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IMPORTANCE OF WATER MANAGEMENT FOR SUGARCANE CULTIVATION IN BANGLADESH

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ABSTRACT

Irrigation is needed for the cultivation of sugarcane and its intercrops. Heavy irrigation causes leaching of nutrients such as N, K, Ca, Mg, S, Zn etc. from the effective root-zone. Moreover, due to presence of impervious substratum within a depth of 30-100 cm from the soil surface, the heavy irrigation, heavy rainfall or intensive rainfall during the monsoon from the perched water table. As a result of water logging nutritional imbalance is created in the root zone. Thus growth is hampered and the biosphere is established in fabour of pests and diseases. Hence the efficient water management in the field, is a must for sugarcane cultivation in Bangladesh.

Key Word: Irrigation, Drainage, Water management, Control pest & disease

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a tropical crop which is grown predominately between 30 ^{0} N and 30 ^{0} S Latitude. Sub-tropical climate is also proved favourable for its cultivation. But in Bangladesh like many other countries of this region, crop production is often restricted by limited seasonal rainfall. The climate in Bangladesh is dominated by Indian Sub-continent monsoon system. Annual rainfall ranged from 1400 mm in the dry Rajshahi (North-West) region to over 5000 mm in the wet Sylhet (North-East) region. About 90% of the annual precipitation generally occurs during four months, from June to September. Therefore, drought of varying intensities occurs in almost all parts of Bangladesh during eight months from October to May. In November almost whole country receives rainfall less than 50 mm (Karim *et al.*, 1983).

This situation of heterogeneous precipitation emphasizes the need for irrigation in the dry periods for successful cultivation of sugarcane along with its intercrops such as vegetables, spices, pulses etc. Besides, Sugarcane, the perennial crop that remains in the field for nearly 12-15 months, needs drainage during June to September. Because The sugarcane requires large supplies of water to support its growth, but like most other crops can't tolerate wet feet" (Barnes, A.C. 1974; Pathmanathan, 1980).

Sugarcane is the 2nd cash crop in Bangladesh. It occupies about 0.16 million hectare of cultivable land with an average production of 42 t/ha (Ali, *et al.*, 1989). The average production of sugarcane in India is 66 t/ha, Phillipines is 64.3 t/ha and Australia is 73.5 t/ha (Rivero, 1992).

Among the various factors so far identified, which are responsible for low yield of sugarcane in Bangladesh, irrigation and drainage are the most important ones. Adopting almost all technologies developed in Bangladesh Sugarcane Research Institute, some growers produced even over 200 t/ha in their respective fields. Hence, it is obvious that there is a potentiality of high average yield of sugarcane in Bangladesh.

NEED FOR IRRIGATION

Soil water management refers to the activities concerned with keeping the required amount of soil moisture within the root zone of soil, that is best suited to a specific crop in order to achieve economic yield. Consequently irrigation water management includes the integrated process of intake, conveyance, regulation, distribution of irrigation water to crop lands in proper time and proper amount in order to achieve the best return.

From the Fig.1 and Fig.2 it is clear that irrigation is needed for successful production of sugarcane. Even though it is considered that 30-50% of total evapotranspiration (ET) may be obtained by capillary rise from ground water table under rain fed condition (Yang, 1979). Moreover, in recent times, it has been recognized that the productivity of land devoted to sugarcane may be increased by the use of irrigation to supplement rainfall, even when the latter alone is capable of contribution to profitable yields" (Barnes, 1974; Pathmanathan, 1980).

It has been estimated that ``approximately 1.25 to 1.5 acre inches of water passes through the plant in the production of each ton of millable cane. Using these figures, the water requirement for a crop of 40 tones per acre would be 50 to 60 inches i.e. 1270 to 1524 mm (King *et al.*, 1965).

The computed range of water consumption by sugarcane in India is from 1400 mm to 2500 mm i.e. 1400 mm in Bihar, 1700-1800 mm in Punjab and 2500 mm in Maharashtra. Recommended number of irrigations during pre-monsoon period is 8 to 10 in Punjab and 6 to 10 in West Bengal and during post monsoon 2 to 4 in Punjab and 2 to 3 in west Bengal. Bihar recommends a total of 5 to 8 irrigations during the crop cycle (Srivastava and Johari, 1979).

In accordance with the above references, we may decide that the ET or water consumption as computed for the selected area are appropriate. The ET for Ishurdi is about 1600 mm and for Mymensingh is about 1500 mm. In 1990-91 an experiment was conducted in Jamalpur district to see the effect of irrigation frequency on sugarcane intercropped with potato. Before monsoon ten irrigation (including 6 irrigations up to potato harvest) with 420 mm irrigation water (effective rainfall was 96 mm) applied at the pan ratio (IW/CPE) 0.9 produced highest yield (103 t/ha). The yield was 37% higher over that with 2 base irrigations- one as life irrigation and other for urea application (Siddique *et al.*, 1998). In 1994-95 crop year 8 irrigations before monsoon with 400 mm irrigation water (effective rainfall was 119 mm) produced highest yield (97 t/ha) of sugarcane intercropped with onion. The yield was 20% higher over that with 2 base irrigations (Siddeque *et al*., 2001). Agronomy and Soil Division of BSRI, Ishurdi, Pabna found 54% increase in yield of sugarcane by irrigation over rainfed condition (Anon., 1991).

NEED FOR DRAINAGE

Drainage may be defined as the means by which soil and sub-soil water is controlled in and removed from the root zone in relation to the health and vigour of the crop. Underground streams, springs, water drained from highland impermeable sub-soil, inadequate runoff, a high water table, heavy falls of rain in short periods, and irrigation can individually and collectively give rise to the need to assist natural drainage by carefully planed artificial means" (Barnes, 1974; Pathmanathan, 1980).

From the figures 1 & 2 it is evident that during monsoon (June-September) excess water may certainly cause water logging if sufficient drainage facilities (natural and artificial) are not available. `Estimates show that about one-third of the total acreage of sugarcane is planted on land where water remains stagnant for long period resulting in low productivity. Besides, with increasing pressure of land for food crops, sugarcane is being pushed to very marginal land often prone to seasonal inundation and unprecedented flood. Rather one of the major causes of poor yield of sugarcane in Bangladesh is the vulnerability of the existing varieties to water-logging (Rahman and Alam, 1985). During the last decades, communication has been improved and kacha roads are made without drainage facilities. Thus more and more areas has brought under water-logging condition. In the mean time, a few varieties have been identified suitable for water-logging and drought tolerant but they can not yield up to the desired mark.

Moreover floodplain areas occupy about 80% cultivable area of Bangladesh, which is a flat alluvial plain, cris-crossed by the mighty Padma, Megna, Jamuna and their innumerable tributaries and distributaries (Karim *et al.*, 1983). More than 90% of sugarcane growing areas are under alluvial soil. In most areas compact soil mass called ploughpan, has been developed. In some cases it is extended from 8 cm to 25 cm soil depth (Rahman, 1985). In many areas there is a hard impermeable clay layer or structure less substratum at such a depth that these can not be broken by deep tillage practices. In BSRI farm it is within 70-100 cm from soil surface.

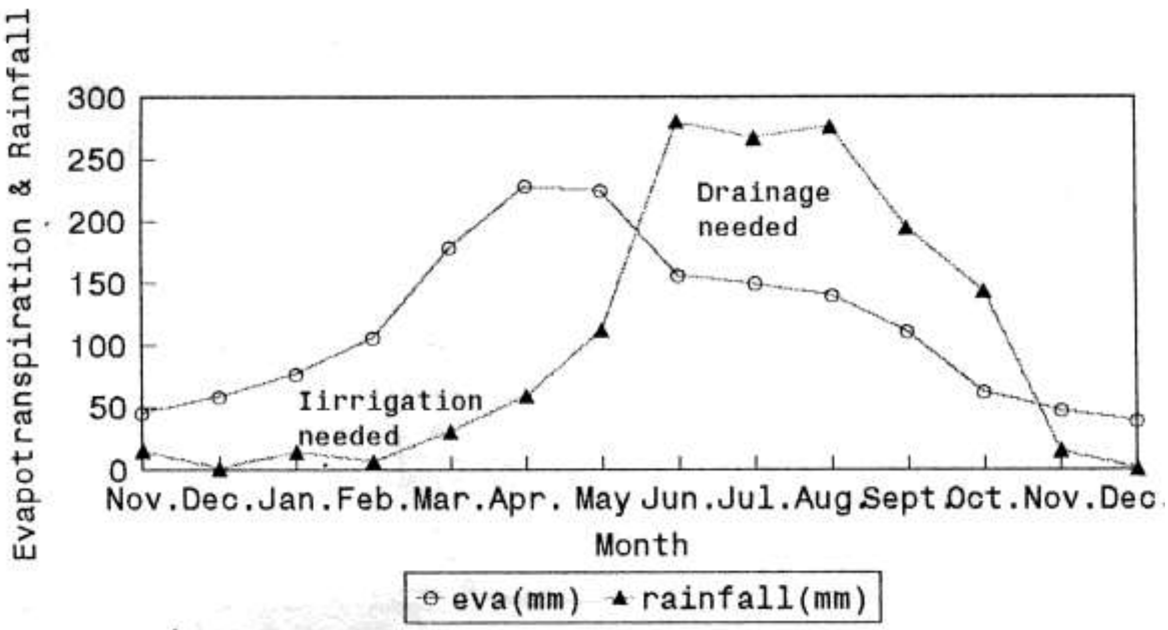

Fig.1 Monthly evapotranspiration of sugarcane and Rainfall at Ishurdi, Pabna.
Source:Crop coefficient of sugarcane and potential evapotranspiration data after Karim et al,1983 and Rainfall after Karim and Akhand,1982.

In the above situation the lower plots achieve a fluctuating perched water table during dry period (due to heavy irrigation from deep tube wells) and also during monsoon period. Hence most of the plots of the BSRI farm suffer from either periodical or prolonged water logging due to improper drainage facilities (Annual reports, SRTI, 1990-93). This is the position of maximum sugarcane growing areas of Bangladesh because of her undulated lands and minimum drainage facilities. Moreover, internal drainage conditions of most alluvial soils are poor.

