Physiological Adaptation of Sugarcane Genotypes under Water Logging Stress Condition

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ABSTRACT

Yield and juice quality of some selected sugarcane genotypes under water-logging stress condition was investigated at Bangladesh Sugarcrop Research Institute during November, 2016 to February, 2018. The genotypes were I 290-08, I 127-09, I 130-09, I 85-10, I 101-10, I 103-10, I 131-10, Isd 39 and Isd 45. Data were collected on cane yield, brix per cent, purity per cent, pol per cent cane and reducing sugar per cent. Though all the genotypes showed higher pol percentage earlier under stress condition than to control but decreasing trend were observed in pol percentage in Isd 39, Isd 45, I 290-08, I 130-09 and I 103-10 up to February. Genotypes I 127-09, I 85-10, I 101-10 and I 131-10 produced higher and stable pol percentage from October to February under water logging stress. All these information will help the breeders to select the potential genotypes both for millers and goor (jaggery) makers in water logging areas.

Key words: Sugarcane, Water logging stress, Juice quality, Yield

INTRODUCTION

Water logging or excess water is one of the abiotic stresses limiting the potential productivity of crop plants. In Bangladesh, area under waterlogged and flood is increasing day by day due to climatic change. All the sugarcrops viz. datepalm, palmya palm, nypa palm including sugarcane are the crops which can easily survive in waterlogged and flooded field. Sugarcane crop was most susceptible to water logging in the first 3–4 months, comparatively tolerant at 5–9 months age and hastens early maturity at later stages of stress. Higher water table during active growth phase adversely affects stalk weight and plant population resulting in yield loss at the rate of about one ton per acre for one inch increase in excess water (Carter and Floyed, 1974; Carter 1976), although sugarcane is relatively tolerant to high water tables (Roach and Mullins, 1985; Deren et al., 1991a, 1993). It is reported that well-established cane can survive few months into flood/waterlog, while less established cane appears to be much more vulnerable to flooding/waterlogging (Deren *et al.* 1991b).

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The reduction in yield is attributed to low moisture and nitrogen in the tissue at grand growth phase. Increase in number of internodes, profuse tillering and increase in phosphorous percentage in both stem and plant as a whole, decrease in nitrogen content characterized tolerance to flood condition Pandey, 1964). Some physiological effects of cane found due to water-logging are (1) transpiration rates are reduced due to stomatal closure, (2) rate of photosynthesis is considerably reduced presumably due to the reduction of effective leaf area, (3) crop growth rates are drastically reduced during water-logging, (4) higher respiration rate of submerged organs compared to leaves. A shift in respiratory metabolism from aerobic to anaerobic pathways is one of the main effects of oxygen deficiency caused during water logging. The effects of water logging on respiration rate depend on the varieties and its physiological age. Plant hormones have been show into play an important role in adaptation to adverse environmental stress. Changes in endogenous plant hormones have shown to influence morphological adaptations and facilitate internal transmission of messages between stressed roots and shoots. Nutrient uptake is badly affected under waterlogging where aerobic respiration by sugarcane root system is poor (Singh, 1990). It is also reported that under water logging condition significant morphological, anatomical, physiological and biochemical changes take place in plant for adaptation/survival (Barcly and Crawford, 1982; Gomathi and Chandran, 2009). The average yield loss due to water logging is estimated to be 15–25 % and can exceed 40 % depending on the stage of the affected crop and duration of flooding (Gomathi and Chandran, 2009). However, water logging tolerance is likely to be a complex trait affected by several mechanisms and complicated by confounding factors such as temperature, plant development stage, nutrient availability, soil type and sub-topography.

