The studies were carried out at Sugarcane Research Station, Khanpur during the year 2004-05 to find out effective means for reducing lodging in sugarcane.

The experimental treatment comprised of two sowing techniques i.e., shallow furrows, deep trenches and three earthing up treatments i.e., no earthing, earthing up with spade and earthing up with ridger. A

commercial sugarcane variety SPF-234 was sown in September using a seed rate of 75000 double budded setts per hectare according to split plot design. The sub plot measured 4.8 m x 8 m with four replications. The sowing techniques were placed in main plots and earthing up treatments in sub plots. The crop was fertilized at the rate of 168-112-112 kg NPK/ha. The whole P and K were applied at the time of sowing. The N was applied in three splits, 1/3 at the completion of germination, 1/3 at tillering and remaining 1/3 at the time of earthing up. All other cultural practices were kept uniform at recommended level. The data on different parameters were recorded using standard procedures during the course of study. The data thus collected were analyzed using Fisher's Analysis of Variance Techniques and the treatments were compared using Least Significance Difference Test at 5% level of probability (7).

RESULTS AND DISCUSSION

Germination and tillering

Germination is the basic factor determining the millable cane stand to a large extent. A glance at table 1 revealed that sowing techniques exerted a measurable influence on germination during the specific years and in pool analysis. Sugarcane seed sown in deep trenches germinated more than that sown in shallow furrows probably because of prolonged moisture retention in the first case. Whereas earthing up and the interaction of both the test factors did not affect the germinability of sugarcane. Tiller formation remains an important character affecting the final harvests of sugarcane. The data presented in table 1 shows non significant effect of all the treatments on tillering during the years individually and in pool analysis.

Cane Weight and Density

Millable cane weight is an important chancier, which directly affects final crop yield. The data recorded in table 2 indicate that on an: avenge canes in trench were heavier than those of furrow sown but the differences were not tangible enough to reach a level of significance. Similarly, earthing up increased cane weight, yet the differences were non significant. The interactive impact of test factors also remained at par with one another. Millable cane density plays a pivotal role in determining the economic crop yield. The sowing techniques resembled in their effect on cane formation (table 2). However, the response of earthing up was significant on the establishment of final cane stand during the years individually and in pool analysis. Highest number of millable canes (106.80 thousand per hectare) were recorded in the spade earthed up plots which woe at par to those earthed up with ridger (104.68) and greater than no earthing control (90.92) in the pool analysis. Greater cane stand in the earthed up plots may probably be I due to reduced lodging and hence low tiller mortality.

Cane and Sugar Yield

Cane yield is the ultimate goal of every grower. The data embodied in table 3 elucidate that although trench sowing gave more cane yield than furrow sowing, yet the differences were statistically non significant. Earthing up improved cane yield to a significant level of 19.20 %. Earthing up either with spade or tractor mounted ridger gave significantly more yield than no earthing control. The interactive effect of test factors remained non significant during pool analysis. Better cane yield in the earthed up plots may be attributed to the reduced lodging, better cane weight and cane formation. Significantly greater cane yield with earthing up has also been reported by Ahmad (2), Anonymous (3), Minhas *et al*., (5), Sarwar *et al*., (6) and Von and Lin (8).

Cane Lodging

The data set out in table 3 depict that cane lodging was confined to 25.00% in trench sowing against 30.70% in shallow furrows. The impact of earthing up on cane lodging

was more pronounced. Lodging was reduced to a level of 14.80% in case of earthing up with ridger and 15.80% in spade earthing against 52.90% lodging in case of no earthing up control during the pool analysis. The minimum lodging in earthed up treatments may be ascribed to proper soil compaction around the cane plants, which provided sufficient anchorage to cane plants against lodging.

Commercial Cane Sugar

The data packed in table 4 are indicative of the fact that CCS was improved earthing up white sowing techniques did not exert any marked effect. Earthing up with cane ridger gave 11.51% CCS and earthing up with spade gave 11.41% against 8.54% in case of non-earthed canes. Higher CCS in earthed up plots may be attributed to minimum lodging and hence no sprouting of axillary buds or false tillering. Improvement in cane quality as a result of earthing up has also been noticed by Ahmad (2), Anonymous (3) and Sarwar *et al*., (6).

CONCLUSION

On the basis o f the results and discussion, the following conclusions m ay b e arrived at.

- Trench sowing enhanced germination and final cane yield non-significantly.
- Earthing up either with spade or ridger reduced cane lodging significantly.
- Earthing up increased cane yield upto 19.20%.
- Earthing up improved cane juice quality.