A high water table in the monsoon may cause a reduction in oxygen and enhancement of carbon dioxide concentration in root zone. Oxygen deficiency can cause an increased resistance to water movement through roots, reduced root respiration and nutrient uptake, and formation of toxic products in the soil and plant. When such poor aeration condition persists for long time, especially during booming growth stage of sugarcane, death of cell and roots, retardation of vegetative growth and declining in yield are resulted (Yang, 1979; Pathmanathan, 1980). On the contrary Drainage enhances soil aeration, stimulates beneficial microbial activity, hastens the warming of soils, enhances tillage and cultivation and promotes the development of vigorous root systems of plants growing in the soil" (Humbert, 1968; Pathmanathan, 1980).

For the above reasons, serious nutrient deficiency symptoms of the sugarcane under water logged condition and healthy appearance of cane on well drained land are noticed in many parts of Bangladesh during post-monsoon period.

WATER MANAGEMENT TO CONTROL PEST

In Bangladesh the major sugarcane pests are borers (top shoot borer, early shoot borer, stem borer and root stalk borer); Soil insects (termites, white grub, nematode etc.) and suckers (Pyrilla, Scale insects etc.).

It is well known that when there is a soil moisture stress, incidence of shoot borer in sugarcane increases. When irrigations were given after 25% of available moisture was depleted at Anakapalle in India, the percentage of dead heart incidence in a normally manure crop was noted to be 16.46 as against 31.09 when irrigations were given after 75% of available moisture was depleted. Crops in water logged fields are found susceptible to top shoot borer (Lakshmikantham, 1983).

Proper irrigation and drainage have been found to be useful in suppressing pests like borers (shoot borer, inter-node borer & stalk borer), sucking pests (scale insects, mealy bugs and white flies), soil insects (white grubs) etc. But increased soil moisture level (heavy and excess irrigations) and water logged conditions are found to favor some species of borers (top borer) and sucking pests like white flies (Easwaramoorthy and Jayanthi, 1986).

Extensive research in light of water management as a tool of pest control has not been undertaken. However Entomology Division of Bangladesh Sugarcane Research Institute has recommended that rootstalk borer (root borer), termites (white ants) and white grubs may successfully be controlled by flood irrigation (Anon., 1980). In possible cases, severely infested fields of root borer should be sub-merged with water for few days (Anon., 1993).

It has been observed that soil insect pests like white grub, termites, and nematodes multiply abundantly during dry periods in sandy-to-sandy loam soils of sugarcane belt. In irrigated conditions their flourishment is reduced to a great extent. Rather the timely application of granular pesticides becomes ensured and their performance increases.

WATER MANAGEMENT TO CONTROL DISEASES

One of the most important causes of low yield of sugarcane in Bangladesh is due to diseases specially the red rot. This disease within a short time in the Quarantine station has affected resistant varieties so far been imported from abroad. At best some passed Q. station to main station of sugarcane research institute. Among the other diseases, wilt may come in epidemic form.

Poor drainage and excess moisture in heavier soils contribute to the development of red rot disease in infected seed pieces and plants" (Barnes, 1974). 'In two seasons characterized by severe drought in a district in India incidence of wilt occurred in an epidemic form. This was the experience in Mauritious also. Canes grown in fields subjected to water logging are reported to be susceptible to red rot' (Lakshmikanthan, 1983).

Extensive researches have not been taken regarding the effect of water logging on the propagation of diseases. But it is identified that diseases like red rot and wilt cause major damage to the standing cane of BSRI farm due to water-logging during rainy season from long since (Annual Reports, SRTI, 1990-93). Incidence of red rot is also observed in sugar mills area in water-logged condition.

In the year 1985-86 seeds infected by red rot were planted in three locations (Thana of Rajshashi sugar mills area) as registered seed plot. Due to severe crisis of seed due to flood those were planted. After harvesting, the sugarcanes of the seed plots in two locations were found damaged about 50% but in the remaining plot sugarcane did not show any symptom of red rot incidence. There was optimum yield in that plot which was well drained by deep canal on two sides. Rather the soil type was sandy loam whereas the other two plots had clay loam soil. The matter clearly indicates that well drained soil is one of the best solutions to control red rot though further investigation is needed.

NEED FOR IRRIGATION WATER MANAGEMENT

Sometimes it is reported that irrigation has no effect on cane yield when compared with adjacent rain fed plots. Sometimes the observations are made in the experimental plots also.

In 1981-82 crop year Agronomy Division of BSRI conducted two experiments to find the effect of irrigation. In one experiment there was no significant yield deviation of sugarcane in irrigated plots over non-irrigated ones. Soil moisture depletion in the non-irrigated plots was 40% of available moisture. After investigation it was found that a continuous water supply occurred from the main canal to the experimental plots through sub-soil. The other experiment (Anon., 1983) produced a bit lower yields in irrigated plot than in non-irrigated plot (other variables remaining same). That was due to moisture supply from adjacent irrigated plots. In both the experiments the impermeable substratum below the soil was the barrier to achieve the effect of irrigation.

In 1989-90, BSRI (Anon., 1991) had two experiments in the same locality. Experiments were conducted both in irrigated and rain fed conditions. In one experiment, irrigation had significant effect but in the other, irrigation had no effect. On the contrary irrigation lowered the recovery of sugar significantly. However the authors pointed out that soil erosion, uprooting of newly planted cane settlings and wash out of basal fertilizers due to flood irrigation in coarse textured soil of experimental plots were the causes of this.

When no effect of irrigation is found, there exist one or more reasons behind, which are as follows:

(a) There is no drainage facility to remove excess irrigation water, applied unwisely.
(b) There is no need of irrigation water as there is moisture entry into the plot from outside or high water table.
(c) The irrigation is followed by heavy rainfall and the plot has no drainage facility.

In any way if nutrients like N, S, K, Ca, Mg, Zn etc. are washed out by irrigation water or rainfall through leaching or percolation (Dakshinamurti and reddy, 1975, Pinna and valdivia, 1977) and nutrient-loss by stagnation of water occurs, irrigation cannot give positive result. Even in some cases adverse effect is a must. Because Lakshmikanthan (1983) reported that application of excess water is not conducive to optimum yield. Sizable amount of dead canes are found at harvest and one of the important causes for this phenomenon appears to be excess water application and its stagnation especially in monsoon months. He agreed with Sir T. S. venkaraman that while sugarcane loves moving water, it cannot withstand wet feet'.

Rather excess irrigation water or intensive rainfall causes nutritional imbalance. During March-April when rainfall occurs with tremendous thunder, a considerable amount of nitrate (NO_3) is added to the soil. Rain fed sugarcane specially drought tolerant varieties, having deep and abundant root system utilize the natural nitrogen-nutrient many times more than irrigated sugarcane. On the other hand heavily irrigated sugarcane suffers from malnutrition (nutrients leached out of root zone) and rain fed sugarcane receives nutrients from applied fertilizers in the available form. Hence rain fed sugarcane produces better yield ultimately.

CONCLUSION

In Bangladesh supplemental irrigation is necessary for successful cultivation of sugarcane as well as the intercrops. Irrigated fields should be leveled with requisite grade to have benefit from surface irrigation. Identifying the area suffered from surface and sub-surface water logging (stagnation) feasibility study is required for planning drainage. Resistant varieties should be selected for the area prone to water logging and flood. For the sake of crop nutrition, crop control from pest & disease incidence, we must emphasize on water management i.e. justified irrigation and well planned drainage. For this, we must know when to irrigate, how much water to be applied, how much and how swift the excess water to be removed and what are the economic ways! To solve the problems the country needs experts, trained workers as well as farmers. We all are liable to solve the problems.

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QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF SOME AUTUMN SOWN PROMISING SUGARCANE VARIETIES

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ABSTRACT

The present study comprised of a field experiment with 11sugarcane promising varieties was conducted to compare their yield and quality in autumn season during 2004-05 & 2005-06. The experiment was laid out in randomized complete block design with 3 repeats having net plot size of 5 x 9.6 m^2. The data revealed that all the varieties gave significantly different yield from one another. The varieties S2002-US-637 and S2002-US-698 gave higher yields of 109 and 105.5 t/ha than that of test varieties CPF-243 and SPF-245 producing yields of 103 and 98 t/ha. So the maximum sugar recovery of 12.99% was recorded in S2002-US-698.

Keywords: Promising, sugarcane, yield, quality, higher, autumn.

INTRODUCTION

Sugarcane contributes substantially to Pakistan's economy. Sugarcane crop serves as a major raw material for production of white sugar and gur (concentrated form of sugarcane juice). Their share in value added of agriculture and GDP are 3.4% and 0.7%, respectively. For 2005-2006, the area under sugarcane crop was targeted at 955 thousand hectares as against 966 thousand hectares of last year. However, sugarcane has been sown in the area of 907 thousand hectares, – 5% below the target and 6.1% less than last year. Sugarcane production for the year 2005-06 was estimated at 44.3 million tones against the 47.2 million tones last year. Thus sugarcane production is estimated to be lower by 6.2% over the last year with an average yield of 48.85 t/ha. Factors responsible for decline in sugarcane production include late harvesting of wheat, frost affecting the crop and farmer's shifting to other competing crops (Anonymous, 2006). The major cause of low yield of sugarcane is the growing of old varieties loosing yield potential due to disease infestation. Efforts made during past decades to increase cane production were mainly introduction of high yielding varieties and adoption of improved crop production techniques (Gill, 1995).

Sugarcane is an important cash crop and plays a remarkable role in the economic uplift of the growers especially in Central Punjab (Pakistan) and country as a whole as well. But unfortunately, yield harvested by the farmers is very low showing a wide yield gap between realized potential and harvested on among different cane varieties. Although there are a number of cane varieties having reasonable yield potential but in spite of this, the yield uplift is very small. (Ali *et al.* 2002) Sarwar *et al*., (2003) found that the standard varieties like BF-162 and SPF-234 are susceptible to red rot and smut diseases in Central and Northern Punjab. Chattha *et al.,* (2002) stressed to study the new genotypes before final recommendations. Keeping in view, the present study was conducted to achieve the following objectives:

1. To evaluate the best suitable and adaptive genotype of sugarcane for commercial cultivation.
2. To compare the cane and sugar yield potential of some new sugarcane genotypes developed through fuzz at Sugarcane Research Institute, Faisalabad.
3. To develop high yielding potential varieties of sugarcane.

