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SHORT COMMUNICATION

Effects of Water-logging Stress of Some Sugarcane Genotypes under Different Locations of Bangladesh

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Water-logging is associated with monsoon rainfall, river floods, in adequate and improper drainage facilities due to unplanned road development in Bangladesh. Cane yield and juice quality loss due to water-logging depends upon genotype, environmental conditions, stage of development and duration of inundation (Orchard and Jessop, 1984). In sugarcane cultivation, water-logging is an acute problem particularly where surface drainage facilities are inadequate. Due to growing demand of cereal and vegetables crops one-third areas of land where sugarcane is grown are relatively low lying where water remains stagnant for longer period resulting poor growth and yield. Higher water table during active growth phase adversely affects stalk weight and plant population resulting 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 a relatively tolerant to high water tables and flooding (Roach and Mullins, 1985; Kang *et al.* 1986; and Deren *et al.* 1993). Well-established cane survives few months into flood, while less established cane appears to be much more vulnerable to flooding (Deren and Raid, 1997). The cause of low yield, attributed to low moisture and nitrogen in the tissue at grand growth phase. Increase in number of internodes, profuse tillering and increase in Phosphorus percent in plant but decrease in nitrogen content are the characteristics tolerance to flood condition (Pandey, 1964). Some physiological effects of cane are found due to water-logging are (i) transpiration rates are reduced due to stomata closure, (ii) rate of photosynthesis is considerably reduced presumably that causes the reduction of effective leaf areas, (iii) growth rates are drastically reduced during water-logging (iv) 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 causing from water-logging. This result is accumulation of various end products of an aerobic respiration and rapid depletion of organic compounds. The effects of water-logging on respiration rate depend on the varieties, and on its physiological age. Nutrient uptake is badly affected under water-logging where aerobic respiration by sugarcane root system is poor (Singh, 1990). It is also reported that under water-logging condition, some morphological, anatomical, physiological and biochemical changes take place in plant for the sack of adaptation/survival (Barclay and Crawford, 1982). In general, water-logging induces anaerobic condition in soil. It also leads to a real rooting resulting rapid moisture loss, increase fiber per cent and non-sugars and yellowing of leaves in anaerobic state during water-logging condition (Malik and Tomer, 2003). Therefore, present study, was undertaken to evaluate performance of eight genotypes alone with two known water-logging tolerant commercial varieties under water-logging stress condition.

The field experiments were conducted at water-logging prone farmers' field at Natore, Sirajgonj, Jamalpur districts of Bangladesh during November 13, November 14 and November 16, 2009 to December 22, December 24, December 26, 2010, respectively. Eight genotypes I 124-00, I 112-01, I 07-03, I 78-03, I 111-03, I 137-03, I 139-03 and I 231-03, two water-logging tolerant commercial varieties/genotypes Isd 39 (Standard), Isd 40 (Standard) were tested. The experiments were laid out in Randomized Complete Block Design (RCBD) with three replications. Two budded setts were planted at furrow following end to end method of planting in the month of November, 2009. Row to row distance was maintained 100 cm. The 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 was applied in two splits. Total TSP, ZnSO4, half of MP, one third urea were applied at planting. Rest of urea and MP were applied as top dressing. For controlling insect pests, chlorpyrifos (trade name: regent 3 GR) was applied @ 33 kg ha^{-1} during planting and carbofuran (trade name: furadan 5G) was applied @ 40 kg ha^{-1} in two splits between March to May, 2010. All cultural practices were done as and when required. In the month of June 15 to October 15 the experimental fields were inundated 30-90 cm for 120 d to create water-logging stress condition. Tillering was recorded at an interval of 30 d starting from March until August. Millable cane, cane yield and Brix per cent were recorded at harvest in the month of December 22, December 24, December 26, 2010, respectively. Brix reading was taken by hand refractometer.

Stalk height at harvest: At harvest 20 cane stalks were selected randomly and the length of individual cane stalk was measured from the bottom to the top using a meter tape. The stalk height of cane was expressed in meter (m).

Cane diameter: Slide calipers from 20 randomly selected stalks measured the stalks diameter. Average of bottom, middle and top diameter was considered as the actual diameter of the cane stalks. The cane diameter was expressed in centimeter (cm).
The data were analyzed following slandered statistical procedures (Gomez and Gomez, 1984) and mean difference were adjusted by Duncan's Multiple Range Test (DMRT) using a computer operated program named MSTAT.