The effect of excess water stress from temporary or continuous flooding has been studied extensively (Scott *et. al.,* 1989; Jackson *et. al.,* 1978). Sugarcane root density is greatest near the soil surface with 60% in the 0-30cm depth, but roots may penetrate to 180cm in well-drained soils (Gascho and Shih, 1983; Paz-vergara *et. al.,* 1980). One morphological change in sugarcane roots growing under high water tables 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 adaptation 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). Presence of root aerenchyma is a key requisite for sustained root activity in flooded soil. The roots of all of the 40 sugarcane genotypes examined contained aerenchyma (Ray *et. al.,* 1996; Van Der Heyden *et. al.,* 1998). 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.,* (2002) grew nine sugarcane cultivars under 15 and 38-cm water table depths. They reported a mean yield reduction of 8.3% at the 15-cm water table, but two cultivars had similar yields at both water tables, and the yield of one cultivar was reduced by 25% at the 15-cm water table. Generally, sugarcane is not considered a flood/waterlog tolerant species, but when it exposed to flood sugarcane produces adventitious roots which contains aerenchyma.

These adaptations allow some sugarcane genotypes to sustain growth under flood stress. In previous studies, germination and early seedling growth stages were found most susceptible to flood (Miah and Rahman, 2002). In Bangladesh, sugarcane is not planted before November, December which reduces the possibility of waterlog/flood stress during early growth. Main objective of this experiment was to find out the harvesting pattern considering the early, mid and late cultivars for millers and goor (jaggery) makers both in high and waterlog areas of Bangladesh. The ripening point is determined primarily by the levels of sucrose, reducing sugars and stalk humidity during the crop season. According to the Brazilian Sugarcane, Sugar and Ethanol Producers Council (CONSECANA) standards, millable cane, i.e., stalks that have the technological and economic conditions for industrial processing, need sucrose (Pol) levels of at least 12.257 % (Lavanholi, 2008). Early cultivars are those with Pol levels greater than 12.257 % at the beginning of the harvesting season, while middle and late cultivars possess Pol concentrations above this threshold from the middle to the end of the season (Lavanholi, 2008). Early cultivars are those with Pol levels greater than 12.257 % at the beginning of the harvesting season, while middle and late cultivars possess Pol concentrations above this threshold from the middle to the end of the season (Lavanholi, 2008).

On the contrary, According to our Physiology and Sugar Chemistry Division recommendation varieties which achieved 11% sucrose and 0.6% R. S. in the month of October are known as early ripening , varieties which fulfil these criteria in the month of November are known as mid and those which fulfil the above criteria in December are late ripening varieties.

MATERIALS AND METHODS

An experiment was carried out to observe the performance of some BSRI bred genotypes under water logged conditions through analyzing the juices in different months collected from the selected clones during the 2016-2017 cropping seasons at BSRI farm. BSRI developed sugarcane genotypes I 290-08, I 127-09, I 130-09, I 85-10, I 101-10, I 103-10, I 131-10, Isd 39 and Isd 45 were used for this purpose. The experiment was laid out in RCB design with three replications. Two budded setts were planted at trenches following end to end method of planting. NPKS fertilizers were applied @ 325 kg urea, 250 kg TSP, 190 kg MP, 180 kg Gypsum and 9 kg $ZnSO_4$ per hectare. Urea was applied in 3 splits and MP in two splits. Intercultural operations were done as and when required. The experimental field was inundated up to 60 cm by flood water, and lasted up to 90 days. Data on brix, pol, purity and reducing sugar percentage were recorded at different months from October to February and also recorded the cane yield at harvest. Laboratory analysis of cane juices were done at different months of growth. The cane samples were crushed in a three-roller mill (power crusher). Brix was determined by Brix hydrometer standardized at 20^0C and Horne's dry lead method was used for sucrose determination using an automatic polarimeter (ADP-220). Juice purity was calculated as the ratio of the sucrose content and corrected Brix reading. Reducing sugars were determined by the method described in Queensland Laboratory Manual (Anon, 1970). Statistical analysis was performed and mean values were compared using LSD at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Pol percentage

The genotype Isd 39 showed the lowest level of pol% (11.78) in single effect of genotype on pol% but in interaction effects it showed higher pol% in December (14.88%) under control and under stress it showed higher level in the month of October (14.04%) and November (14.24%). Genotype Isd 45 also showed lower level of pol% (12.38%) in single effect of genotypes on pol% but in interaction effect it showed highest level in February (15.16%) under control and under stress it reaches highest level in November (14.84%).