MATERIALS AND METHODS

A field experiment with 11sugarcane promising varieties was conducted at Sugarcane Research Institute, Faisalabad to compare their yield and quality in autumn season during 2005-06. The experiment was laid out in R.C.B.D. with three repeats at 120 cm apart trenches having net plot size of 5 x 9.6 m^2. The experiment was sown in the first week of September. The sugarcane seed rate of 75,000 DBS/ha was used for crop sowing. The crop was fertilized at 168-112-112 kg NPK ha^{-1}, as urea, single super phosphate and sulphate of potash for N, P, and K; respectively. Whole of the phosphtic and potassic fertilizer were broadcasted in the trenches before the placement of seed setts. Nitrogenous fertilizer was applied in three equal splits viz. 45 days after sowing (at the completion of emergence), 90 days after sowing (at the completion of tillering) and in mid February during 2005. Thereafter, the crop was earthed up in the mid March 2005. First irrigation was applied immediately after sowing and then irrigation interval was maintained according to water requirement of the crop after the completion of germination. Weeds were controlled chemically by the application of Gesapax Combi at 3.75 kg/ha and interculture. All other agronomic practices such as seed bed preparations, planting pattern (120 cm apart trenches) and plant protection measures were kept normal. The crop was harvested at the time of its maturity. The data on germination (%), tillers / plant, thousand canes/ ha, sugar recovery (%) and cane yield (t/ha) were recorded and analyzed using standard procedures and techniques and subjected to statistical analysis through MSTAT-C statistical computer programme (MSTAT-C, Manual, 1991).

RESULTS & DISCUSSION

Germination (%)

The data presented in table revealed that the germination (%) of all varieties was significantly affected when sown in autumn season. The results given in table showed that CPF-243 gave the maximum germination (54%) which was statistically at par with both SPF-245 and S 2002-US-637 having germination of 53%. This might be due to the variability in genetic make up of different genotypes. Ahmad *et al.* (2003) and Zafar *et al.,* (2003) also reported variable behaviour of different genotypes for germination. The poor germination shown by some genotypes could also be due to low temperature during autumn season (Rafiq *et al.,* 2007)

Number of tillers per plant

The data presented in table revealed that the tillering behaviour of all varieties was significantly affected when sown in autumn season. However maximum number of tillers / plant (3.60) were produced by S2002-US-637 which was statistically at par with CPF-243 producing number of tillers / plant of 3.59. The variety S2002-US-504 produced minimum number of tillers / plant of 1.57. This may be due to reason that tillering is largely a verietal character and is partly affected by cultural practices as reported by Rashid *et al.,* (2001) and Rehman *et al.,* (2007).

Number of canes per hectare

Number of canes is an important yield contributing parameter, which directly contribute to the final cane yield (Rafiq *et al.*, 2007). It is also evident from table that CPF-243 produced maximum thousand canes / ha (130) which was followed by SPF-245, SPF-241 and S2002-US- 698 producing 122.5, 120.5 and 119.5 thousand canes / ha, respectively. The minimum thousand canes / ha (99.5) were produced by S2002-US-504. Similar results were also reported by Zafar *et al*. (2003) and Rafiq *et al.* (2007).

Stripped cane yield (t/ ha)

The final cane yield of a sugarcane variety is a function of the well co-ordinated inters play of its genetic constitution as well as environment to which it is grown (Rafiq *et al.,* 2007). The data given in table revealed that S2002-US-637 gave maximum stripped cane yield of 109 t/ha which was statistically at par with S2002-US-698 giving cane yield of 105.5 t/ha as against test varieties CPF-243 and SPF-245 producing cane yield of 103 and 98 t/ha respectively. Similar results were also reported by Chattha *et al*. (2004) and Bashir *et al.,* (2005).

Sugar Recovery (%)

Sugar recovery 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). The sugar recovery of different sugarcane varieties was significantly affected. Table revealed that maximum sugar recovery (12.99%) was recorded in S2002-US-698 which was followed by S2002-US-504 and CPF-243 having sugar recovery of 12.74% and 12.56% respectively. This might be due to the genotypes of the parent material of these varieties (*Naich et al*., 2006). These results are in agreement with the findings of Saxena *et al.,* (1996) and Block *et al.,* (2004) who studied a number of sugarcane varieties and found different levels of sugar recovery %.

Conclusions

The varieties S2002-US-637 and S2002-US-698 should be promoted and other good yielding varieties having highest sugar recovery (%) must also be planted during the both autumn and spring season.

Table Yield; yield components and quality comparison of promising varieties of autumn sown sugarcane

(Average of two years data)

Sr. No.	Varieties	Germination %age	Tillers/ plant	'000' cane/ha	Stripped Cane yield t ha^{-1}	Sugar recovery %age
1.	S2002-US-698	42 cd	2.15 cd	119.5 bc	105.50 ab	12.99
2.	S2002-US-772	43 c	1.59 g	107.5 e	102.60 bc	10.49
3.	S2002-US-640	42 cd	2.05 de	101.5 f	90.00 f	12.11
4.	S2002-US-637	53 a	3.60 a	118.5 c	109.00 a	11.98
5.	S2002-US-573	48 b	1.88 ef	106.5 e	97.00 d	11.22
6.	S2002-US-560	42 cd	2.93 b	100.0 f	96.00 de	12.19
7.	S2002-US-504	42 cd	1.57 g	99.5 f	92.00 ef	12.74
8.	CPF-243	54 a	3.59 a	130.0 a	103.00 b	1254
9.	S98-SP-108	38 d	1.65 fg	111.0 d	102.50 bc	11.44
10	SPF-241	52 ab	2.32 c	120.5 bc	104.00 b	11.22
11.	SPF-245	53 a	2.15 cd	122.5 b	98.00 cd	10.53
	LSD at 5%	4.225	0.2348	3.439	4.741	-

Values followed by the same letter in the same column do not differ significantly at 0.05 probability.

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IN VITRO SELECTION OF SOMACLONES OF SUGARCANE UNDER DROUGHT STRESS CONDITION AND THEIR EVALUATION IN FIELD CONDITION

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ABSTRACT

In vitro selection was conducted to select for drought tolerant somaclones derived from sugarcane variety Isd 28. Unexpanded spindle leaf sheath was used as explants. MS medium supplemented with 2,4-D (3 mg l^{-1}) and coconut water (10 %) or BAP (2 mg l^{-1}) with Kn (1 mg l^{-1}), or NAA (5 mg l^{-1}) was used for callus induction, shoot regeneration and root formation, respectively. To screen for drought tolerant sugarcane somaclones, *in vitro* medium was stressed with different concentrations of PEG at 5, 7.5 and 10 % along with control (without PEG). Callus growth was vigorous at control as well as at lower concentration of PEG. However, the frequency of callus induction decreased with the increase of PEG concentration. The same for shoot and root production. Most calli became reddish black and died within 40-45 d on medium supplemented with 10 % PEG. Shoot and root formation was observed on medium supplemented with 5 % PEG.

Twenty somaclones were studied for drought tolerance. In correlation to drought tolerance in somaclones and parents, biochemical parameters such as total chlorophyll, chlorophyll a, chlorophyll b, ratio of chlorophyll a:b and CSI showed positive correlation but morphological parameters such as leaf number and leaf area showed negative correlation to drought tolerance in somaclones and parents. Tolerance level was measured based on leaf greenness and the biochemical and morphological data. A close association between biochemical and morphological parameters was observed for drought tolerant reaction. Less variation on Brix (%) was observed among somaclones and their parents. Somaclones Isd 28Sc-3, Isd 28Sc-8,Isd 28Sc-11, Isd 28Sc-17 and Isd 28Sc-18 were observed as highly tolerant somaclones to drought.

INTRODUCTION

Abiotic stresses includes drought, salinity, extreme temperature, chemical toxicity and oxidative stress are serious threats to agriculture, and natural states of environment (Wang *et al.,* 2003). Abiotic stresses significantly increased negative effects on both quantity and quality of crop production and limited plant growth and impaired productivity by limited plant growth (Moshin, 2004). Drought is one of the principal environmental stresses limiting crop productivity around the world (Watanabe, 2002).

Sugarcane cultivars slowly deteriorate over a period of time due to vulnerability to pests, diseases, and especially soil moisture stress during formative phase (Rao, 2003). Among environmental stresses, drought stress is one of the major problems in causing crop yield reduction. It hampers the biochemical process of cane plant, which affects growth and sugar synthesis. However, degree of damage varies with extent of drought and period it prolongs (Malik, 1992). In these circumstances, irrigation may not be considered a reasonable means of boosting up sugarcane yield (Miah, *et al*., 1993). Sugarcane cultivation under drought stress received no attention in the past, but due to increased demand for sugar and gur, it has now become imperative to explore production potentiality of sugarcane.

Since the conventional plant breeding methods are slow to create substantial improvement over drought stress, an alternative approach of regenerating plants from potential cell mutant through plant cell culture has received increased attention. Sugarcane varieties those are cultivated under drought stress do not have proven capabilities to grow under extreme stress condition (Miah, *et al*., 1993).

It is known that somaclonal variation can bring about desirable agronomic changes in the progeny and increased sugar yield in sugarcane. Variation in differentiation ability in *Saccharum spp*. has been reported elsewhere (Liu *et al.*, 1972; Banshali and kishan, 1982). Considering enrichment of sugarcane productivity under drought stress and meeting with ever-increasing demand of sugar and 'gur', regeneration of drought tolerant varieties is very important. To achieve, this goal it is necessary to understand basic phenomenon of stress. Therefore, the present investigation was carried out to establish i*n vitro* regeneration under induced drought stress condition, and e*x vitro* evaluation of regenerated somaclones for drought tolerance.