Tiller production

The number of tiller production of sugarcane is an important growth parameter, affected in different genotypes. Significantly the highest number of tiller production was observed in Isd 39 ($155.8\times10^3ha^{-1}$) followed by I 231-03 ($155.4 \times10^3ha^{-1}$) and Isd 40 ($149.4 \times 10^3ha^{-1}$). The lowest tiller production was recorded in I 78-03 ($123.9 \times 10^3ha^{-1}$) under water logging stress condition (Table 1). Number of tiller production was significantly affected by different locations. The highest number of tiller was produced at Jamalpur location. Statistically similar numbers of tiller production were observed in Natore and Sirajgonj locations (Table 2). The interaction effects of genotypes and locations on number of tiller production were significant. The highest number of tiller production was observed in I 231-03 ($174.7 \times 10^3ha^{-1}$) at Jamalpur location and the lowest number of tillers was obtained in I 07-03 ($115.4\times10^3ha^{-1}$) at Sirajgonj location (Table 3). The results are in agreement with this finding of Islam *et al.* (2011a) and Islam *et al.* (2007) who also obtained number of tillers per hectare varied to different sugarcane genotypes.

Millable cane production

The number of millable cane production varied significantly with varying genotypes of sugarcane. The highest number of millable cane was observed in I 231-03 ($131.6 \times 10^3 ha^{-1}$) and the lowest number of millable cane was found in I 137-03 ($100.6 \times 10^3 ha^{-1}$) under water logging stress condition (Table 1). The locations effects on number of millable cane was statistically significant. The highest number of millable cane ($120.0 \times 10^3 ha^{-1}$) was observed at Jamalpur location and lowest number of millable cane ($110.4 \times 10^3 ha^{-1}$) was observed in Sirajgonj location. Statistical similar millable cane was observed in Natore and Sirajgonj locations (Table 2). An interaction effect of genotypes and locations on number of millable cane production was significant. The highest number of millable cane was found in I 231-03 ($141.9 \times 10^3 ha^{-1}$) at Jamalpur location. The lowest number of millable cane was observed in I 07-03 ($93.9 \times 10^3 ha^{-1}$) at Sirajgonj location (Table 3). Similar results were also reported by Islam *et al.* (2011b) and Hasan *et al.* (2003) under water-logging stress condition.

Cane yield

The data on cane yield was affected significantly by different genotypes (Table 1). The highest cane yield was observed in Isd 39 (95.7 t ha^{-1}) and the lowest cane yield was found in I 137-03 (62.0 t ha^{-1}) (Table 1). Different locations showed no significant effects of cane yield.

It was ranged in 73.9 t ha^{-1} to 76.4 t ha^{-1} (Table 2). Interaction of genotypes and locations showed significant effects on cane yield. The highest cane yield was observed in Isd 39 (99.7 t ha^{-1}) at Jamalpur location. The lowest cane yield was found in I 137-03 (60.4 t ha^{-1}) at Natore location (Table 3). The results were in agreement with Islam *et al.* (2011a) and Rahman *et al.* (2010) described different sugarcane varieties/promising genotypes and revealed different trend of cane yield per unit area.

Stalk height

It was seen from the Table 4 that the genotypes were significantly affected on stalk height. The highest stalk height was obtained in Isd 39 (2.9 m) and the lowest stalk height was observed in I 137-03 (2.2 m) under water-logging stress condition. The stalk height was significantly affected at different locations. The highest stalk height (2.8m) at Jamalpur location and the lowest and similar stalk height were observed in Natore and Sirajgonj location (Table 5). Interaction effects of genotypes and locations on stalk height were significant. The highest stalk height was observed in I 231-03 (3.3 m) at Jamalpur location. The lowest stalk height was observed in I 139-03 (2.0 m) at Sirajgong location (Table 6). These results are in agreement with findings of Alam *et al.* (2010) and Rahman *et al.* (2012).