A wider scale testing of the results in different agro-ecological conditions is invited.

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Table-1 Effect of sowing depth and earthing up on the germination and tillering of presown sugarcane

Treatment	Germination %			Tillers Plant^{-1}		
Sowing techniques	2004	2005	Mean	2004	2005	Mean
S_1= Furrow sowing	47.61 b	54.27	50.94b	2.57	2.59	2.58
S_2= Trench sowing	56.19 a	65.31	60.75a	2.59	2.61	2.60
LSD = 0.05	8.71	6.19	7.28	N.S	N.S	N.S
E_1 = No earthing up	52.07	59.00	55.72	US	-	24
E_2= With spade	52.33	60.50	56.41	2.56	2.58	2.57
E_3= With ridger	51.32	59.53	55.42	2.60	2.60	2.60
LSD = 0.05	N.S	N.S	N.S	N.S	N.S	N.S
Interaction S x E						
S_1 xE_1	48.44	54.13	51.28	2.58	2.60	2.59
S_1xE_2	47.58	55.29	51.43	2.51	2.62	2.56
SixE_3	46.82	53.41	50.12	2.63	2.59	2.61
S_2xEi	55.69	64.64	60.16	2.59	2.64	2.61
S_2xE_2	57.08	65.71	61.39	2.61	2.58	2.59
S_2xE_3	55.82	65.85	60.83	2.57	2.61	2.59
LSD = 0.05	N.S	N.S	N.S	N.S	N.S	N.S

Treatments having no or same letter(s) do not differ significantly

Table-2 Effect of sowing depth and earthing up on cane weight and density of presown sugarcane

Treatment	Cane weight			Cane density (000/ha)		
Sowing techniques	2004	2005	Mean	2004	2005	Mean
S_1= Furrow sowing	122.67	102.67	112.67	100.28	99.10	99.69
S_2= Trench sowing	126.58	102.00	114.29	102.34	101.48	101.91
LSD = 0.05	N.S	N.S	N.S	N.S	N.S	N.S
Earthing up						
EI= No earthing	121.87	99.83	110.85	91.21b	90.63b	90.92b
E_2= With spade	124.61	103.50	114.05	108.69a	104.9 la	106.80a
E_3= With ridger	126.37	103.67	115.02	104.03a	105.34a	104.68a
LSD = 0.05	N.S	N.S	N.S	6.43	3.58	5.01
Interaction S x E						
S_1 xE_1	122.75	99.33	111.04	90.88	88.11	89.94
S_1xE_2	121.25	104.00	112.62	106.83	103.56	105.19
S_txE_3	124.00	105.00	114.50	103.12	105.64	104.38
S_2xEi	125.00	100.67	112.83	91.53	93.14	92.33
S_2xE_2	126.00	103.00	114.50	110.55	106 .25	108.40
S_2xE_3	128.75	102.33	115.54	104.95	105 .03	104.99
LSD = 0.05	N.S	N.S	N.S	N.S	N.S	N.S

Treatments having no or same letter(s) do not differ significantly

Table-3 Effect of sowing depth and earthing up on yield and lodging of presown sugarcane

Treatment	Cane yield			Cane lodging (0-9)		
Sowing techniques	2004	2005	Mean	2004	2005	Mean
S_1= Furrow sowing	122.78	102.02	112.40	2.66	3.48	3.07
82= Trench sowing	129.31	103.35	116.33	2.33	2.67	2.50
LSD = 0.05	N.S	N.S	N.S	—	....	....
Earthing up						
EI= No earthing	112.92b	90.57b	101. 74b	5.00	5.58	5.26
E7= With spade	133.94a	108.63 a	121.28a	1J7	1.79	1.58
E_3=With ridger	131.27a	108.85a	120.06a	1.12	1.84	1.48
LSD = 0.05	8.21	2.01	6.14	—	—	—
Interaction S x E						
S_1 x E_1	111.45e	87.23	99.34	5.25	5.81	5.53
S_1xE_2	129.29c	107.80	118.54	1.50	2.11	1.81
S_1xE_3	127.59c	111.02	119.31	1.25	2.52	1.88
S_2xEi	114.38d	93.92	104.15	4.75	5.36	5.05
S_2xE_2	138.59a	109.46	124.03	1.25	1.48	1.37
S_2xE_3	134.95b	106.68	120.81	1.00	1.17	1.09
LSD = 0.05	2.58	N.S	N.S	....	....	—