MATERIALS AND METHODS

The experiment was conducted at the Biotechnology Laboratory and Experimental Farm of BSRI, Ishurdi during the cropping season 2006-2007. Unexpanded young leaf sheaths from 3-4 month- old- field sugarcane of variety Isd 28 were collected and cultured aseptically on MS (Murashige and Skoog, 1962) medium supplemented growth regulators.

For the induction of callus, regeneration of shoots, or roots, MS medium was supplemented with 2,4-D (3 mg l^{-1}), or BAP (2 mg l^{-1}) with Kn (1 mg l^{-1}), or NAA (5 mg l^{-1}) respectively (Islam, 2006). To screen for drought stress tolerant somaclones, *in vitro* medium was stressed with different concentrations of polyethylene glycol (PEG) at 5.0, 7.5 and 10.0 % along with a check (without PEG). Besides, agar (0.6 %) was added to make the medium semi-solid. At the first step callus was induced on MS medium supplemented with 2,4-D (3 mg l^{-1}), 10% coconut water and different concentrations of PEG. Then calli were transferred to MS medium supplemented with BAP 2 mg l^{-1} and Kinetin 1 mg l^{-1}. Regenerated shoots were transferred to MS medium supplemented with 5 mg l^{-1} NAA for rooting. PEG was also added to both shooting and rooting media.

Rooted plants were washed using tap water to remove medium adhered with roots and planted in earthen pots containing sterilized soils and kept under polyethylene shed with higher moisture (90%) for 2-3 weeks to harden plants for successful establishment of transplanted somaclones in the field.

After hardening, plants were transplanted into the field of BSRI Experimental Farm line spacing of 1m and pit spacing of 50 cm. Plants were transplanted in pits containing soils: pressmud at 3:2 ratio. The soils-pressmud mixture of each pit was fertilized at the rate of 4, 3 and 3 g of Urea, TSP and MP respectively. Full amount of TSP, MP and 2.0 g urea were applied in each pit as basal dose at transplanting time and the rest 2.0 g of urea was applied as top dressing at 45d after transplanting. Intercultural operations including irrigation, weeding and plant protection measures were done as usual.

Data collection from *in vitro* drought stress stage:

To develop drought tolerant sugarcane variety, data were collected from *in vitro* drought stress stage on the following parameters: per cent of explants induced callus; degree of callus induction; morphology of callus; number of shoots per callus; number of roots per shoot. In case of *ex vitro* drought tolerance studies, data were collected under field condition on the following parameters: chlorophyll a; chlorophyll b; total chlorophyll; chlorophyll a: b ratio; chlorophyll stability index (CSI); leaf number; leaf area; visual tolerance rating; Brix (%)

Amount of chlorophyll a, chlorophyll b and total chlorophyll were calculated on a fresh weight basis employing following formulae (Mahadevan and Sridhar, 1982):

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{20.2A645 + 8.02A663}{a \times 1000 \times w} \times v$$

$$\text{Chlorophyll a (mg g}^{-1}\text{)} = \frac{12.7A663 - 2.69A645}{a \times 1000 \times w} \times v$$

$$\text{Chlorophyll b (mg g}^{-1}\text{)} = \frac{22.9A645 - 4.68A663}{a \times 1000 \times w} \times v$$

Where,

A = Optical density in each sample

a =Length of light path in the cell (usually 1cm)
v =Volume of extract in ml and
w=Fresh weight of sample in 'g'

Chlorophyll stability index (CSI) is a good parameter for drought tolerance measurement in sugarcane. CSI was estimated following the method of Kilen and Andrew (1969). Number of green leaves of all canes from each pit was counted for this purpose. Ten leaves were randomly collected from each pit for this purpose. The leaf area (cm^2) was measured by using leaf area meter (Model- CI-202 Area meter, USA). Brix readings were taken and recorded with the help of Hand Refractometer from randomly selected three canes of each pit. The Data collected were statistically analyzed following completely randomized design (CRD) using computer software MSTAT-C. The analysis of variance was done and means were compared by Duncan's New Multiple Range Test (DNMRT) at 5% level of probability for discussion of results.

RESULTS AND DISCUSSION

In the present investigation, techniques of *in vitro* callus induction, shoot regeneration and root formation of variety Isd 28 under control and PEG induced drought stress conditions, hardening of regenerated plants and their establishment in soil after transplanting, and *ex vitro* drought tolerance studies have carefully been described and discussed under following headings and sub-headings.

Part I. *In vitro* Regeneration under PEG Induced Drought Stress Condition

Induction of callus under *in vitro* PEG induced drought stress condition:

Results of callus induction are presented in the Figure 1and Tables 1-2. Calli were found to be initiated from cut edges of explants, and callus mass was produced within 3-4 weeks of culture. The callogenic response of explants declined when PEG concentration was increased. The highest percentage (95%) of explants responded to callus induction in control treatment (without PEG). The lowest percentage (65%) of explants responded to callus formation when medium was supplemented with 10 % PEG. Taghian (2002) used three concentrations of PEG (50, 75, 100 g l^{-1}) of PEG and reported that callus induction and its differentiation decreased in the presence of PEG in medium. The formation of callus decreased from 88.33 % (in non-stressed medium) to 15.55 % when 50 g l^{-1} PEG was added to medium. El-Aref (2002) also observed that callus induction and its differentiation decreased with PEG level increased from 2.5 to 10 %. At 10 %PEG level, the most of cultured calli (99%) turned brown and failed to regenerate.

Table 1: *In vitro* effects of PEG % on callus induction in variety Isd 28

Treatments	Number of Explants	Response of explants for callus induction (%)
		Variety: Isd 28
Control	10	95
MS + 5 % PEG	10	90
MS + 7.5 % PEG	10	80
MS + 10 % PEG	10	60
Mean	-	81.3

Whitish colour vigorous callus formed where no PEG was used in the medium. Most of callus formed became reddish in colour in medium where PEG was added. With the increase of PEG level callus became reddish black in colour. The callus became black and died after 40-45 d of incubation at the highest level (10 %) of PEG (Table 2).

Table 2: *In vitro* effects of PEG on morphology of callus formed in variety Isd 28.

Treatments	Variety: Isd 28
Control	Vigorous and whitish (Fig. 1a)
MS + 5 % PEG	Vigorous and reddish (Fig. 1b)
MS + 7.5 % PEG	Vigorous and reddish (Fig. 1c)
MS + 10 % PEG	Poor, reddish black and dead (Fig. 1d)

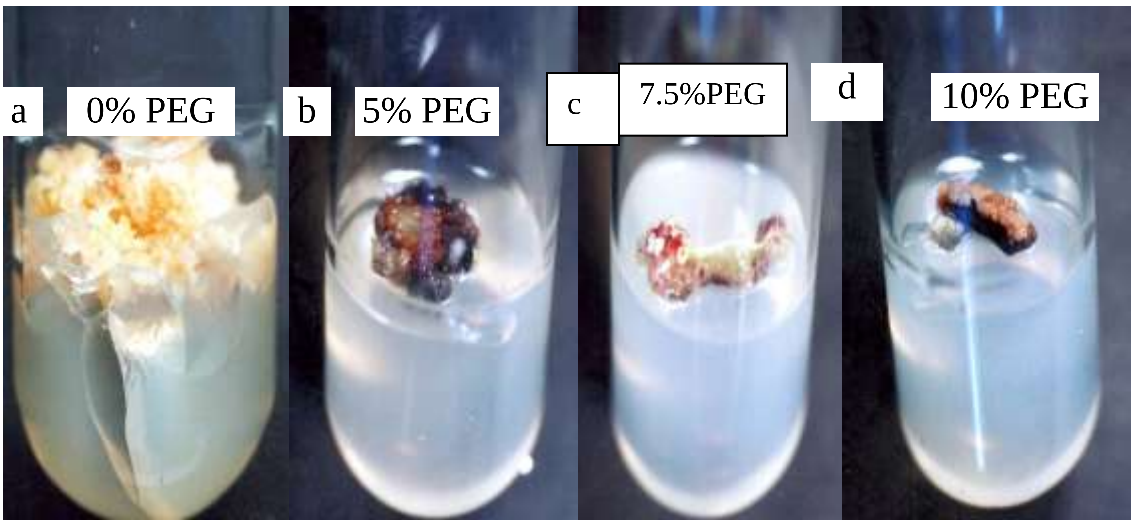

Figure-1 Effects of PEG concentrations (0, 5, 7.5, 10 %) on callus induction in variety Isd 28 (a-d)

Regeneration of shoots under PEG induced drought stress:

Results on shoot regeneration and multiplication are summarized in Figure 2 and Tables 3-4. Higher number of shoots and usable shoots per culture were obtained where no PEG was used (Table 4). Similar results were reported by El-Aref, 2002. He stated that the regeneration of shoots decreased from 305.3 shoots per 100 calli in control medium to 14.5 shoots per 100 calli under 7.5 % PEG level. El-Tayeb and Hssanein (2000) observed that fresh and dry shoots of all tested lines were markedly decreased as level of PEG was increased.

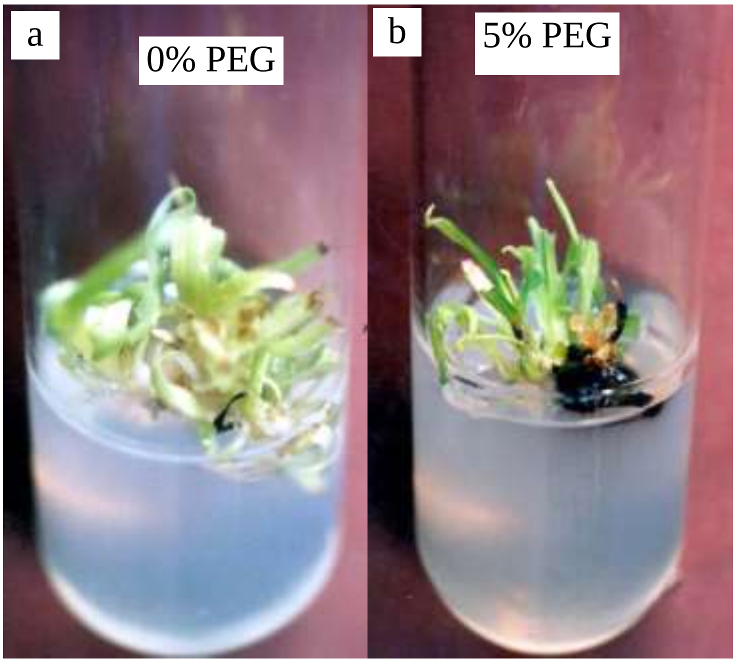

Figure-2 (a-b) Effects of PEG levels (0 and 5 %) on shoot regeneration in variety Isd 28

Root formation in shoots under PEG induced drought stress:

Results on root formation are shown in Figure 3 and Tables 3-4. The highest number of roots per shoot was observed where no PEG was used (Table 4). *In vitro* healthy and well-established rooted plantlets were transplanted to earthen pots containing soils-pressmud mixture, and kept under hardening shed for 2-3 weeks (Fig 4).