Stalk diameter

Stalk diameter varied significantly at different genotypes of sugarcane. The highest stalk diameter was observed in Isd 39 (2.8 cm) and the lowest stalk diameter was observed in I 137-03 (2.1 cm) (Table 4). The location effect of stalk diameter was statistically significant. The highest stalk diameter (2.6 cm) was observed at Jamalpur location and the lowest diameter (2.4 cm) was observed at Sirajgonj and Natore locations. Stalk diameter was found to be statistical similar observed at Natore and Sirajgonj locations (Table 5). Interaction effects of genotypes and locations on stalk diameter were found significant. The highest stalk diameter was found in I 231-03 (3.1 cm) at Jamalpur location and the lowest stalk diameter was observed in I 111-03 (2.0 cm) at Sirajgonj location (Table 6). The findings of the present experiment are in agreement with Alam *et al.* (2010) and Rahman *et al.* (2012).

Brix (%)

Table 4 shows the significantly highest Brix per cent at water-logging stress condition in I 124-00 (20.6%), followed by I 07-03 (20.2%), I 111-03 (20.2%), variety Isd 40 (20.1%), while the lowest Brix per cent was obtained in I 78-03 (17.7%). The effects of locations on Brix per cent was recorded statistically significant. The highest Brix per cent (19.8 %) was observed at Jamalpur location, and the lowest Brix per cent (19.5 %) was observed at Sirajgonj and Natore locations. Statistical similar Brix per cent was observed in Natore and Sirajgonj location (Table 5). Interaction effects of genotypes and locations on Brix per cent were significant. The highest Brix per cent was found in I 124-00 (21.0 %) at Jamalpur location. The lowest Brix per cent was observed in I 78-03 (17.3 %) at Sirajgonj location (Table 6). These results were in agreement with findings of Islam *et al.* (2011a), Islam *et al.* (2011b) and Islam *et al.* (2007) who studied Brix per cent of sugarcane varieties/clones and found different levels of Brix per cent.

Tolerance rating scale

Tolerance rating scale was measured on the basis of tiller number, number of millable cane, cane yield, stalk height, stalk diameter, Brix per cent, greenness of leaves and visual observation under water-logging stress condition. It was revealed that I 231-03, Isd 39, Isd 40 were highly tolerant having tolerance rating scale 1 and I 124-00 and I 112-01 were found to be tolerant to water-logging stress having tolerance rating 2. Genotypes I 07-03, I 78-03, I 111-03, I 137-03 and I 139-03 were found to be moderately tolerant to water-logging stress condition having tolerance rating scale 3 (Table 1). The locations effect of tolerance rating scale was found to be tolerant to water-logging stress having tolerance rating 2 (Table 2). Interaction effects of genotypes and locations on tolerance rating scale were found highly tolerant having tolerance rating scale 1 in I 231-03, Isd 39 and Isd 40 at all locations (Table 3). These findings are supported by Islam *et al.* (2011a) and Islam *et al.* (2011b).

It may be concluded that genotype I 231-03 may be considered as highly tolerant on the basis of number of tiller, number of millable cane, cane yield, stalk height and stalk diameter natural water-logging stress condition.

Table 1. Genotypes effects on number of tillers (10^3ha^{-1}), number of millable cane (10^3ha^{-1}), cane yield ($t\ ha^{-1}$) and tolerance rating scale under water-logging stress condition

Genotypes	Number of tillers (10^3ha^{-1})	Number of millable cane (10^3ha^{-1})	Cane yield ($t\ ha^{-1}$)	*** Tolerance rating scale (1-5)
I 124-00	131.1 de	111.0 b-d	78.0 b	2b
I 112-01	138.5 b-d	112.0 b-d	73.8 bc	2b
I 07-03	125.4 de	100.6 d	66.5 cd	3a
I 78-03	123.9 e	102.5 cd	64.9 cd	3a
I 111-03	125.8 de	102.3 cd	63.0 d	3a
I 137-03	136.5 c-e	108.2 cd	62.0 d	3a
I 139-03	150.6 ab	125.7 ab	65.7 cd	3a
I 231-03	155.4 a	131.6 a	90.2 a	1c
Isd 39 (Standard)	155.8 a	126.4 ab	95.7 a	1c
Isd 40 (Standard)	149.4 a-c	119.1 a-c	90.0 a	1c
Level of significance	**	**	**	**
CV (%)	9.81	14.08	1186	18.23
LSD (0.05)	12.98	15.13	8.39	0.40

** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant
*** Tolerance rating scale (1-5), where,1 = highly tolerant, 2 = tolerant, 3 = moderately tolerant, 4 = intolerant and 5 = highly intolerant

Table 2. Location effects on number of tillers (10^3ha^{-1}), number of millable cane (10^3ha^{-1}), cane yield ($t\ ha^{-1}$) and tolerance rating scale under water-logging stress condition