Treatments having no or same letter(s) do not differ significantly

Table-4 Effect of sowing depth and earthing up on CCS and sugar yield of presown sugarcane

Treatment	Commercial Cane Sugar %			Sugar Yield (t/ha)		
Sowing techniques	2004	2005	Mean	2004	2005	Mean
S_1= Furrow sowing	10.53	10.33	10.43	12.93	10.54	11.73
S_2= Trench sowing	10.66	10.42	10.54	13.78	10.77	12.27
LSD = 0.05						
Earthing up						
EI= No earthing	8.70	8.38	8.54	9.82	7.59	8.71
E_2= With spade	11.53	11.30	11.41	15.44	12.28	13.86
£3= With ridger	11.57	11.45	11.51	15.18	12.46	13.82
LSD = 0.05						
Interaction S x E						
S_1 x E_1	8.61	8.32	8.46	9.59	7.25	8.42
S_1xE_2	11.45	11.25	11.35	14.80	12.13	13.46
S_1xE_3	11.54	11.41	11.47	14.72	12.67	13.69
S_2xE,	8.79	8.43	8.61	10.05	7.92	8.98
S_2xE_2	11.61	11.35	11.48	16.09	12.42	14.25
S_2xE_3	11.59	11.49	11.54	15.64	12.26	13.95
LSD = 0.05						

Treatments having no or same letter(s) do not differ significantly

Sugar Industry Abstracts

By
M. Awais Qureshi & Dr. Shahid Afghan

AGRICULTURAL ENGINEERING

Performance of irrigation systems and water use of sugarcane: a field to catchments scale perspective

N.L. Lecler, D.J. Clark, R.E. Schulze, B.A.K. Griffiths And J.C. Smithers
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In this paper a perspective of irrigation systems performance is provided. To contribute to this perspective, an appropriately representative agro-hydrological simulation model is described and was used to estimate the water balance and various fates of applied irrigation water for typical and top performing furrow irrigation systems compared to equivalent typical and top performing centre pivot irrigation systems. Characteristics of the different systems, such as the uniformity of applied water, were derived from representative in-field evaluations. Often, when irrigation efficiencies are quoted or interpreted, the fates of applied water are poorly specified or appreciated, which leads to the widespread belief that water just disappears with low irrigation efficiencies and will re-appear with improvements. As demonstrated in this paper, such beliefs are an over-simplification. Often the amount of water actually consumed in irrigation, i.e. the evaporated component, remains little changed at various levels of efficiency. Simulations showed that reductions in non-beneficial water balance components were affected more by design and management considerations than by the type of irrigation system. Changing from furrow irrigation to centre pivots, which are often perceived to be more efficient, did result in slightly improved crop yields. However, availability of water to other users supplied from a downstream dam was less, owing to the timing and magnitude of associated irrigation return flows and the higher evaporation losses simulated under the pivots. Quantification of the water balance in an integrated systems context is essential for assessing the performance of irrigation and water management systems and should be promoted rather than promoting the plethora of often misinterpreted irrigation performance indices.

Development and modification of machinery for an improved farming system in the Australian sugar industry

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The need for sustainable sugarcane production in the Australian sugar industry prompted the development of an improved farming system that incorporates the use of legume fallow crops, reduced tillage operations and controlled in-field traffic. Significant economic and environmental benefits can be obtained from adoption of improved farming practices. To implement this system successfully, some modification of machinery is necessary. This paper examines some of the machinery needs associated with the adoption of the improved farming system within the industry. The development of appropriate planter technologies and modifications for chopper harvesters is discussed, and the introduction of machinery for successful management of legume crops is described and assessed. The development and/or modification of machinery and equipment have been, and continue to be, an important

component of this process. Future enhancement may include incorporation of emerging precision agriculture technologies, with the aim of additional economic and environmental benefits.