October and November showed highest level of pol% in single effect of months on pol%, but in interaction effect most of the genotypes showed lower level of pol% under control in October and November but showed higher level under stress condition in October and November. In case of treatment effects on pol% stress condition showed better pol percentage than to control.

In interaction effects maximum genotypes except I 127-09, I 85-10, I 101-10 and I 131-10 showed comparatively higher pol percentage earlier in stress conditions and decreasing trend were observed up to February. On the contrary, in control condition all the genotypes showed lower level of pol% earlier and increasing trend were observed up to February. Isd 39 showed higher pol percentage in October and November (14.04% & 14.24%) under stress condition while in control condition that genotype showed less pol percentage in October and reached in highest level at December. Isd 45 showed highest pol percentage at February (15.16%) in control condition while under stress condition it showed lower level of pol percentage on that month. Under stress condition I 290-08 produced significantly higher sucrose in earlier at October (13.89%) and November (14.96%) and decreasing trend of pol% was observed up to February. In control condition lower level of sucrose was produced by I 290-08 in October and November and highest pol% was observed in December (13.41%). Increasing trend of sucrose percentage were observed in the genotype I 127-09 under both stress and control condition. The highest pol% were observed at January under both in control (14.93%) and stress (14.84%) conditions. Increasing trend of pol percentage were observed in I 130-09 up to the month of February (14.96 %) under control condition while under stress condition highest level (13.75%) was observed in November than decreasing trend was observed up to February. I 85-10 showed the highest pol percentage in the month of October and become constant level up to February under stress. On the contrary, in control condition though this genotype showed lower level of sucrose in earlier, it reached the highest level in the month of February (15.54%). Like the genotype I 85-01, I 101-01 also showed the higher and constant pol% starting from earlier up to the month of February under stress condition but in control condition it showed lower level in earlier and reached in highest level in the month of December.

Both the genotypes I 103-10 and I 131-10 showed lower level of pol% in earlier and increasing trend was observed up to February in control condition, but in stress condition both of them showed highest level in November and then showed decreasing trend.

Begum *et. al.,* (2013) conducted an experiments with some BSRI genotypes in control and stress conditions and observed that under stress condition genotypes showed better performance considering on juice quality than to control which is similar with this findings. All the genotypes produced higher pol% earlier under stress than control due to low temperature and creating physiological drought under waterlog condition. We know lower temperature and water stress in soil enhances the photosyanthates converted into sucrose. Scarpari and Beauclair, (2004, 2009) found that temperatures below 20 C slow down sugarcane growth rates and increase sucrose accumulation in stalks. Meteorological variables are the primary variables responsible for the productivity and quality of sugarcane (Keating *et. al.,* 1999). Low temperatures and moderate water deficits associated with nitrogen deficiency are the most effective ripening agents (Alexander, 1973). As growth rates decrease, a lower amount of sugar is used in new tissue formation, and a greater amount of sucrose is stored. The sucrose levels vary during the harvesting season, with higher accumulation rates observed during the last phase of the sugarcane cycle, when the plant has a low growth rate, which is conditioned by adverse weather conditions (Alexander, 1973). In Southeastern Brazil, the lower air temperature in the fall-winter months combined with the occurrence of a moderate water deficit are the major ripening factors, which result in a very rapid increase in sucrose content. Cardozo (2012) indicated that the sucrose stalk content in the four months before harvesting increased from 7.32 % to 15.29 %, while the total biomass only increased from 122 to132 t ha^{-1} (8 %). Therefore, despite the intense work of breeding programs to produce earlier-ripening cultivars, sugarcane rarely achieves its full ripening potential, as it is harvested while still actively accumulating sucrose (Legendre, 1975), especially in the first months of harvesting season, when the air temperature and soil moisture are usually high.