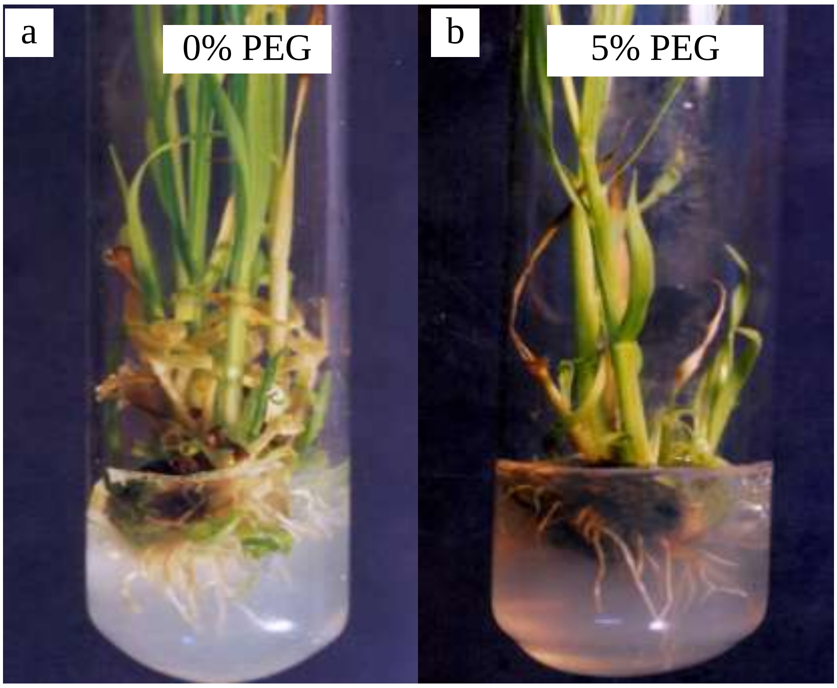

Figure-3 **Effects of PEG levels (0 and 5 %) on root formation in variety Isd 28 (a-b)**

Table-3 **Effects of PEG on shoot and root production under *in vitro* condition in variety Isd 28**

Varieties	Total shoots number/culture	Usable shoots number/culture	Roots number/shoot
Isd 28	11.15	6.80	13.40

Table-4 **Combined effects of PEG levels and variety on shoot and root production under *in vitro* condition**

PEG × Varieties		Total shoots number/culture	Usable shoots number/culture	Roots number/shoot
PEG 0 %	Isd 28	13.00a	13.00a	14.00a
PEG 5 %	Isd 28	9.30c	7.50c	12.80b

* Figures in the columns followed by different letters are significantly different by DNMR test at p= 0.05.

Hardening of plantlets

Rooted plantlets were hardened for 2-3 weeks under locally made low cost polyethylene shed. After hardening, plantlets were directly transplanted to pits having soil-pressmud mixture in the field for drought tolerance studies.

Figure-4 Hardening of plantlets in locally made low cost polythene shade (a) hardened plantlets in small earthen pots; (b) ready for transplantation to pits in the field.

Part-II *Ex vitro* Evaluation of *In vitro* Regenerated Plants for Drought Tolerance

Chlorophyll a, chlorophyll b, total chlorophyll and chlorophyll a:b ratio:

Biochemical parameters such as chlorophyll a, chlorophyll b, total chlorophyll content and chlorophyll a:b ratio of different somaclones have been presented in the Table 5. Chlorophyll a, and total chlorophyll content were found significantly higher in somaclones Isd 28Sc-3 and Isd 28Sc-11. Chlorophyll b content was significantly higher in Isd 28Sc-3 followed by Isd 28Sc-11. In addition, chlorophyll a, chlorophyll b, and total chlorophyll content of all but 28Sc-13 somaclones were recorded higher than their parent variety Isd 28. The chlorophyll a:b ratio was found significantly higher in Isd 28Sc-14. Comparatively higher chlorophyll a, chlorophyll b, and total chlorophyll content, and lower chlorophyll a:b ratio was observed in PEG induced drought tolerant somaclones. Kamat *et al.*, (2004) reported that chlorophyll a and chlorophyll b content are important characters for screening sugarcane varieties under rainfed situation due to their positive and significant correlation. However, Daneshmand *et al.*, (2007) reported that drought stress increased chlorophyll a:b ratio because of greater decrease in chlorophyll b content.

Chlorophyll Stability Index (CSI):

Chlorophyll stability index of all somaclones is presented in Table 6. Comparing to Isd 28, which had the lowest CSI, Isd 28Sc-3 had significantly the highest CSI. Somaclones Isd 28Sc-11 and Isd 28Sc-17 had statistically identical CSI values. All other somaclones recorded higher CSI values than Isd 28 (Table 6). Kaloyereas (1958) described a CSI method for determining relative drought resistance, which is the difference between cholorometric reading of chlorophyll extract from heated and unheated leaf samples. In general, the higher the CSI, the higher the drought tolerance and lower the CSI, lower the drought tolerance. Mohan *et al*., (2000) also reported that a high CSI value was a indication of less drought effect on the chlorophyll content and how well chlorophyll could perform helped plants withstand stress through better availability of chlorophyll. This leads to increase photosynthetic rate, more dry matter production, and higher productivity. Fanous (1967) also reported a close association between CSI and drought resistance in pearl millet. Higher positive correlation was also found between the CSI and field drought resistance in pine and rice (Kaloyereas, 1958; Murty and Majumder, 1962).

Number of green leaves and leaf area:

The highest number of green leaf was recorded in parent variety Isd 28 followed by somaclone Isd 28Sc-15 (Table 7). The lowest number of green leaf was recorded in somaclones Isd 28Sc-3 and Isd 28Sc-8. Green leaf number of all somaclones was lower than Isd 28. Malik (1992) reported that number and size of green leaf were reduced in drought resistant varieties. Smith *et al.*, (2005) studied effects of water stress on canopy development in two sugarcane cultivars viz N 22 and NCo 376 under rain shelter facility. They reported a simultaneous reduction in leaf appearance rate and increase in leaf senescence rate, resulting in the reduction of green leaf number in both cultivars.

On the other hand, the higher leaf area was recorded in drought intolerant somaclones and their parent variety compared to drought tolerant somaclones. The highest leaf area was observed in parent variety Isd 28 and somaclone Isd 28Sc-15 followed by Isd 28Sc-6. The lowest leaf area was observed in somaclone Isd 28Sc-3. The variation in leaf area might occur due to the variation in number of leaves and expansion of leaf. Sinclair *et al*. (2004) reported that leaf area development is critical in the establishment of a full canopy to maximize interception of solar radiation and achieve higher crop productivity. Vasantha *et al., (*2005) reported that drought stress significantly reduced individual leaf area, leaf number, leaf area index and tiller population.

Tolerance rating:

Comparing to the parent variety Isd 28, somaclones Isd 28Sc-3, Isd 28Sc-8, Isd 28Sc-11, Isd 28Sc-17 and Isd 28Sc-18 were highly tolerant to drought stress having tolerance rating scale of 1; somaclones Isd 28Sc-1, Isd 28Sc-2, Isd 28Sc-4, Isd 28Sc-5, Isd 28Sc-6, Isd 28Sc-7, Isd 28Sc-9, Isd 28Sc-10, Isd 28Sc-12, Isd 28Sc-13, Isd 28Sc-14, Isd 28Sc-15, Isd 28Sc-16 and Isd 28Sc-19 showed a tolerance rating scale of 2. In the present investigation the parent variety Isd 28 showed a moderately tolerant reaction having a tolerance rating scale of 3 (Table 7).

Brix %:

The highest Brix was recorded in somaclones Isd 28Sc-15 and Isd 28Sc-17. The lowest Brix was observed in somaclones Isd 28Sc-5 and Isd 28Sc-8. Brix reading of all somaclones were found to be higher than their parent variety Isd 28 except somaclones Isd 28Sc-5 and Isd 28Sc-8 (Table 8). Similarly, Hossain *et al*. (2005) reported higher Brix reading in all tissue culture derived clones compared to donor variety. They also reported that higher Brix readings were associated with tolerance level and increased as tolerance level increased.

Table-5 Variation in Biochemical parameters in somaclones of variety Isd 28 regenerated from PEG induced drought tolerant callus.