AGRICULTURAL AGRONOMY

Integrated agronomic practices for sustainable sugarcane production. a report on the 2006 agronomy workshop

K. F. Ng Kee Kwong
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The 2006 Agronomy Workshop was held from 22 to 26 May 2006 in Khon Kaen, Thailand. The response by sugar cane technologists to the Workshop was very positive with the presence of 92 participants coming from 16 different countries (41 of them traveling from overseas). The scene for discussion and interaction among the technologists was set by 30 oral presentations and 10 posters divided under the five following specific themes: new/refined technologies for sustainable sugar cane production; ratoon yield decline and its management; soil management and the utilisation of plant residues; challenge of environmental pressure and strategy for the sugar cane grower; modelling sugar cane growth and production. It emerged at the Workshop that the key for sustainable sugar cane production lies in soil organic matter conservation. The benefits from measures that enhance and conserve soil organic matter can, however, be gauged most often in the medium or long term through the improvement in soil health. Though soil organic matter conservation and build up in the soil are most critical for better management practices, it was also clear that research findings should not be considered as universally applicable and should be tested under the specific local conditions. The Workshop also provided the opportunity to acquire an overview of the sugar industry in Thailand and the status of research and development in the country. The problems that the Thai sugar industry has to overcome are not more daunting than those experienced in other sugar producing countries. With an integrated approach encompassing a more effective technology transfer and a more efficient breeding program to produce cane with improved ratooning ability and resistance to pests and diseases, the Thai sugar industry would certainly be capable of improving very significantly its productivity and sustainability.

A new approach to implementing computer-based decision support for sugarcane farmers and extension staff: the case of *my canesim*

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Sugarcane production regularly requires complex and quick decision-making under ever changing conditions. Adoption of computer-based decision support systems has been disappointing. This paper reviews a new approach to developing and implementing decision support for sugarcane production. The main features are (1) use of state-of-the-art technology, (2) limiting users. exposure to system complexity (3) participation of users in system design and implementation. The *My Canesim* system consists of a sugarcane model, an on-line weather database and a communication network. The system uses basic field data, initially entered by the user via the Internet, to calculate the soil and crop status for each day of the growing season as the season progresses. The system was implemented on a pilot scale on two small-scale irrigation schemes in Pongola and Makhathini, South Africa. Farmers, extension staff and mill cane supply management contributed to the design of the web

interface, the advice and the reports generated by the system. Irrigation advice and yield estimates are disseminated weekly to 39 farmers using cell phone text messages. Summaries for each scheme are faxed to three extension officers and to mill management. Reports containing detailed information such as estimated current and predicted future cane yield, sucrose content and soil water deficit can be downloaded from the website. The study revealed various inefficient irrigation practices that could be eliminated and showed that significant savings in irrigation water and costs could be achieved by following the advice. System reports served as a useful benchmark of field and crop status. These reports were used by extension staff as a basis for discussion during field visits and by mill management as an indicator of crops that are ready for harvesting. It is believed that a similar approach could be followed to support other aspects of crop production, e.g. fertiliser management and harvest scheduling.

SUGARCANE BREEDING

An evaluation of interspecific families of different nobilised groups in contrasting environments for breeding novel sugarcane clones for biomass

K. Ramdoyal And M.G.H. Badaloo
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The MSIRI breeding program is widening its scope to exploit sugarcane biomass for alternative commodities such as fuel ethanol and electricity to ensure sustainable sugarcane production. In this context, seventeen families comprising different nobilised generations (F1, BC1, BC2) were evaluated in two contrasting environments, sub-humid and very humid, to identify crosses that can produce different types of canes. Most of the female parents were commercial-type clones chosen for incorporating genomes from *S. spontaneum*. Some 60 seedlings from each of 5 F1, 8 BC1 and 4 BC2 families were planted in each environment in randomised complete block designs with three replicates of 20 progenies per block. The characters evaluated were stalk number, diameter, and height; quality characters were analysed from millable cane stalks. Families differed significantly for all characters within each group and environmental effects were prominent for the quality characters but were not consistent for the morphological traits within the different groups. Family × environment interactions were not important except for Brix and pol percent cane for the F1 group indicating that segregating seedlings need not be replicated in different environments at this stage. High stalk density, small stalk diameter, high vigour, low pol, and high fibre content were typical of the F1 groups. Pol percent cane improved in BC1 and BC2 generations while fibre content and general vigour decreased. Large between-family variances within all groups accounted for moderately high to high narrow-sense heritability estimates for nearly all characters in the very humid zone, but these estimates were moderately low to moderate in the sub-humid one. Bivariate analyses for pol and fibre, based on the sum of ranks statistics (RANK) and the observed frequency of genotypes that transgress preestablished threshold levels simultaneously (FREQ) within each group, were useful in identifying families for selecting different types of genotypes with different levels of pol and fibre. F1 families could easily be identified that produced relatively high frequency of progenies with fibre exceeding 24% whereas BC1 and BC2 families could yield progenies suitable for ethanol and enhanced fibre for energy production. The implication of these observations is discussed within a diversified breeding strategy.