Table1. Effects of varieties on pol percentage

Sl. No.	Name of varieties	pol percentage
1.	lsd 39	11.783 f
2.	lsd 45	12.385 e
3.	I 290-08	13.291 d
4.	I 127-09	13.617 c
5.	I 130-09	13.754 bc
6.	I 85-10	13.503 cd
7.	I 101-10	13.994 ab
8.	I 103-10	13.756 bc
9.	I 131-10	14.253 a

Table 2. Effects of months on pol percentage

Sl. No.	Name of months	pol percentage
1.	October	13.616 a
2.	November	13.482 a
3.	December	13.216 b
4.	January	13.096 b
5.	February	13.443 a

Table3. Effects of treatments on pol percentage

Sl. No.	Treatments	pol percentage
1.	Control	12.941 b
2.	Stress	13.800 a

* Figures accompanied by same letter are not significantly different at 5% level as per LSD test.

Table 4. Interation effects of varieties, months and treatments on pol percentage

Sl. no.	Variety	Treatment	Months				
			October	November	December	January	February
1.	Isd 39	Control	10.92 jk	11.16 i-k	14.88 a-h	14.14 f-s	14.35 d-o
		Stress	14.04 g-s	14.24 e-q	13.79 l-t	13.84 k-t	13.67 m-u
2.	Isd 45	Control	10.78 kl	13.22 s-c	14.07 f-s	14.05 f-s	15.16 a-e
		Stress	12.99 t-d	14.84 a-l	14.09 f- s	12.59 x-e	12.42 a-g
3.	I 290-08	Control	11.16 i-k	11.66 f-j	13.41 p-y	13.28 r-a	13.30 r-a
		Stress	13.89 j-t	14.96 a-g	12.19 d-h	12.34 b-g	12.11 d-h
4.	I 127-09	Control	9.53 m	11.59 g-j	13.35 q-z	14.93 a-g	14.26 e-q
		Stress	12.44 a-g	14.73 a-k	14.83 a-l	14.84 a-l	14.74 a-k
5.	I 130-09	Control	9.80 l-m	10.80 jk	12.31 c-g	14.49 c-n	14.96 a-f
		Stress	12.29 d-g	13.75 l-u	13.26 s-b	12.71 v-e	12.58 x-f
6.	I 85-10	Control	11.29 h-k	12.11 e-i	14.65 a-i	12.52 y-f	15.54 a
		Stress	15.46 a-b	15.25 a-d	14.57 b-m	14.88 a-l	15.29 a-c
7.	I 101-10	Control	10.63 k-l	12.64 w-e	14.29 e-p	13.99 h-s	14.20 f-r
		Stress	14.05 f-s	14.96 a-g	14.67 a-i	14.44 c-n	14.21 f-r
8.	I 103 -10	Control	9.68 m	11.59 g-j	13.80 l-t	13.89 j-t	14.66 a-l
		Stress	14.05 f-s	14.31 e-p	13.52 o-w	13.24 s-c	12.86 u-d
9.	I 131-10	Control	10.82 jk	11.93 e-i	13.80 l-t	13.94 l-s	14.79 a-j
		Stress	12.47 z-g	13.90 j-t	13.67 m-u	13.59 n-v	13.45 o-x

Purity percentage

The genotype Isd 39 showed the lowest level of purity % (84.65) in single effect of genotype on purity % but in interaction effects it showed higher purity% in February (89.50%) under control and under stress it showed higher level in the month of December (89.68). Genotype Isd 45 also showed lower level of purity% (85.72%) in single effect of genotypes on purity% but in interaction effect it showed highest level in February (88.80%) under control and under stress it reaches highest level in December (89.03%).