Locations	Number of tillers (10^3ha^{-1})	Number of millable cane (10^3ha^{-1})	Cane yield ($t\ ha^{-1}$)	*** Tolerance rating scale (1-5)
Natore	135.6 b	111.5 b	74.6	2
Sirajgonj	131.1 b	110.4 b	76.4	2
Jamalpur	151.1 a	120.0 a	73.9	2
Level of significance	**	**	NS	NS
CV (%)	9.81	14.08	11.86	18.23
LSD (0.05)	7.09	8.28	-	-

** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant
*** Tolerance rating scale (1-5), where, 1 = highly tolerant, 2 = tolerant, 3 = moderately tolerant, 4 = intolerant and 5 = highly intolerant.

Table 3. **Interaction effects of genotypes and locations on number of tillers (10^3 ha^{-1}), number of millable cane (10^3ha^{-1}), cane yield (t ha^{-1}) and tolerance rating scale under water- logging stress condition.**

Genotypes	Locations	Number of tillers (10^3ha^{-1})	Number of millable cane (10^3ha^{-1})	Cane yield (t ha^{-1})	*** Tolerance rating scale (1-5)
I 124-00	Natore	124.1g-i	107.9 b-f	76.8 b-g	2 b
	Sirajgonj	141.4 c-i	117.7 a-f	86.4 a-e	1 c
	Jamalpur	127.7 f-i	107.5 b-f	70.9 d-g	2 b
I 112-01	Natore	134.9 e-i	108.7 b-f	73.8 c-g	2 b
	Sirajgonj	132.9 e-i	107.7 b-f	70.1 e-g	2 b
	Jamalpur	147.9 b-g	119.7 a-f	77.4 b-g	2 b
I 07-03	Natore	124.0 g-i	98.2 d-f	66.5 g	3 a
	Sirajgonj	115.4 i	93.9 f	68.8 fg	3 a
	Jamalpur	136.7 e-i	109.6 b-f	64.1 g	3 a
I 78-03	Natore	123.9 g-i	102.5 c-f	66.2 g	3 a
	Sirajgonj	118.1 hi	98.53 d-f	64.2 g	3 a
	Jamalpur	129.7 e-i	106.5 b-f	64.2 g	3 a
I 111-03	Natore	121.8 g-i	95.93 ef	63.0 g	3 a
	Sirajgonj	116.8 hi	98.60 d-f	63.0 g	3 a
	Jamalpur	138.8 d-i	112.3 a-f	63.0 g	3 a
I 137-03	Natore	130.8 e-i	104.8 b-f	60.4 g	3 a
	Sirajgonj	126.1 f-i	105.8 b-f	64.4 g	3 a
	Jamalpur	152.5 a-f	113.8 a-f	61.4 g	3 a
I 139-03	Natore	147.2 b-g	125.7 a-f	61.0 g	3 a
	Sirajgonj	140.9 c-i	121.0 a-f	68.0 fg	3 a
	Jamalpur	163.6 a-d	130.4 a-d	68.0 fg	3 a
I 231-03	Natore	155.4 a-e	135.6 ab	91.6 ab	1 c
	Sirajgonj	136.1 e-i	117.2 a-f	95.2 a	1 c
	Jamalpur	174.7 a	141.9 a	83.9 a-f	1 c
Isd 39 (Standard)	Natore	151.5 a-f	123.7 a-f	95.7 a	1 c
	Sirajgonj	142.8 c-h	124.4 a-f	91.7 ab	1 c
	Jamalpur	173.2 ab	131.1 a-c	99.7 a	1 c
Isd 40 (Standard)	Natore	142.1 c-i	111.5 a-f	90.0 a-c	1 c
	Sirajgonj	140.1c-i	119.0 a-f	92.6 ab	1 c
	Jamalpur	166.1 a-c	126.9 a-e	87.3 a-d	1 c
Level of significance	-	**	**	**	**
CV (%)	-	9.81	14.08	11.86	18.23
LSD (0.05)	-	22.42	26.21	14.54	0.69

** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant
*** Tolerance rating scale (1-5), where, 1 = highly tolerant, 2 = tolerant, 3 = moderately tolerant, 4 = intolerant and 5 = highly intolerant.

Table 4. Genotypes effects on stalk height (m), stalk diameter (cm) and Brix per cent under water-logging stress condition.