Use of predictive statistics for early identification of genetic potential of sugarcane families to produce elite genotypes in advanced trials

M. G. H. Badaloo And K. Ramdoyal

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The identification of crosses that have the highest probability of producing elite genotypes is a desirable feature to enhance the efficiency of sugarcane breeding programs. Studies were carried out with 20 biparental crosses to assess their genetic potential and the application of predictive statistics in the superhumid environment of Mauritius. A number of agro-morphological characters were measured on random samples of progenies at the seedling and the replicated 3rd clonal stages: breeder's preference (BP), stalk number (SNO), stalk diameter (SDIA), stalk height (SHT), and plot yield (PY). Selection was performed at the 3rd clonal stage based on kiloBrix probability (field Brix × plot weight) on cumulative plant cane and first ratoon crops with respect to five commercial controls. The families differed significantly and the between families variation was significantly higher than the within family variation for most traits. At the seedling stage, narrow-sense heretability ranged from low to moderate (0.16–0.62) but improved in the replicated trial (0.67–0.95). Three univariate methods were examined: the predicted proportion of elite genotypes (PROB), the family mean (MEAN), and the observed proportion of elite genotypes that transgress set values (OBS). There were highly significant positive correlations among the three predictive statistics indicating their reliability in predicting potential of crosses (r = 0.58–1.00). The best univariate predictors were MEAN and PROB for BP and PY at the seedling stage. Family ranking, based on BP at the seedling stage, is a reliable predictor of PY at the 3rd clonal stage. Two bivariate methods, sum of ranks (RANK) and the observed frequency of genotypes that transgress set targets simultaneously (FREQ) were equally useful in identifying the desirable crosses (r = –0.77–0.93). Highest correlation coefficients between the RANK and FREQ statistics at the seedling stage were obtained for BP-PY (–0.92**) and BP-SNO (–0.93**). In addition, the multivariate RANK statistics, based on simultaneous ranking for all five characters at the seedling stage, was reliable in identifying the best three crosses that ultimately produced 82% of elite genotypes for testing in final stages of selection.

SUGARCANE ENTOMOLOGY

Natural enemies of sugarcane longhorn stem borer, *Dorysthenes buqueti* guerin (coleoptera: cerambycidae), in Thailand

Pimpan Sommartya, Wiwat Suasa-Ard And Arporn Puntongcum

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The sugarcane longhorn stem borer, *Dorysthenes buqueti* Guerin, is a major soil insect pest of sugarcane on many plantations in Thailand. Survey and evaluation of natural enemies of sugarcane longhorn stem borer were conducted and only a mite, *Caloglyphus* sp., and the pathogen *Metarhizium anisopliae* were found as natural enemies. *Caloglyphus* sp. is an ectoparasite of the larva, pupa and adult sugarcane longhorn stem borer, but it is not effective as a biological agent. *M. anisopliae* is an entomopathogenic fungus in soil and is frequently found infecting *D. buqueti* in nature. In the laboratory, a symptom of infected larva of sugarcane longhorn stem borer is its slow movement 6 days after inoculation. There was no visible external fungal development on the larva before death. Death of larva occurred 7 days after inoculation. The pathogen can infect eggs, larvae, pupae and adults of sugarcane longhorn stem borer. The mortality of larva was 100% at 14 days after inoculation with a conidial suspension of 1x108 conidia/mL. In the greenhouse, data showed that 80–100% of

sugarcane longhorn stem borer were killed 20 days after application. Our investigation showed that *M. anisopliae* is an efficient natural enemy and appropriate for biological control of the sugarcane longhorn stem borer in Thailand.