Parent variety	Somaclones	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Total chlorophyll (mg g^{-1})	Chlorophyll a:b ratio
Isd 28	-	0.5567j *	0.1603k	0.717m	3.473ab
	Isd 28Sc-1	1.028g	o.3153h	1.343j	3.263bcd
	Isd 28Sc-2	1.189d	0.4020d	1.591de	2.960fgh
	Isd 28Sc-3	1.384a	0.4800a	1.864a	2.883gh

	Isd 28Sc-4	1.242bc	0.4327bc	1.675bc	2.890gh
	Isd 28Sc-5	1.178d	0.4110cd	1.589de	2.867h
	Isd 28Sc-6	1.075fg	0.3517fg	1.427hi	3.063cdefgh
	Isd 28Sc-7	1.149de	0.3583fg	1.507g	3.207cdef
	Isd 28Sc-8	1.054g	0.3670fg	1.421hi	2.877h
	Isd 28Sc-9	1.052g	0.3480fg	1.400ij	3.023defgh
	Isd 28Sc-10	1.148de	0.3663fg	1.514fg	3.133cdefg
	Isd 28Sc-11	1.392a	0.4523b	1.844a	3.077cdefgh
	Isd 28Sc-12	1.121ef	0.3460g	1.467gh	3.247bcd
	Isd 28Sc-13	1.279b	0.3673fg	1.646cd	3.483ab
	Isd 28Sc-14	0.7803i	0.2187j	.9990l	3.567a
	Isd 28Sc-15	0.9077h	0.2817i	1.189k	3.227cde
	Isd 28Sc-16	1.279b	0..4420b	1.721b	2.893gh
	Isd 28Sc-17	1.199cd	0.3753ef	1.574ef	3.197cdef
	Isd 28Sc-18	1.170de	0.3533fg	1.523fg	3.313bc
	Isd 28Sc-19	1.281b	0.3973de	1.678bc	3.227cde
	Isd 28Sc-20	0.8660h	0.2907i	1.157k	2.977efgh

Figures in the columns followed by different letters are significantly different by DNMR test at p= 0.05.

Table-6 Variation in Chlorophyll Stability Index in somaclones of variety Isd 28 regenerated from PEG induced drought tolerant callus.

Parent variety	Somaclones	CSI
Isd 28	-	1.007j *
	Isd 28Sc-1	2.577h
	Isd 28Sc-2	3.857de
	Isd 28Sc-3	5.030a
	Isd 28Sc-4	4.320bc
	Isd 28Sc-5	2.393h
	Isd 28Sc-6	4.390b
	Isd 28Sc-7	3.467ef
	Isd 28Sc-8	2.393h
	Isd 28Sc-9	2.593h
	Isd 28Sc-10	3.407f
	Isd 28Sc-11	4.610ab
	Isd 28Sc-12	3.337f
	Isd 28Sc-13	1.253ij
	Isd 28Sc-14	1.050ij
	Isd 28Sc-15	2.820gh
	Isd 28Sc-16	3.950cd
	Isd 28Sc-17	4.627b
	Isd 28Sc-18	4.223bcd
	Isd 28Sc-19	3.127fg
	Isd 28Sc-20	1.457i

Figures in the columns followed by different letters are significantly different by DNMR test at p= 0.05.

Table-7 Variation in morphological characters in somaclones of variety Isd 28 regenerated from PEG induced drought tolerant callus.

Parent variety	Somaclones	Number of leaf	Leaf area (cm^2 $plant^{-1}$)	Tolerance rating scale (1-5)**
Isd 28	-	15.00a *	5662.580a	3
	Isd 28Sc-1	12.33bcde	5259.143i	2
	Isd 28Sc-2	11.33de	5227.260j	2

	Isd 28Sc-3	10.67e	5021.567n	1
	Isd 28Sc-4	13.67abc	5569.330c	2
	Isd 28Sc-5	12.00bcde	5338.717h	2
	Isd 28Sc-6	13.67abc	5592.443b	2
	Isd 28Sc-7	13.33adcd	5538.110d	2
	Isd 28Sc-8	10.67e	5043.773m	1
	Isd 28Sc-9	12.67bcde	5349.073gh	2
	Isd 28Sc-10	12.00bcde	5092.857l	2
	Isd 28Sc-11	11.33de	5106.343l	1
	Isd 28Sc-12	13.67abc	5544.057d	2
	Isd 28Sc-13	13.00abcd	5495.677e	2
	Isd 28Sc-14	13.33abcd	5258.123i	2
	Isd 28Sc-15	14.00ab	5652.640a	2
	Isd 28Sc-16	13.67abc	5542.427d	2
	Isd 28Sc-17	12.67bcde	5251.460i	1
	Isd 28Sc-18	12.33bcde	5184.373k	1
	Isd 28Sc-19	13.00abcd	5454.613f	2
	Isd 28Sc-20	13.33abcd	5366.597g	2

* Figures in the columns followed by different letters are significantly different by DNMR test at p= 0.05.

** Tolerance rating scale (1-5) is based on greenness of plants and other data collected, where 1=highly tolerant, 2=tolerant, 3=moderately tolerant, 4=intolerant and 5=highly intolerant.

Table-8 Variation in Brix % in somaclones of variety Isd 28 regenerated from PEG induced drought tolerant callus.

Parent variety	Somaclones	Brix %
Isd 28	-	13.77i *
	Isd 28Sc-1	20.20ab
	Isd 28Sc-2	15.17ghi
	Isd 28Sc-3	17.83cdef
	Isd 28Sc-4	15.17ghi
	Isd 28Sc-5	10.77j
	Isd 28Sc-6	18.10bcdef
	Isd 28Sc-7	18.13bcdef
	Isd 28Sc-8	10.23j
	Isd 28Sc-9	19.07bcde
	Isd 28Sc-10	19.17bcde
	Isd 28Sc-11	16.53fgh
	Isd 28Sc-12	17.53def
	Isd 28Sc-13	19.73abcd
	Isd 28Sc-14	19.87abc
	Isd 28Sc-15	21.47a
	Isd 28Sc-16	16.53fgh
	Isd 28Sc-17	21.83a
	Isd 28Sc-18	17.27efg
	Isd 28Sc-19	14.77hi
	Isd 28Sc-20	17.10efg

* Figures in the columns followed by different letters are significantly different by DNMR test at p= 0.05.

In the present investigation it was found that both biochemical parameters and morphological characters showed superiority in somaclones compared to their donor parent variety Isd 28. These results indicate feasibility, and effectiveness of selection for drought tolerant sugarcane genotypes through tissue culture by adding PEG in the medium. It was also observed that callus could be induced when up to 10% PEG was present in the culture medium. Shoots and root formation were possible at 5% PEG level. However it was reported elsewhere that, recurrent *in vitro* selection can effectively be applied for further improvement of desired traits (Ochatt *et al,*. 1989; Lutts *et. al.*, 2001).

In this work drought tolerant somaclones were selected under both *in vitro* and *ex vitro* conditions. Biochemical parameters were affected due to heat-induced changes in leaf samples under water stress. Adverse effects of drought stress were higher in tolerant somaclones as compared to moderately tolerant somaclones of parent variety Isd 28. It demonstrates the possibility of desired genetic manipulation to produce drought tolerant somaclones.

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COMPARATIVE STUDY OF SOME SUGARCANE STRAINS IN RELATION TO YIELD AND QUALITY

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ABSTRACT

A field trail was conducted during 2005-06 with the objectives to evaluate suitability and adoptability potential along with comparing yield and quality triats of fourteen sugarcane strains viz; S2000-SP-203, S2000-US-722, S2001-US-62, S2001-US-71, S2001-US-104, S2001-US-400, S2002-US-36, S2002-US-89, S2002-US-109, S2002-US-114, S2002-US-118, S2002-US-140, SPF-213 (standard) and HSF-240 (standard). All strains varied significantly from each other. Statistically significant and tabulated data showed maximum values of germination (51.27%) and CCS (13.35%) in S2000-US-203, tillers per plant (1.74) and number of millable canes (109.38 000/ha) in S2001-US-400, cane yield (96.53 t/ha) and sugar yield (11.16 t/ha) in S2000-SP-722 respectively when these strains were compared with early maturing as well as medium and late maturing standards.

Keywords: Sugarcane, strains, germination, cane yield, sugar yield and CCS.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a major cash crop of Pakistan and there is no need to emphasize its importance in the agrarian economics of country because of its higher value as a cash crop, a major source of gur, shakkar and white sugar and as a raw material for various agro based industries (Atta *et al.,* 1991). In Pakistan, the cane area under cultivation along with its production is decreasing with the course of time as it was cultivated on an area of 966.4 thousand hectares with an annual production of 47244.1 thousand tons in 2004-2005 while during 2005-2006 the area under cultivation and production was 907.3 thousand hectares and 44665.5 thousand tons respectively (GOP, 2006). Inspite of introduction of many high yielding cultivars in past, the cane yield per hectare did not increases to a desirable level, because of their unstable production behavior, which deteriorate rapidly with the course of time (Ahmad *et al.,* 1996). Similarly sugarcane varieties run out after a certain period of time because of pathogenic attacks or change in the environment. So it is essential to maintain a constant flow of fresh varieties in the fields (Khan *et al.,* 1990). In the same way one of the major causes of our low yields is the short growing season comprising of nine to twelve months as compare to other countries containing fifteen to twenty two months (Mahmood and Nazir, 1987). Thus sugarcane production could never be improved until and unless the promising varieties are adopted on large scale (Glaz, 2000). Some of the research work done in the past regarding study is reviewed in the coming lines. Rao *et al.,* (1992) selected an early maturing variety CoA 89085 (85 A 261) with sucrose% (19.43), CCS% (14.1) and sugar yield (15.68 t/ha) showing resistance to all strains of red rot. More *et al.,* (1993) compared eight cane cultivars with respect to different physical and chemical parameters and found Co 8325 as best because it produced highest cane yield (105 t/ha), ratoon yield (83 t/ha) and sugar yield (14.6 t/ha) as compare to other cultivars. Rajeseharam *et al.,* (1992) tested three varieties CoC. 90063, CoC, 91061 and CoC. 92061 against CoC.671 and found them superior for cane and sugar yield in plant as well as ratoon crop.

Glaze *et al.,* (2000) pointed out that clonal selection at the pre-commercial stages helped to identify the improved genotypes for commercial production of sugarcane. Similarly Chockalingam and Balusamy (1989) noted cane yield (48.8 t/ha) and sugar yield (12.5 t/ha) in cultivar CoC. 771 while comprising eight varieties for similar traits.
The reported study was conducted to evaluate the different agronomic traits of sugarcane strains during selection process at Faisalabad.