October and November showed highest level of pol% in single effect of months on pol%, but in interaction effect most of the genotypes showed lower level of pol% under control in October and November and showed higher level under stress condition in October and November.

In case of treatment effects on purity% stress condition showed better purity percentage than to control.

Genotypes Isd 39, Isd 45, I 290-08 and I 130-09 showed comparatively higher purity percentage earlier in stress conditions and decreasing trend were observed up to February. On the contrary, in control condition all the genotypes showed lower level of purity% earlier and increasing trend were observed up to February. Isd 39 showed higher purity percentage in October to December under stress condition while in control condition that genotype showed less purity percentage in October and reached in highest level at February. Isd 45 showed highest purity percentage at February (88.80%) in control condition while under stress condition it showed highest level at December (89.03%). Under stress condition I 290-08 showed higher purity% at November (89.05%) and then showed decreasing trend up to February. In control condition lower level of purity% was observed in October and November and highest was observed in December. Increasing trend of purity percentage were observed in the genotype I 127-09 from October to December under both stress and control condition. Increasing trend of purity percentage were observed in I 130-09 up to the month of February under control condition while under stress condition highest level (89.26%) was observed in November than decreasing trend was observed up to February. I 85-10 showed the highest purity percentage in the month of November under stress. On the contrary, in control condition though this genotype showed lower purity percentage in earlier, it reached the highest level in the month of February (89.04%). Like the genotype I 85-01, I 101-01 also showed the higher and constant purity% starting from earlier up to the month of February under stress condition but in control condition it showed lower level in earlier and reached in highest level in the month of January. Both the genotypes I 103-10 and I 131-10 showed lower level of purity % in earlier and increasing trend was observed up to February in control condition, but in stress condition both of them showed highest level in December. Our findings are in agreement with the findings of Begum *et al.,* (2013).

Table 5. Effects of varieties on purity percentage

Sl. No.	Name of varieties	purity percentage
1.	Isd 39	84.647 d
2.	Isd 45	85.715 c
3.	I 290-08	87.244 b
4.	I 127-09	88.125 a
5.	I 130-09	88.099 a
6.	I 85-10	88.222 a
7.	I 101-10	87.788 ab
8.	I 103-10	87.733 ab
9.	I 131-10	87.093 b

Table 6. Effects of months on purity percentage

Sl. No.	Name of months	purity percentage
1.	October	87.637 a
2.	November	87.347 a
3.	December	86.586 b
4.	January	87.145 a
5.	February	87.211 a

Table 7. Effects of treatments on purity percentage

Sl. No.	Treatments	purity percentage
1.	Control	86.764 b
2.	Stress	87.606 a

Table 8. Interation effects of varieties, months and treatments on purity percentage

Sl. no.	Variety	Treatment	Months				
			October	November	December	January	February
1.	lsd 39	Control	84.10 y-b	86.60 i-x	88.93 a-g	88.95 a-e	89.50 ab
		Stress	88.86 a-i	88.187 a-o	89.68 a	86.51 j-x	82.40 cd
2.	lsd 45	Control	85.26 t-y	87.89 a-q	88.60 a-l	87.57 a-s	88.80 a-i
		Stress	85.95 o-y	88.81 a-i	89.03 a-f	88.81 a-i	88.94 a-g
3.	I 290-08	Control	84.10 y-b	84.09 o-b	87.01 e-x	85.59 r-y	87.01 e-x
		Stress	86.29 m-y	89.05 a-f	87.32 b-u	85.68 q-y	86.79 f-x
4.	I 127-09	Control	79.36 e	86.23 n-y	86.89 f-x	89.46 ab	88.52 a-m
		Stress	84.95 v-a	89.21 a-e	89.73 a	81.85 cd	89.32 a-d
5.	I 130-09	Control	84.80 x-a	87.32 b-u	85.79 p-y	89.30 a-d	88.73 a-j
		Stress	84.87 w-a	89.26 a-d	87.72 a-s	87.78 a-r	86.72 g-x
6.	I 85-10	Control	84.10 y-b	86.44 k-x	89.03 a-f	86.32 m-y	89.04 a-f
		Stress	86.66 h-x	89.46 ab	89.17 a-e	82.40 cd	88.18 a-o
7.	I 101-10	Control	86.23 n-y	88.27 a-n	88.62 a-l	88.81 a-i	88.41 a-n
		Stress	87.76 a-r	89.33 a-d	89.03 a-f	87.25 b-u	89.13 a-f
8.	I 103-10	Control	83.013 z-c	85.34 t-y	88.52 a-m	88.32 a-n	88.96 a-g
		Stress	88.19 a-o	88.60 a-l	89.01 a-f	86.89 f-x	88.90 a-h
9.	I 131-10	Control	84.80 x-a	85.68 q-y	89.77 a	88.54 a-m	88.70 a-j
		Stress	85.49 s-y	87.32 b-u	89.35 a-c	86.89 f-x	86.67 h-x