Biological control of the sugarcane woolly aphid (*Ceratovacuna lanigera)* in Indian sugarcane through the release of predators
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Sugar cane Woolly Aphid (SWA), *Ceratovacuna lanigera* Zehnt. (Hemiptera: Aphididae), is an important pest of sugarcane in Asia. In India, an epidemic of this pest was detected in Maharashtra State during 2002–03 and again in 2003–04. Losses of 39 tonnes cane/ha and 3.43 units in sugar recovery were observed. The predators, *Dipha aphidivora* Meyrick (Lepidoptera: Pyralidae), *Micromus igorotus* Bank (Neuroptera: Hemerobiidae) and *Eupeodus confractor* Wiedemann (Diptera: Syrphidae) were observed feeding on SWA and augmentative releases of field collected and shade-net reared predators were made in affected areas. More than 1.6 million predator larvae and cocoons were released during 2002–03 to 2005–06. *Dipha aphidivora* and *M. igorotus* established and multiplied throughout the year. During 2002–03, the year of the initial outbreak, control of SWA was achieved by means of insecticide applications over 41.22% of the affected area, while predators were established on only 12.537 ha (7.63% of the affected area). The implementation of a biological pest management program in 2003–04 that included the rearing and release of predators obtained satisfactory control of SWA on over 92.302 ha (49.23% of the affected area), out of a total of 187.475 ha affected. Thereafter, insecticide use has declined. In 2004–05, predators controlled the SWA infestation on 47 308 ha (76.25% of the affected area). In the following season control was achieved in 77.87% of the affected area through predation and the SWA infestation was restricted. Release of predators at 2500 larvae and/or cocoons per ha effectively controlled the SWA. This success has increased farmers' confidence in the value of biological pest control. Now, establishment of predators automatically coincides with the incidence of SWA. Possible losses in cane yield and sugar recovery due to SWA infestation were reduced. The details of this study are deal with in this paper.

MOLECULAR BIOLOGY

Development of a dependable microsatellite-based fingerprinting system for sugarcane
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For a long time, sugarcane breeders have been trying to develop a reliable molecular marker-based fingerprinting system that could aid their breeding programs. The International Union for the Protection of New Varieties of Plants (UPOV) has also pursued such a system that, once it meets the standard of a DUS (Distinctness, Uniformity and Stability) test, would be used in addition to or to replace morphological characterisation used to guarantee breeders´ property rights until now. A large EST database was screened and ~37 000 SSR motifs were identified in 33 000 sequences. Candidate clusters (112 loci) were selected and validated (primer design, PCR amplification and PAGE/DNA sequencer analyses) in a group of sugarcane accessions sharing diverse levels of genetic relationship. These loci were classified according to their Polymorphism Information Content (PIC) values and visual quality of molecular profiles. The top loci were elected to form a .Sugarcane Microsatellite-based Fingerprinting System.. Three loci discriminated a collection of 1205 entries in a germplasm

bank with at least two differences (discriminatory alleles). This system is being routinely used in our laboratory in several process such as: i) quality control of the tissue culture facility to avoid varietal mislabelling; ii) identification of duplicated accessions in the germplasm bank; iii) determination of genetic similarity indexes to aid the selection of crosses to be performed; iv) determination of selfing levels in seed samples; v) identification of male progenitor of clones originated from polycrosses; vi) identification of hybrids. In the near future we plan to use it as an additional tool for the protection of our varieties. The system has passed several evaluations for stability and repeatability. Protocols for high throughput genotyping in a DNA sequencer have been developed. We believe that this system will discriminate all varieties and related sugarcane genotypes existing in the world, qualifying it to become an important tool for all those involved in breeding and property rights of sugarcane varieties.

Evidence of sugarcane resistance against *Mahanarva fimbriolata* (stål, 1854) (hemiptera: cercopidae)

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In spite of the stalk yield and quality loss brought by spittlebugs, relatively little research has been done to understand the interaction of this pest to sugarcane. This work was conducted to study *M. fimbriolata* resistance in three sugarcane varieties, SP80-1816, RB72454, and SP83-5073. The effect of spittlebug infestation on sugarcane growth and the survival rate of *M. fimbriolata* were determined to compare the varietal reaction to the pest. An experiment was carried out in a greenhouse, and arranged in a completely randomised design, in a 3 x 2 x 4 factorial with 3 sugarcane genotypes, 2 infestation levels (control and 10 nymphs per plant), 4 sampling dates (8, 17, 39 and 68 days after inoculation) and 4 replicates. Data were subjected to an analysis of variance, and means were compared by the Tukey test at 5% of probability. The varieties SP80- 1816 and RB72454 were significantly affected by *M. fimbriolata* infestation while, in SP83-5073, there was no difference between control and infested plants. The survival rate of the nymph was significantly lower in SP83-5073. The latter variety and SP80-1816 as a susceptible genotype were used in a cDNA-AFLP experiment, in an attempt to identify genes that may be involved in spittlebug resistance. Roots were collected from both varieties immediately before spittlebug inoculation and at 1, 2, 7 and 14 days after being subjected to nymph attack for RNA extraction, mRNA purification, cDNA synthesis and cDNA-AFLP analysis. A 250-bp band was found to be differentially expressed in the variety SP83-5073 when subjected to spittlebug infestation. This band is being isolated and will be sequenced and characterised.