Genotypes	Stalk height (m)	Stalk diameter (cm)	Brix (%)
I 124-00	2.7 bc	2.5 bc	20.6 a
I 112-01	2.6 b-d	2.5 bc	19.6 c
I 07-03	2.4 d-f	2.4 cd	20.2 b
I 78-03	2.5 c-e	2.5 bc	17.7 e
I 111-03	2.3 ef	2.2 d	20.2 b
I 137-03	2.2 f	2.1 d	19.5 c
I 139-03	2.3 ef	2.2 d	18.5 d
I 231-03	2.8 ab	2.7 ab	19.8 c
Isd 39 (Standard)	2.9 a	2.8 a	19.5 c
Isd 40 (Standard)	2.7 a-c	2.6 a-c	20.1 b
Level of significance	**	**	**
CV (%)	9.07	10.55	1.40
LSD (0.05)	0.22	0.24	0.25

** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant

Table 5. Locations effect on stalk height (m), stalk diameter (cm) and Brix per cent under water-logging stress condition.

Locations	Stalk height (m)	Stalk diameter (cm)	Brix (%)
Natore	2.4 b	2.4 b	19.5b
Sirajgonj	2.4 b	2.4 b	19.5b
Jamalpur	2.8 a	2.6 a	19.8a
Level of significance	**	**	**
CV (%)	9.07	10.55	1.40
LSD (0.05)	0.12	0.13	0.14

** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant

Table 6. Interaction effects of genotypes and locations on stalk height (m), stalk diameter (m) and Brix per cent under water-logging stress condition.

Genotypes	Locations	Stalk height (m)	Stalk diameter (cm)	Brix (%)
I 124-00	Natore	2.4 f-l	2.4 c-h	20.4 b
	Sirajgonj	2.5 f-k	2.5 c-h	20.4 bc
	Jamalpur	3.2 ab	2.6 a-f	21.0 a
I 112-01	Natore	2.2 h-l	2.4 d-h	19.4 hi
	Sirajgonj	2.6 e-i	2.3 d-h	19.5 f-i
	Jamalpur	3.0 a-e	2.8 a-d	20.0 b-f
I 07-03	Natore	2.1 j-l	2.3 d-h	20.1 b-e
	Sirajgonj	2.4 f-l	2.2 e-h	20.3 b-d
	Jamalpur	2.7 d-h	2. a-e	20.2 b-d
I 78-03	Natore	2.1 j-l	2.2 e-h	17.7 lm
	Sirajgonj	2.5 e-j	2.5 c-h	17.3 m
	Jamalpur	3.0 a-e	2.8 a-d	18.1 kl
I 111-03	Natore	2.2 i-l	2.0 h	20.3 b-d
	Sirajgonj	2.3 g-l	2.4 d-h	20.3 b-d
	Jamalpur	2.4 f-l	2.1 gh	19.9 b-g
I 137-03	Natore	2.2 i-l	2.2 e-h	19.4 hi
	Sirajgonj	2.3 g-l	2.2 e-h	19.3 i
	Jamalpur	2.1 j-l	2.1g-h	19.8 c-h
I 139-03	Natore	2.3 g-l	2.3 d-h	18.3 jk
	Sirajgonj	2.0 l	2.2 e-h	18.7 j
	Jamalpur	2.7 d-h	2.1f-h	18.6 j
I 231-03	Natore	2.8 b-f	2.5 c-h	19.7 ei
	Sirajgonj	2.3 g-l	2.6 b-g	19.4 hi
	Jamalpur	3.3 a	3.1 a	20.2 b-d
Isd 39 (Standard)	Natore	2.7 c-g	2.7 a-e	19.5 g-i
	Sirajgonj	2.9 a-e	2.8 a-d	19.3 i
	Jamalpur	3.1 a-c	2.9 a-c	19.8 d-h
Isd 40 (Standard)	Natore	2.7 c-g	2.5 c-h	19.8 d-h
	Sirajgonj	2.3 g-l	2.3 d-h	20.1 b-e
	Jamalpur	3.1 a-d	3.1 ab	20.2 b-d
Level of significance	-	**	**	**
CV (%)	-	9.07	10.55	1.40
LSD (0.05)	-	0.37	0.42	0.45

** Significant at 1% level of probability, * Significant at 5% level of probability, NS = Not significant

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