Reducing sugar percentage

The genotypes Isd 39, Isd 45, I 290-08 and I 130-09 showed higher level of reducing sugar in single effects of genotypes on reducing sugar but in interaction effect all of them showed decreasing trend of reducing sugar from October to February both in control and stress condition. Genotypes Isd 39 and Isd 45 showed comparatively lower reducing sugar under stress than control in October and showed decreasing trend up to February in both the situation. I 290-08, I 127-09 and I 131-10 showed comparatively higher reducing sugar at earlier under stress conditions than control but decreased remarkably at February. I 130-09 also showed comparatively higher reducing sugar at earlier under stress conditions than control but decreased remarkably at January. Though the genotype I 85-10 showed higher reducing sugar in October under both the situation but decreased remarkably up to February under stress condition. Genotypes I 103-10, I 131-10 showed comparatively lower reducing sugar under control condition than stress in different months from October to February.

Table 9. Effects of varieties on R S percentage

Sl. No.	Name of varieties	R S percentage
1.	Isd 39	0.6400 a
2.	Isd 45	0.6080 b
3.	I 290-08	0.6040 c
4.	I 127-09	0.4490 e
5.	I 130-09	0.4800 d
6.	I 85-10	0.2750 i
7.	I 101-10	0.3940 g
8.	I 103-10	0.3040 h
9.	I 131-10	0.4280 f

Table 10. Effects of months on R S percentage

Sl. No.	Name of months	R S percentage
1.	October	0.4372 e
2.	November	0.4450 d
3.	December	0.4739 b
4.	January	0.5178 a
5.	February	0.4494 c

Table11. Effects of treatments on R S percentage

Sl. No.	Name of months	R S percentage
1.	Control	0.5129 a
2.	Stress	0.4164 b

Table 12. Interation effects varieties, months and treatments on R S percentage

Sl. no.	Variety	Treatment	Months				
			October	November	December	January	February
1.	Isd 39	Control	0.50 y	0.50 y	0.33 h	0.27 m	0.09 w
		Stress	0.30 k	0.29 l	0.15 r	0.08 x	0.08 x
2.	Isd 45	Control	0.55 v	0.39 d	0.23 p	0.23 p	0.29 l
		Stress	0.35 f	0.13 t	0.13 t	0.14 s	0.10 v
3.	I 290-08	Control	0.60 s	0.60 s	0.58 u	0.62 q	0.47 a
		Stress	0.61 r	0.43 b	0.36 e	0.43 c	0.13 t
4.	I 127-09	Control	0.80 i	0.75 j	0.69 m	0.67 n	0.61 r
		Stress	1.11 a	0.87 g	0.56 v	0.43 c	0.15 r
5.	I 130-09	Control	0.71 k	0.60 s	0.60 s	0.58 u	0.50 y
		Stress	0.87 g	0.78 i	0.57 u	0.17 r	0.47 a
6.	I 85-10	Control	1.05 c	0.90 e	0.90 e	0.80 l	0.65 o
		Stress	0.63 p	0.76 j	0.25 o	0.13 t	0.10 v
7.	I 101-10	Control	0.36 e	0.36 e	0.34 g	0.26 o	0.12 u
		Stress	0.46 b	0.81 i	0.39 d	0.28 m	0.58 u
8.	I 103-10	Control	0.88 f	0.35 f	0.31 j	0.31 j	0.34 g
		Stress	0.33 g	1.08 b	0.56 v	0.32 i	0.52 w
9.	I 131-10	Control	0.58 u	0.32 i	0.29 l	0.23 p	0.46 b
		Stress	1.08 b	1.00 d	0.36 e	0.35 f	0.34 g