MATERIALS AND METHODS

An experiment containing fourteen sugarcane strains was planned at Sugarcane Research Institute Faisalabad during 2005-2006 in RCBD arrangement where each treatment (strain) was replicated thrice. The crop was sown by deep trench method during spring season and harvested in the spring next year. The fertilizers were applied@168-112-112 kg ha^{-1} NPK to the crop sown@70, 000 DBS/ha seed rate. Ametryn and Atrazine was used @ 2.50 litre ha^{-1} to control weeds after first irrigation while earthing up was done 90 days after sowing. All the potash and phosphatic fertilizers were applied at sowing while Urea was applied in three splits i.e. 0,45,90 days after sowing. The following yield and quality parameters were recorded:

1- Germination (%)
2- Tillers per plant
3- Number of millable canes (000 /ha)
4- Cane yield (t/ha)
5- Sugar yield (t/ha)
6- Commercial cane sugar (%)

Where germination and tillering were recorded after 45 and 90 days of sowing while data regarding number of millable canes, cane yield and sugar yield were taken at harvest. Compound samples of each strain were analyzed according to procedures described by Spencer and Meade (1963) on monthly basis so it was not subjected to statistical analysis. However, the means relating germination, tillers per plant, cane yield, number of millable canes and sugar yield were compared at probability levels 5% as mentioned by Steel and Torrie (1980).

RESULTS AND DISCUSSION

The results along with their statistical interpretations, given in tables are discussed in coming lines, under following headings.

Germination:
It is considered the most critical physiological phase, as without it there is no plant. The data given in table indicated that differences in strains were significant for germination. Higher germination percentage, as compare to standard HSF-240, was produced by S2001-US-104, S2000-US-203, S2002-US-109, S2000-SP-722, S2001-US-400, S2001-US-71, S2002-US-114, and S2001-US-62 with 56.56%, 51.27%, 50.40%, 44.12%, 44.01%, 42.03%, 37.87% and 36.89% respectively. But no strain could show higher number of germinant as compare to second standard strain SPF-213 (58.70%). Similarly the lowest germination (27.33%) was noticed in 2002-US-36. The results are also in conformity with those reported by Chang (1999).

Tillers per plant:

The extent and nature of tillering is largely a varietal character. The data presented in table indicated that high tillering compensated relatively poor germination but better germination reduced tillering. The data also showed that differences among different cane stains were significant. Five strains (S2001-US-400, S2002-US-36, S2000-SP-722, S2001-US-104 and S2002-US-118), crossed early maturing standard HSF-240, by producing 1.74, 1.71, 1.71, 1.70 and 1.69 number of tillers per plant. These five strains were also statistically at par with HSF-240. In the same way six strains, which produced higher number of tillers per plant as 1.74, 1.71, 1.71, 1.70, 1.69 and 1.61, were S2001-US-400, S2002-US-36, S2000-SP-722, S2001-US-104, S2002-US-118 and S2002-US-114 as compare to the standard SPF-213 (1.59). The minimum number of tiller per plant (0.75) was observed in S2000-US-203. Variation in the tillers per plant produced by different strains was probably due to their inharent character. The results are in accordance with those reported by Jayamani (1992).

Number of millable canes:

It is the interaction of germination, tillering, resistance against insect pest and disease attack. A perusal of data given in table indicated that statistically significant number of millable canes was noted in all strains. While considering HSF-240 as standard, seven strains produced higher number of millable canes, which were S2001-US-400 (109.38 000/ha), S2000-SP-722 (107.55 000/ha), S2001-US-104 (102.17 000/ha), S2001-US-71 (101.39 000/ha), S2002-US-109 (97.31 000/ha), S2002-US-36 (96.53 000/ha) and S2002-US-118 (94.79 000/ha) respectively. However one strain succeeded to show higher cane count than SPF-213, which was S2001-US-400 (109.38 000/ha). Singh *et al.,* (1993) noticed the similar findings.

Cane yield:

It is the most desirable characteristic from farmer's point of view. Cane yield is the product of genetic potential of a variety and environmental conditions through agronomic management. The yield data revealed that the differences among strains under test were significant. Only one strain (S2000-SP-722) yielded higher canes (96.53 t/ha), that was also the maximum yield is this study, as compare to the medium and late maturing standard SPF-213 (90.32 t/ha). However three strains S2000-SP-722, S2001-US-104 and S2001-US-400 showed higher yields (96.53, 91.18 and 89.24 t/ha) as compare to the early maturing standard HSF-240 (80.90 t/ha). The strain S2002-US-89 yielded the minimum canes (31.94 t/ha) in this study. The results reported by Parameswar *et al.,* (1995) are in accordance with the present explanations.

CCS:

The real cane quality is reflected by its CCS% as it stands the factor of prime importance both for millers and breeders. A perusal of data indicated variable CCS for all strains under study. If HSF-240 was considered as standard, then eight strains S2002-US-203, S2002-US-140, S2002-US-118, S2002-US-36, S2002-US-109, S2001-US-71, S2002-US-114 and S2002-US-89 showed higher CCS% as 13.35%, 13.27%, 12.71%, 12.63%, 12.34%, 12.29%, 12.11% and 11.99% respectively. Similarly ten strains including the previous eight strains compared with HSF-240 produced higher CCS% than medium and late maturing standard SPF-213 (11.23). These were S2000-SP-722 and S2001-US-104. However, S2001-US-62 ranked lowest with respect to CCS% (10.56%) in this study. Highly variable CCS% among different cane cultivars has been recorded by Mcintyre *et al.,* (1994).

Sugar yield:
It is the function of cane yield and corresponding recoverable sugar percentage. While considering early maturing standard HSF-240, five strains out of twelve gave higher sugar yield, which were S2000-SP-722 (11.16 t/ha), S2001-US-71 (10.50 t/ha) S2001-US-104 (10.32 t/ha), S2002-US-36 (10.09 t/ha) and S2001-US-400 (9.73 t/ha) respectively. However two strains namely S2000-SP-722 and S2001-US-71 produced higher sugar yield as 11.16 t/ha and 10.50 t/ha when all strains were compared with medium and late maturing standard SPF-213. Variable sugar yield for different strains was also observed by Sharar *et al.,* (1995).

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Table: Qualitative and quantitative characteristics of some sugarcane strains

Sr.#	Strains	Germination (%)	Tillers per plant	Number of millable canes (000/ha)	Cane yield (t/ha)	CCS (%)	Sugar yield (t/ha)
1.	S2000-US-203	51.27ab	0.75f	66.66e	43.06f	13.35	5.75g
2.	S2000-SP-722	44.12bcd	1.71ab	107.55ab	96.53a	11.56	11.16a
3.	S2001-US-62	36.89def	1.20cdef	47.92fg	56.25e	10.56	5.94fg
4.	S2001-US-71	42.03cde	1.25bcde	101.39abc	85.41b	12.29	10.50ab
5.	S2001-US-104	56.56a	1.70ab	102.17abc	91.18ab	11.32	10.32a
6.	S2001-US-400	44.01bcd	1.74a	109.38a	89.24ab	10.90	9.73ab
7.	S2002-US-36	27.33g	1.71ab	96.53c	79.86bc	12.63	10.09ab
8.	S2002-US-89	35.73ef	0.95def	38.19g	31.94g	11.99	3.83h
9.	S2002-US-109	50.40b	1.38abcd	97.31bc	66.84d	12.34	8.25cde
10.	S2002-US-114	37.87def	1.61abc	72.22de	64.24de	12.11	7.78e
11.	S2002-US-118	35.42ef	1.69ab	94.79c	73.26cd	12.71	9.31bcd
12.	S2002-US-140	32.96fg	0.81ef	51.74f	54.86e	13.27	7.28ef
13.	SPF-213 (std)	58.70a	1.59abc	108.25a	90.32ab	11.23	10.14ab
14.	HSF-240 (std)	36.15ef	1.66abc	79.95d	80.90bc	11.82	9.56bc
	LSD at 0.05	**7.771**	**0.4747**	**10.83**	**10.50**	**-**	**1.45**

Std. = Standard

SUGAR INDUSTRY ABSTRACTS

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AGRICULTURAL ENGINEERING

AGRICULTURAL AGRONOMY

Evaluating the impact of and capacity for adaptation to climate change on sectors in the sugar industry value chain in Australia

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Australia is predicted to be hotter and generally drier, with more frequent extreme events, in coming decades similar to that expected in most sugarcane producing nations. To assess the direct and indirect climate change impacts on the cane-growing regions of Queensland, and adaptive capacity, projections for 2030 were considered using (i) a review of literature on climate/plant interactions and sugarcane physiology, (ii) a brief qualitative assessment in collaboration with industry stakeholders throughout the value chain, and (iii) a quantitative estimate of yield potential and the efficacy of an adaptation strategy using an eco-physiological model of plant growth. The review and qualitative assessment indicated that the greatest impacts are likely to be experienced on the grower sector of the industry. Productivity gains/losses will ultimately depend on the availability of a number of resources, particularly water, and the plant's physiological response to relative changes in all climate variables. Capacity within the sugar industry value chain is considered sufficient to absorb an increase in yield, but a decrease may financially challenge many mills. The paper then focused on providing more quantitative estimates of impact using the Agricultural Production Systems simulator (APSIM) to estimate yield potential in response to temperature and rainfall projections up to 2030 for the most northerly (Mossman) and southerly (Rocky Point) regions of the Queensland sugarcane industry. Response surfaces produced from model simulations suggest yield losses are likely be greater in the cooler southern regions due to increased water stress. The vast majority of adaptation strategies identified by stakeholders as potentially useful were an extension and enhancement of the current practices used to manage sugarcane production in the highly variable Australian climate. An eco-physiological model (APSIM) was used for the first time to assess the adaptive strategy of changing the date of planting in a sugarcane production system. The simulations suggest that yield potential will increase marginally if the planting date occurs earlier than presently practiced in the south, while a delay in planting date in the north may increase productivity by the year 2030. This study showed that collaborative research between industry stakeholders from all sectors and the use of an ecophysiological modeling tool, such as APSIM, can aid in the identification of critical areas of climate change impact, quantify these impacts and assist in the identification of adaptation strategies at a regional scale.

