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Growth and phasic development of sugarcane genotypes under waterlogged and normal condition in subtropical India

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ABSTRACT

A field experiment was conducted during spring seasons of 2009 – 10 and 2010 – 11 under sandy loam soil at Sugarcane Research Institute, Pusa, Bihar to evaluate nine sugarcane genotypes for morpho- physiological characteristics and sugar yield under waterlogged and normal conditions. Results showed that the genotype 'BO 147' recorded higher plant height at all the stages of crop growth under both the conditions. The magnitude of increase in plant height on mean basis at 180, 210, 240 and 270 days after planting over 150 DAP were 44.5, 65.3, 84.4 and 98.5 per cent, respectively under waterlogged condition, whereas these were 42.9, 72.4, 94.4 and 106.4 per cent, respectively under normal condition. The genotype 'BO 147' was followed by 'BO 146' and showed the highest leaf area index at all the stages of crop growth. A significant increase in dry matter accumulation was observed with the genotype 'BO 147'at all the stages of crop growth under both the conditions. However, it posses maximum absolute growth rate during 60 – 120 DAP (0.93 g/plant/ day) and 120 – 180 DAP (2.09 g /plant/ day) under waterlogged condition and during 60 – 120 DAP (0.81 g/ plant/ day) only under normal condition. Significant genotypic differences on relative growth rate was observed during 180 – 240 DAP only during both the conditions. Significantly higher sugar yield was obtained by the genotype 'BO 147' in waterlogged (7.50 t/ ha) and normal condition (10.04 t/ ha) closely followed by 'BO 146' with a values of 7.12 and 9.53 t/ ha under waterlogged and normal conditions, respectively with 25.3 per cent reduction under waterlogged condition. The mean reduction for sugar yield was 31.4 per cent (2.76 t/ ha) under waterlogged condition. Though the genotype 'BO 76' was worse sufferer and observed 49% reduction in sugar yield over same genotype in normal condition. However, least affected genotype for sugar yield was 'CoLk 94184' (17.1 %).

Key words: Growth parameters, sugarcane genotypes, sugar yield, water logging

Sugarcane, the only agro-industrial crop of Bihar, occupies an area of 0.25 million hectares with a production of 12.8 mt and the productivity is 51.4 t/ ha. The cultivation of sugarcane in most of the part of north Bihar faces the problem of water logging and poor aeration, resulting in significant morphological and physiological changes besides limiting the cane and sugar yields. In the water logged areas of Bihar, the water stagnation starts after onset of monsoon in last week of June and the rainfall continued up to September. Since such areas have poor drainage, the water remains in the field until October and the land is tillable only in January. Therefore, planting of spring sugarcane in the months of February- March is common. Losses due to water logging mainly depend upon genotypes and depth and duration of water logging. If water logging occurs in early grand growth stage as in the months of July- August, tolerant genotypes also fail to give desired yield. As water logging is an important constraint, tolerance is an adaptive feature of sugarcane genotypes grown successfully under these conditions. High yielding sugarcane genotypes are relatively less tolerant of water logging; however, they vary in degree of tolerance. Vigorous early growth and development of genotypes enable the crop to escape with water logging during early vegetative stage, and the plants as good initiation before adverse effects of water logging set in. The use of old and low yielding genotypes with susceptibility to water logging are the major causes of low yield of sugarcane under such conditions; identification of water logging tolerant genotype is the single factor to sustain the sugarcane productivity in the region. Keeping in view, the present investigation was undertaken for evaluation of nine genotypes of sugarcane; *viz.,* 'BO 76', 'BO 91', 'BO 151', 'BO 146', 'BO 147', 'CoLk 94184', 'UP 9530', 'CoP 042' and 'CoSe 96436' with special reference to growth and phasic development under waterlogged and normal condition of Bihar.

MATERIALS AND METHODS

A field experiment was conducted at Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar under water logged and normal condition during 2009 - 10 and 2010 - 11. The soil of the experimental plot under both the conditions was sandy loam with pH 8.0 and 8.3, organic carbon 0.52 and 0.45 %, free $CaCO_3$ 29.8 and 31.4%, EC 0.29 and 0.23 dS/m