SUGARCANE PATHOLOGY

Genetic diversity of sugarcane mosaic virus complex in Tucuman, Argentina

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Sugarcane leaves with mosaic symptoms were collected in 2006 from six locations throughout Tucuman, Argentina, and analysed by the RT-PCR-RFLPs (Yang and Mirkov, 1997) and the nucleotide sequences of the coat protein (CP) genes amplified. The presence of the flexuous virions typical of the potyviruses was confirmed by the transmission electron microscopy in all samples. Using the primers SCMV R3/F4, a 900-bp fragment was

amplified from 93% of samples and 33% of them had the E strain RFLP profile, while the rest of them produced nine different profiles that did not match with those of any known strains. Sequence analyses of the CP genes amplified from these samples with unknown RFLP profiles show that 20% of the samples with the unknown profiles was a strain close to the SCMV D strain, while the rest showed a great genetic diversity. The presence of SrMV was detected in 90% of the total samples, and most of these samples were also infected by SCMV, indicating that the co-existence of SCMV and SrMV is common in the region. The RFLP analysis determined the presence of SrMV strains SCM and SCI in 68% and 14% of the samples, respectively while, in approximately 18% of the cases, both the strains SCM and SCH were present. No RT-PCR product was produced by either SCMV or SrMV primer pair in one symptomatic sample, suggesting the presence of another pathogen that produces similar symptomatology.

Status of *sugarcane yellow leaf virus* in commercial fields and risk assessment in Guadeloupe

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Sugarcane yellow leaf virus (SCYLV), the causal agent of sugarcane yellow leaf disease, is present in Guadeloupe, but its incidence and distribution in commercial fields was unknown. Therefore, five sugarcane cultivars located in 48 plant cane fields in seven sugarcane growing areas in Guadeloupe were analysed for virus infection and populations of *Melanaphis sacchari*, the aphid vector of SCYLV. Twenty-one of the 48 fields were also analysed in the first ratoon crop. Depending on the area of the field, 200 to 400 leaf samples per field were tested by tissue blot immunoassay to detect the virus, and presence of aphids was determined on 10% of sampled plants. In addition, virus incidence in five fields of second and third propagations of nursery stocks produced from tissue-cultured plants was determined. Mean virus incidence in plant cane crops was 6.4%, and it ranged from 0% to 21% according to cultivar and geographical location. *M. sacchari* was widespread in all areas. Mean virus incidence increased to 11.2% in the first ratoon crop, and it increased in all cultivars except in cultivar B69566. Cultivar B69566 consistently had the lowest virus incidence, whereas virus incidence was consistently high in cultivar R579, even if cultivar B69566 was more colonised by aphids. In the second stage nursery fields, virus incidence ranged from 2.5% to 17.3%. Overall, virus incidence did not increase in the third stage nursery step that derived from the second stage nurseries. SCYLV genotype REU was found in all commercial fields, whereas genotypes BRA and CUB were found only in a few samples from five fields. In Guadeloupe, SCYLV appears to be spread by aphid vectors and infected cuttings. Presence of a major virus genotype suggested that this genotype was more adapted to the local environment, or that the two other genotypes were only recently introduced and have not spread yet on the island. Yield losses may occur in extending cultivars such as R579, as it was shown in Reunion Island. Because variation in virulence exists between SCYLV genotypes, disease impact may vary in Guadeloupe in the future.

COPRODUCTS

Life cycle analysis of different alternatives for the treatment and disposal of ethanol vinasse

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Ethanol production through sugar juice fermentation has a serious problem related to the quantities and high organic content of its main residue called vinasse or stillage. The awareness of the impact of the vinasse disposal by fertigation caused the environmental agencies to implement more rigorous conditions regarding this practice. Alternative disposal options are being analysed such as: anaerobic digestion, combustion, vinasse recirculation during fermentation, and dewatering. A discussion is presented about the main advantages and disadvantages of different vinasse treatment and disposal options and about the feasibility of Life Cycle Analysis for its evaluation. This paper aims at evaluating the energy balance and environmental impacts of the whole vinasse treatment and disposal life cycle. As possible alternatives for this study, the following were defined: conventional fertigation (base reference case); vinasse biodigestion and biogas use as fuel in mill boilers, vinasse dewatering up to 40–50% and its direct combustion in boilers; vinasse dewatering up-to 60% before fertigation in order to reduce transport costs. The methodology applied is the ECO-95 Indicators that uses the software SimaPro 7 (PRé Consultants). At the same time, results about the mass and energy balance of the vinasse life cycle are presented. The conclusions present the advantages and disadvantages of each alternative. Graphics of normalized environmental effects for the evaluated alternatives are also presented.