Practical methods of evaluating on-farm irrigation systems

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Irrigation system evaluation techniques are designed to evaluate the actual operation and management conditions that exist on the farm and help determine the potential for more economical and efficient operation. Optimum on-farm irrigation management and design have traditionally been promoted for reasons of improved yields and farm input costs. More recently, external pressures such as competition for water plus degradation of river flows require even more detail for on-farm irrigation. As irrigation progresses, new techniques to manage water are therefore required. This paper describes practical methods of evaluating the performance of irrigation systems. Measured water distribution efficiencies were 5% lower than the conventional catch can method for overhead (sprinkler and centre pivot) irrigation systems and similar for furrow and drip irrigation systems. The difference was due to climatic variations as, in the conventional catch can method, the cans are placed on the ground whereas in this method the water was collected before reaching the ground. The methods described are simple to implement and have been used in the Swaziland sugar industry to provide growers with the necessary information on improvements that can be made to optimize their systems and on how to select potential, economical and practical modifications.

SUGARCANE BREEDING

Development of effective selection technique through path coefficient analysis in inter varietal hybrid derivatives of sugarcane (*saccharum* spp. l)

R. B. Doule and N. Balasundaram
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A trial was conducted with 28 clones of sugarcane derived through interspecific crosses between *Saccharum officinarum* L., *S. spontaneum* L., and *S. sinense* L, to estimate the relative contribution of various components towards final cane and sugar yield at 300 and 360 days through path coefficient analysis. Considering the path coefficients for sugar yield at 300 days, it was observed that number of millable canes and sucrose percent were important. At 360 days, in addition to number of millable canes and sucrose percent, cane thickness also assumed greater important. Brix percent juice had a negative direct effect towards sugar yield at both stages of harvest. The low levels of residual effects indicated that the characters under study determined cane sugar yield to a considerable extent. The path coefficient analysis indicated the relatively higher contribution of number of millable canes, cane thickness, and cane length towards cane yield and the importance of Brix, sucrose and purity coefficient to sugar yield. Selection based on these characters would be efficient for selection of high yielding hybrids.

Collection and description of wild sugarcane species indigenous to Japan

Shigek Nagatomi and Kounosuke Degi
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Modern sugarcane cultivars developed from a narrow genetic base derived from tropical ancestors, had suffered from cold and freeze damage in subtropical and temperate zones. Wild species originating from subtropical and temperate zones would have great advantages to improve more adaptable cultivars with cold tolerance in higher latitudinal cane belts. Therefore, sugarcane wild species (*Saccharum spontaneum* L.) and the related genera in the Nansei Islands, Japan had been collected since 1977, and more than 500 accessions had been collected as the JW (Japanese Wild) series. Multivariate analyses based on their morphological and agronomic characters revealed that wild species were divided into 11 clusters relevant to their islands of origin. They possessed wider variation in flowering emerging from September to November, and also great genetic variation in the other characters. On the Japanese mainland, several expeditions disclosed that sugarcane wild species were distributed along the South Western coast up to a northern margin at 36°N Lat. where it is usually colder than 10° degree below freezing. More than 190 accessions had been collected as the JW series. The mainland wild species compared with ones in the Nansei Islands showed remarkable tolerance to cold weather and vigorous ratooning ability after over-winter cultivation at colder areas of the mainland. In addition, the mainland wild species had wide variation in soluble solids accumulation ability indicating from 2% to 22% in terms of refractometric Brix. These clones from wild species are promising to improve commercial cultivars not only for cold tolerance but also for growth and ratooning ability under higher latitudinal zones.

SUGARCANE PATHOLOGY

FACTORY ENGINEERING

Detection of sucrose in boiler feed water

M. A. Gooch and A. Wienese
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Numerous authors have outlined the importance of preventing sucrose entrained in condensate from entering the boilers particularly where higher pressure boilers are in use. The condensate from a raw sugar mill, sugar refinery or a raw sugar mill with an attached back end refinery contains different types and quantities of impurities. Because of this, the appropriate technology to measure impurity levels varies between applications. This paper is a review of the different techniques to detect the contamination of sucrose in boiler feed water.

FACTORY PROCESSING

Improving sugar quality and reducing process difficulties by emphasising impurities rather than purity: minimising soluble polysaccharides by use of biocides

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Polysaccharides, such as sarkaran, pullulan, dextran, and starch, and oligosaccharides are impurities that significantly influence sugar quality and recovery. Most of them are produced due to the activities of yeasts, fungi and bacteria, including *Leuconostoc*. These saccharides consume a lot of sucrose during their formation and lose more sucrose to molasses, besides hindering the process, which adversely affects sugar quality. Microbes grow at cane stations, cane carrier, and mills, and proper cane and mill sanitation is essential in order to minimise their growth. Microbes capable of growing at high temperature can be minimized at mills by use of proper technology, including biocide use. Many factories using such technology can reduce the rise in reducing sugars, acidity and dextran contents of final molasses. Data from sixteen representative sugar factories are presented.

MANAGEMENT

Development of a new research strategy for the SMRI

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This paper discusses the new Research Strategy of the Sugar Milling Research Institute (SMRI) and the recent changes that have taken place in how the SMRI's annual Research Program is developed. Traditionally, the Research Program was rather short-term in focus and was often developed by means of a 'bottom up' approach whereby the SMRI, through interaction with the mills, developed projects that were designed to address factory problems and improve the operational efficiency. This approach often lacked strategic focus. Using a 'top-down approach', the strategic needs (not wants!) of our members have been assessed. It is clear that the South African sugar industry is a mature industry, showing signs of decline. To remain competitive and sustainable into the future, step-change, and not merely incremental change, is required. As such, it is clear that radical technological innovation is required. This has resulted in the creation of SMRI Strategic Research Thrust Areas and the move to a more medium-to-long term research focus. Research projects are now developed within the Thrust Areas and evaluated in terms of several criteria, including alignment with industry strategy and probability of implementation success. The SMRI is also managing its research investment in terms of Risk versus Reward using a Portfolio Management approach. The authors are of the opinion that the SMRI's investment is now aligned with the South African milling industry's strategic objectives, and there is a shared common vision of the technical priorities of the industry. Recent initiatives with the University of KwaZulu-Natal and the South African government's Department of Science and Technology to build the resources required to deliver the necessary outcomes are discussed.

Cooperative systems in practice: implementation of value chain management strategies in the MacKay sugar industry

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In response to adverse market and climatic conditions in recent years, Mackay Sugar has developed value chain management strategies to drive change and increase profitability across the local industry. These strategies and a technological framework to implement them were embodied in the Cooperative Systems model, developed in 2003-2005. This paper first discusses some prerequisites for successful implementation of value chain management strategies. It then describes three implementations in the Mackay Sugar Cooperative: a new cane payment system that changes the division of proceeds and shares the risks and rewards of diversification; a harvesting information system to facilitate and manage harvesting contracts based on best practice; and the introduction of service level agreements for cane transport with a mobile delivery tracking system to monitor performance. In each case, the paper explains the shortcomings of previous systems with respect to value chain management; the way that strategies developed in the Cooperative Systems project have been implemented to address these shortcomings; and the impact and effectiveness of these strategies to date. The implementation of these strategies in Mackay Sugar has increased the awareness of whole of industry management issues across all sectors. The Cooperative has been encouraged by the results to date, and the paper mentions other initiatives that are planned or in progress for further change and deregulation of the Mackay industry towards a more competitive, market-driven future.

COPRODUCTS

Formulation of cattle feed from co-products of the sugarcane industry of Sri Lanka

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The co-products of the Sri Lankan sugar industry have not been fully utilized. The depressed price of sugar has adversely affected the viability of the sugar industry. There exists a severe shortage of animal feed in the dry zone of Sri Lanka, particularly during the dry period from May to September, and this has badly affected the milk production in the country. This study aimed at investigating the possibility of production of a cattle feed from sugar industry co-products such as cane tops and molasses to gain additional income to sugar companies and to cater to the feed demand for increasing milk yield and production. Twelve rations were formulated at different levels of cane tops, molasses, coconut, rice polish, urea, dicalcium phosphate and sodium chloride, considering the nutrition requirements of the cattle and tested for their *in-vitro* organic matter digestibility (IVOMD), metabolisable energy (ME), and digestible crude protein (DCP) contents. The ration with the highest ME and DCP contents were used to test its effect on milk yield. The results showed that the ration with 55% cane tops, 15% molasses, 2% urea, 15% coconut poonac, 10% rice polish, 2% dicalcium phosphate and 1% sodium chloride gave the highest ME and DCP. It increased milk yield by 49%, length of lactation period by 17%, total milk production 56%, and fat content by 21%. Financial analysis indicated that cattle feed production from sugarcane co-products were viable at the prevailing prices. Thus, utilization of cane tops and molasses for cattle feed helps both the sugar industry and dairy farmers to raise their income by product diversification and by increasing milk production respectively.

For increased ethanol production

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The technical and economic investigation of the ZeaChem process for increased production of ethanol from sugar process streams has been completed at SRI and this paper reports on these investigations. The main benefit of the process is the theoretical increase in ethanol production by up to 50% per unit dextrose sugar feed. The ZeaChem process utilizes bacteria to convert fermentable sugars to acetic acid either in a one step direct fermentation process or in a two step fermentation process via lactic acid. The production of lactic acid can provide an additional revenue source from the sale of single cell protein produced in the two step process. After fermentation, the acetic acid is extracted from the fermentation broth in an acid recovery stage, esterifies in a reactive distillation process and converted to ethanol by hydrogenolysis. The ZeaChem process has four main production stages. In order to achieve high yields of ethanol, high yields are required for each stage of the process. High yields are obtained for each stage of the process. Several sugar process streams were considered for the process and these included clarified juice, syrup, a molasses, B molasses and C molasses. However, the fermentation process is inhibited if C molasses only is used as feed. Large dilutions of C molasses are required to obtain high yields during the fermentation stage. The reasons for the inhibition of the fermentation of C molasses are not understood and should be targeted in further laboratory scale testing, while the project is progressed to pilot plant trials. The evaluation of the ZeaChem ethanol process has confirmed the potential of the process to achieve significantly higher yields than the conventional yeast fermentation process.