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and 251 and 235 kg N, 28.5 and 24.6 kg P_2O_5 and 110 and 100 kg available K_2O/ ha, under waterlogged and normal condition, respectively. The nine genotypes of sugarcane, *viz,* 'BO 76', 'BO 91', 'BO 151', 'BO 146', 'BO 147', 'CoLk 94184', 'UP 9530', 'CoP 042' and 'CoSe 96436' were evaluated in randomized block design with three replications. All the genotypes were uniformly fertilized with 150 kg N, 85 kg P_2O_5 and 60 kg K_2O/ ha. The total quantity of phosphorus and potassium were applied as basal along with 50 % N, whereas remaining N was top dressed in two equal splits after the first irrigation and at the time of earthing up during both the conditions in each year. Urea, diammonium phosphate and muriate of potash were used as sources of nitrogen, phosphorus and potassium. The different genotypes of sugarcane were planted in second fortnight of February and harvested in first fortnight of January during both the years. All the recommended package and practices were followed for raising the healthy crop. The total rainfall received during the crop season was 914.8 mm in 2009-10 and 760.6 mm in 2010-11. The average depth of water in the crop field under water logged condition in the month of July, August, September and October was 86, 110.9, 177.8 and 37.5 cm respectively, during 2009-10 and 2010-11. For measurement of plant height, ten randomly selected plants from net plot area were located and tagged. Height of these plants were recorded in centimetres from ground level to the base of the spindle cluster at monthly interval starting from 150 days after planting upto 270 DAP and averaged. The leaf area index was calculated by measuring length and maximum width of leaves. Entire leaves of one meter marked row length in second row of each plot were categorized in to small, medium and large and from each group leaf area of two leaves were determined by multiplying length, width, number of leaves and a correction factor (0.6274) determined by Bathla and Sharma (1978). LAI = green leaf area/ ground area. The relative growth rate (RGR) is expressed in g/g/day and mathematically calculated by using standard formula.

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

Where, $\ln W_1$ and $\ln W_2$ indicates the natural logarithm of dry weights (g) of the plant at times t_1 and t_2 respectively. Absolute growth rate (AGR) in terms of dry matter was calculated by using the standard formula.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are the dry weights (g) of plant at times t_1 and t_2 in days, respectively

Sugar yield was calculated as; sugar yield (t/ ha) = [S – 0.4 (B - S) x 0.73] x cane yield (t/ ha)/100; Where, S and B are sucrose and brix in cane juice, respectively.

RESULTS AND DISCUSSION

Plant height

Significant variation in plant height was observed among the genotypes in all the stages of observations (Table 1). These findings showed that on mean basis plant attained almost 50.4 and 48.5 per cent plant height at 150 DAP (Mid July), 72.8 and 69.2 per cent plant height at 180 DAP (Mid August), 83.3 and 83.5 per cent plant height at 210 DAP (Mid September) and 92.9 and 94.2 per cent plant height at 240 DAP (Mid October), respectively under waterlogged and normal condition irrespective of the genotypes. Further, rate of increase of plant height was observed to be maximum during 150 to 180 DAP, which decreased with advancement in age of the crop. Plant height recorded at 150 DAP was maximum with the genotype 'BO 147' under waterlogged (147.4 cm) and normal condition (150.9 cm). Reflecting similar trend at 180, 210, 240 and 270 DAP under both the conditions. These results are in close conformity with the earlier findings of Kumar (2009). The mean values of plant height recorded at 150 (132.7 cm) and 180 DAP (191.7 cm) under waterlogged condition was comparatively higher than the plant height recorded at 150 DAP (128.9 cm) and 180 DAP (184.2 cm) under normal condition. This was due to the higher moisture level in the field under waterlogged condition before onset of monsoon create congenial environment for early shoot growth.

Leaf area index

Data pertaining to LAI at six crop growth stages have been recorded for both waterlogged and normal conditions (Fig 1). LAI increased at a rapid rate from 120 to 150 DAP. Thereafter, its increase was at decreasing rate under both the situations. The decrease in LAI towards maturity of sugarcane was due to natural senescence of older leaves and mortality of late formed tillers. Significant genotypic variation was recorded in terms of this parameter. Genotype 'BO 147' showed the highest values of LAI at 60 (0.798 and 0.821), 90 (1.607 and 1.745), 120 (2.908 and 2.881), 150 (3.806 and 3.977), 180 (4.52 and 4.60) and 210 (4.95 and 4.96) days after planting under waterlogged and normal condition, respectively. The next best genotype in terms of LAI was 'BO 146'.