Yield

All the selected genotypes except I130-09 and I 131-10 produced higher yield under stress condition than control condition. Our findings are in agreement with Hidaka Tetsushi and Md. Abdul Karim (2007) who found that plant height of the flooded plants was noticeably higher than that of the control plants. It is possible because sugarcane has constitutive aerenchyma. For this reason when it falls under stress it can easily survive by using oxyzen which is preserved by aerenchyma cell. Aerenchyma formation in the root cortex is the most studied plastic response to flooding (Visser *et al.,*2000; McDonald *et al.,*2002; Evans, 2003; Grimoldi *et al.,* 2005; Seago *et al.,*2005; Striker *et al.,*2007a). This aerenchyma tissue provides a continuous system of interconnected aerial spaces (aerenchyma lacunae) of lower resistance for oxygen transport from aerial shoots to submerged roots, allowing root growth and soil exploration under anaerobic conditions (Colmer & Greenway, 2005). It is predictable that stress from soil flooding on roots also alters shoot morphology because of the close functional interdependence between both of them. In this way, flooded plants of tolerant species are often taller than their non-flooded counterparts as a result of increases in the insertion angles and length of their aerial organs. These responses were well characterized in the dicotyledonous *Rumex palustris* by Cox *et al.*(2003; 2004) and Heydarian *et al.*(2010) among others.

Table 13. Effects of varieties on yield

Sl. No.	Name of varieties	yield
1.	Isd 39	90.67 bc
2.	Isd 45	104.05 a
3.	I 290-08	82.67 c
4.	I 127-09	96.38 ab
5.	I 130-09	98.70 ab
6.	I 85-10	95.23 ab
7.	I 101-10	80.63 c
8.	I 103-10	99.30 ab
9.	I 131-10	105.33 a

Table 14. Effects of treatments on yield

Sl. No.	Treatments	yield
1.	Control	91.885 a
2.	Stress	97.663 a

Table 15. Interation effects varieties and treatments on yield

Sl. no.	Variety	Treatment	Yield
1.	Isd 39	Control	87.8 cd
		Stress	93.6 bc
2.	Isd 45	Control	101.1 abc
		Stress	107.0 ab
3.	I 290-08	Control	75.2 de
		Stress	90.13 bcd
4.	I 127-09	Control	89.73 bcd
		Stress	103.03 abc
5.	I 130-09	Control	103.6 abc
		Stress	93.8 bc
6.	I 85-10	Control	90.83 bcd
		Stress	99.63 abc
7.	I 101-10	Control	68.67 e
		Stress	92.6 bcd
8.	I 103-10	Control	98.53 abc
		Stress	100.06 abc
9.	I 131-10	Control	111.53 a
		Stress	99.13 abc

CONCLUSIONS

It may be concluded that all the genotypes are suitable for early harvesting in waterlog prone areas. The genotypes I 127-09, I 85-10, I 101-10 and I 131-10 are suitable for harvesting any time from October to February under waterlog condition. The genotypes showed better ripening stage from December to February under control condition. All these information would help the millers and goor (jaggery) makers to develop the harvesting pattern of BSRI developed genotypes of sugarcane both in high land and waterlog prone areas.

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