Conversion of cane-derived sugars into poly (3-hydroxyalkanoates) (bioplastics)
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For the sustainability of the Mauritian sugar industry, more co-products need to be produced from sugarcane biomass. One of the co-products that is currently being investigated at the Mauritius Sugar Industry Research Institute (MSIRI) is poly(3-hydroxyalkanoates), more commonly known as PHAs or bioplastics. Cane juice, molasses and bagasse were chosen as raw materials for this study. The sucrose present in cane juice and molasses was quantitatively converted into simple sugars by dilute acids. Pretreated bagasse was converted into simple sugars by either acid or enzymatic hydrolysis, with emphasis being laid on the latter. Enzymes have been produced in situ by *Trichoderma viride* and *T. harzianum*. Media were prepared with the simple sugars obtained from the hydrolysis of sucrose and bagasse, and were inoculated with *Ralstonia eutropha H16 G+* and *Azospirillum* spp. The bacterial cells were harvested, washed, freeze-dried and subjected to solvent extraction. Upon the removal of the solvents, biopolymers were obtained. Once the yields for the production of simple sugars and PHAs have been optimised, the production of these biopolymers will be scaled up. Upon the successful completion of this study, the expertise will be shared with the sugar/plastic industry with the aim of making the commercial production of PHAs a reality in Mauritius. This could not only make the local sugar-cane industry more sustainable, but it could also enable the country to be less dependent on traditional petroleum-derived non-biodegradable (polluting) plastics.

FACTORY ENGINEERING

Flue gas scrubbing equipment for bagasse fired boilers
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Over the past 50 years, sugar factories have been subjected to increasing environmental pressure to conform to new clean air requirements. In most cane sugar producing countries,

legislation now imposes maximum limits on particulate emissions of 100 to 200 mg/Nm3 for new boilers. The paper reviews various types of flue gas cleaning equipment, comparing their merits and disadvantages. Most traditional devices such as dry cyclones cannot achieve the new specifications. Of systems able to meet the targets, some are too costly or maintenance intensive for bagasse (or bagasse + fossil fuel) boilers, and wet scrubbers have been widely accepted as the most practical solution. Various types of wet scrubbers are in service. These are compared in respect of separation efficiency, pressure drop, capital and operating costs, maintenance and reliability. Measurements of particulates in gases from scrubbers in South Africa, Australia and the Philippines are reported. Operating issues such as pressure drops, turn down ratios, entrainment separation, ID fan selection and cleaning, and smuts separation from circulating water are discussed. Typical particle size distributions, their significance and causes of fine particles are discussed. Experience in South Africa has led to the conclusion that sieve plate scrubbers are significantly better than other types of wet scrubber in bagasse boiler applications; 22 of the 36 wet scrubbers in the industry are now of this type.

Experience and utilisation of an on-line sugar colorimeter in a raw cane mill
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An on-line sugar colour instrument was installed on the wet sugar screw directly downstream of the raw sugar centrifugals in the raw cane sugar factory at Harwood Mill and Refinery, Australia. The device accurately and reliably measured raw sugar colour in the process environment. This paper discusses the results and benefits achieved by the system. Pol is arguably the most important and valuable quality parameter of raw sugar. The instrument provided feedback of pol in real time. The Colour/Impurities ratio of sugar is fairly constant from day to day and the constancy of this relationship permitted the sugar pol to be inferred from the colour measurements. Increased vacuum pan capacity, energy economy and reduced molasses losses were achieved by reducing the recirculation of sucrose to the boiling house and avoiding over-washing in the centrifugals, while maintaining quality. The sugar stream discharged from each centrifugal was continuously measured, permitting the identification and diagnosis of problems within and between machines and the subsequent optimisation of each centrifugal of the battery. A more uniform and tighter colour feed to the back-end refinery provided more stable operations and reduced refinery colour load. Broadcast of the instrument output across the plant SCADA system provided information to process supervisors and other operators. The raw sugar boiler operator was able to monitor raw sugar colour for immediate feedback of massecuite quality, and that information was used to assist with decisions on boiling formulation adjustments. The mill supplies up to 90% of the raw feed to the back-end refinery, directly and without blending. Raw sugar colour and pol deviations from standard had previously caused problems in the refinery. The refinery operators were able to use the raw colour data to proactively adjust clarification and decolourisation operating parameters to suit the incoming raws and keep their process within specification.

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