Dry matter accumulation

A perusal of the data on dry matter accumulation it was evident that up to 60 DAP (April end) only 2.8 and 1.95 per cent dry matter was accumulated under waterlogged and normal condition, respectively (Table 2). Plants accumulated on an average 24.1 and 17.1 per cent dry matter up to 120 DAP, 73.3 and 51.0 per cent dry matter up to 180 DAP and 93.5 and 93.8 percent dry matter up to 240 DAP, respectively under waterlogged and normal condition. Although rate of dry matter accumulation was the highest during 60 – 120 DAP. Kumar *et al.* (2010) reported similar variation in dry matter accumulation pattern of sugarcane. Among the genotypes, 'BO

Table 1 Plant height (cm) as affected periodically by various genotypes of sugarcane under waterlogged and normal condition (pooled data of 2 cropping season)

	150 DAP	180 DAP	210 DAP	240 DAP	270 DAP
Genotype			*Waterlogged condition*		
'BO 76'	134.0	186.8	218.5	234.6	253.5
'BO 91'	130.1	191.9	214.4	252.3	269.8
'BO 151'	115.0	177.3	199.5	225.9	246.0
'BO 146'	143.7	202.2	232.8	256.8	272.4
'BO 147'	147.4	205.5	234.4	263.2	292.0
'CoLk 94184'	127.7	180.5	213.9	231.2	255.3
'UP 9530'	137.9	199.9	227.7	254.5	268.7
'CoP 042'	120.3	184.6	208.4	236.7	253.4
'CoSe 96436'	138.2	197.0	224.1	247.2	259.9
Mean	**132.7**	**191.7**	**219.3**	**244.7**	**263.4**
SEm ±	5.95	8.79	10.71	11.26	12.56
CD (P=0.05)	17.8	26.3	32.1	33.8	37.6
Genotype			***Normal condition***		
'BO 76'	132.7	189.6	228.6	244.3	259.4
'BO 91'	124.7	187.0	226.0	252.6	267.1
'BO 151'	102.6	162.8	206.1	240.3	256.7
'BO 146'	130.2	189.9	233.5	268.6	285.1
'BO 147'	150.9	214.0	252.1	283.3	308.8
'CoLk 94184'	134.9	175.1	210.6	243.6	252.0
'UP 9530'	127.3	183.8	220.1	250.5	268.4
'CoP 042'	119.9	163.2	197.6	219.9	235.3
'CoSe 96436'	136.8	192.5	225.5	251.9	261.2
Mean	**128.9**	**184.2**	**222.2**	**250.6**	**266.0**
SEm ±	6.15	11.80	10.71	11.10	12.70
CD (P=0.05)	18.5	35.4	32.1	33.3	38.1

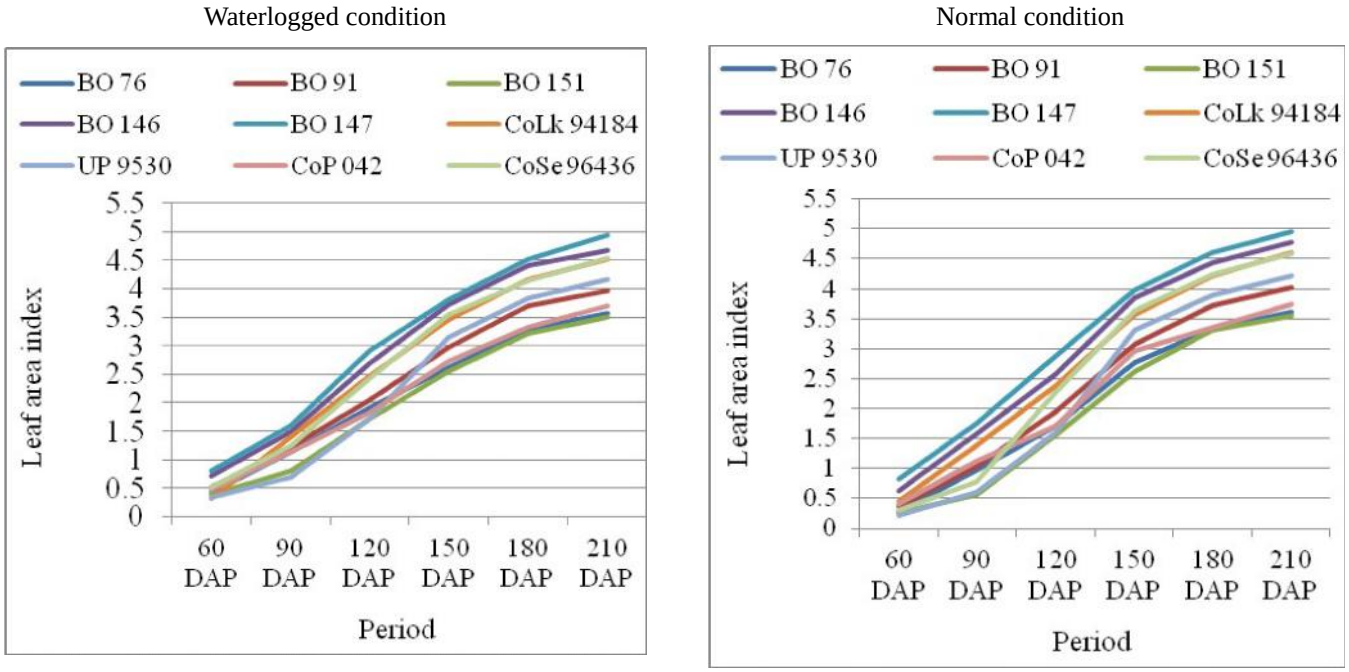

Fig 1 Mean leaf area index in sugarcane as influenced periodically by various genotypes under waterlogged and normal conditions

Table 2 Mean total dry matter accumulation (g/ plant) in sugarcane as influenced periodically by different genotypes under waterlogged and normal condition (pooled data of 2 cropping season)

	60 DAP	120 DAP	180 DAP	240 DAP	300 DAP
Genotype			*Waterlogged condition*		
'BO 76'	6.1	53.7	177.8	201.8	218.5
'BO 91'	5.1	47.1	143.6	177.3	194.8
'BO 151'	5.4	50.8	153.2	196.8	210.5
'BO 146'	6.7	58.7	176.4	240.4	256.3
'BO 147'	7.6	63.2	188.7	252.5	266.4
'CoLk 94184'	6.4	54.3	165.6	241.9	254.7
'UP 9530'	6.9	57.8	174.5	194.1	202.3
'CoP 042'	7.4	62.1	186.5	235.3	253.1
'CoSe 96436'	6.8	61.4	183.4	235.8	256.4
Mean	**6.5**	**56.6**	**172.2**	**219.5**	**234.8**
SEm ±	0.24	2.36	7.74	10.15	11.4
CD (P=0.05)	0.7	7.1	23.2	30.4	34.3
Genotype			***Normal condition***		
'BO 76'	4.5	44.2	133.2	265.4	282.3
'BO 91'	4.0	39.3	115.2	214.2	235.4
'BO 151'	4.7	42.6	123.8	232.9	246.5
'BO 146'	5.9	52.3	150.7	274.8	293.4
'BO 147'	6.8	55.6	159.2	282.0	295.6
'CoLk 94184'	6.3	52.2	156.4	250.7	272.5
'UP 9530'	4.8	40.8	123.3	260.2	276.9
'CoP 042'	5.5	47.9	153.6	276.7	292.2
'CoSe 96436'	5.9	50.2	154.2	278.1	292.8
Mean	**5.4**	**47.2**	**141.1**	**259.4**	**276.4**
SEm ±	0.22	1.97	6.72	12.33	12.40
CD (P=0.05)	0.7	5.9	20.1	37.0	37.2

147' recorded significantly higher dry matter accumulation. The dry matter accumulation recorded at 60, 120, 180, 240 and 300 DAP by the genotype 'BO 147' indicated higher values of 7.6, 63.2 188.7, 252.5 and 266.4 g/ plant respectively under waterlogged condition compared to 6.8, 55.6, 159.2, 282.0 and 295.6 g/ plant respectively under normal condition. The higher leaf area index in 'BO 147' genotypes of sugarcane was mainly attributed to higher total dry matter production, which represents efficient utilization of the resources due to higher leaf area.

Absolute growth rate

AGR of sugarcane increased to 129.8 and 122.9 per cent in between 120 – 180 DAP as compared to 60 – 120 DAP under waterlogged and normal condition, respectively. It was reduced later in between 180 – 240 DAP and 240 – 300 DAP under both the conditions (Table 3). The reduction in AGR towards maturity was the natural phenomenon to check the active growth of plants during its life cycle. Genotypic differences in respect to AGR were found to be significant during all the phases of growth under both the conditions though, definite trend was not being observed. Maximum AGR at 60 – 120 DAP was recorded by the genotype 'BO 147' (0.93 and 0.81 g/ plant/ day) under waterlogged and normal condition, respectively was closely followed by the genotype 'CoSe 96436' (0.91 g/ plant/ day) and 'CoP 042' (0.91g/ plant/ day) under waterlogged condition and 'CoLk 94184' under normal condition. Similarly higher AGR during 120 – 180 DAP under waterlogged condition was recorded by the genotype 'BO 147' (2.09 g/ plant/ day). However, higher AGR at this stage under normal condition was noticed due to the genotype 'CoP 042' (1.76 g/ plant/ day). Genotype 'CoLk 94184' recorded highest AGR (1.27 g/ plant/ day) was significantly superior to rest of the genotypes under water logged condition. However, maximum AGR during 180

– 240 DAP under normal condition was obtained due to UP 9530 (2.28 g/ plant/ day). Maximum AGR during 240 – 300 DAP was obtained due to the genotype 'CoSe 96436' (0.34 g/ plant/ day) was significantly superior to rest of the genotypes under waterlogged condition. Though, significantly higher AGR under normal condition was due to the genotype 'CoLk 94184' (0.36 g/ plant/ day).

Relative growth rate

Results indicates higher values of RGR during early growth stages (60 -120 DAP). Genotypes failed to cause significant impact on RGR during 60 – 120, 120 – 180 and 240 – 300 DAP under both the conditions. However, significant impact was recorded during 180 – 240 DAP under both the conditions (Fig 2). During 180 – 240 DAP, under waterlogged condition

Table 3 Mean absolute growth rate of dry matter of sugarcane (g/ plant/day) as affected periodically by different genotypes under waterlogged and normal condition (pooled data of 2 cropping season)

Genotype	60-120 DAP	120-180 DAP	180 – 240 DAP	240 – 300 DAP
	Waterlogged condition			
'BO 76'	0.79	2.07	0.40	0.28
'BO 91'	0.70	1.61	0.56	0.29
'BO 151'	0.76	1.71	0.73	0.23
'BO 146'	0.87	1.96	1.07	0.27
'BO 147'	0.93	2.09	1.06	0.23
'CoLk 94184'	0.80	1.86	1.27	0.21
'UP 9530'	0.85	1.95	0.33	0.14
'CoP 042'	0.91	2.07	0.81	0.30
'CoSe 96436'	0.91	2.03	0.87	0.34
Mean	**0.84**	**1.93**	**0.79**	**0.25**
SEm ±	0.028	0.062	0.029	0.006
CD (P=0.05)	0.08	0.19	0.09	0.02
Genotype		***Normal condition***		
'BO 76'	0.66	1.48	2.20	0.28
'BO 91'	0.59	1.27	1.65	0.35
'BO 151'	0.63	1.35	1.82	0.23
'BO 146'	0.77	1.64	2.07	0.31
'BO 147'	0.81	1.73	2.05	0.23
'CoLk 94184'	0.77	1.74	1.57	0.36
'UP 9530'	0.60	1.38	2.28	0.28
'CoP 042'	0.71	1.76	2.05	0.26
'CoSe 96436'	0.74	1.73	2.07	0.25
Mean	**0.70**	**1.56**	**1.97**	**0.28**
SEm ±	0.021	0.052	0.068	0.006
CD (P=0.05)	0.06	0.15	0.20	0.02

significantly higher RGR was recorded due to the genotype 'CoLk 94184' (0.006 g/ g/ day) was statistically similar to 'BO 146' and 'BO 147' and significantly superior to rest of the genotypes. However, maximum RGR at that period under normal condition was obtained due to the genotype 'UP 9530' (0.012 g/ g/ day) was significantly superior to 'CoLk 94184' (0.008 g/ g/ day) and 'BO 147' (0.009 g/ g/ day). There were no definite trend in the RGR values at any of the crop growth stage under waterlogged and normal condition was due to low rate of dry matter accumulation beyond 120 DAP and accumulation of dry matter at initial stages was highly variable.

Number of internodes per cane

It was observed from the table 4 that under waterlogged condition, the mean number of internodes per cane was 19 which were reduced by 10.5 % than normal condition. Significantly higher number of internodes per cane was recorded by the genotype 'BO 151' (21) was significantly superior to 'CoLk 94184' (18) and 'CoP 042' (18) and statistically on a par with rest of the genotypes. However, under normal condition 'BO 151' (23) was significantly superior to the genotype 'BO 91' (20), 'CoLk 94184' (20) and 'CoP 042' (19). More *et al*. (2010) also noticed significant variations in number of internodes per cane in different sugarcane genotypes.

Length of internodes

Length of internode was not affected significantly by the genotypes under waterlogged condition. However, significant impact was noticed under normal condition (Table 4). The mean values of genotypes in respect to internode length under waterlogged (11) and normal conditions (11) were similar.

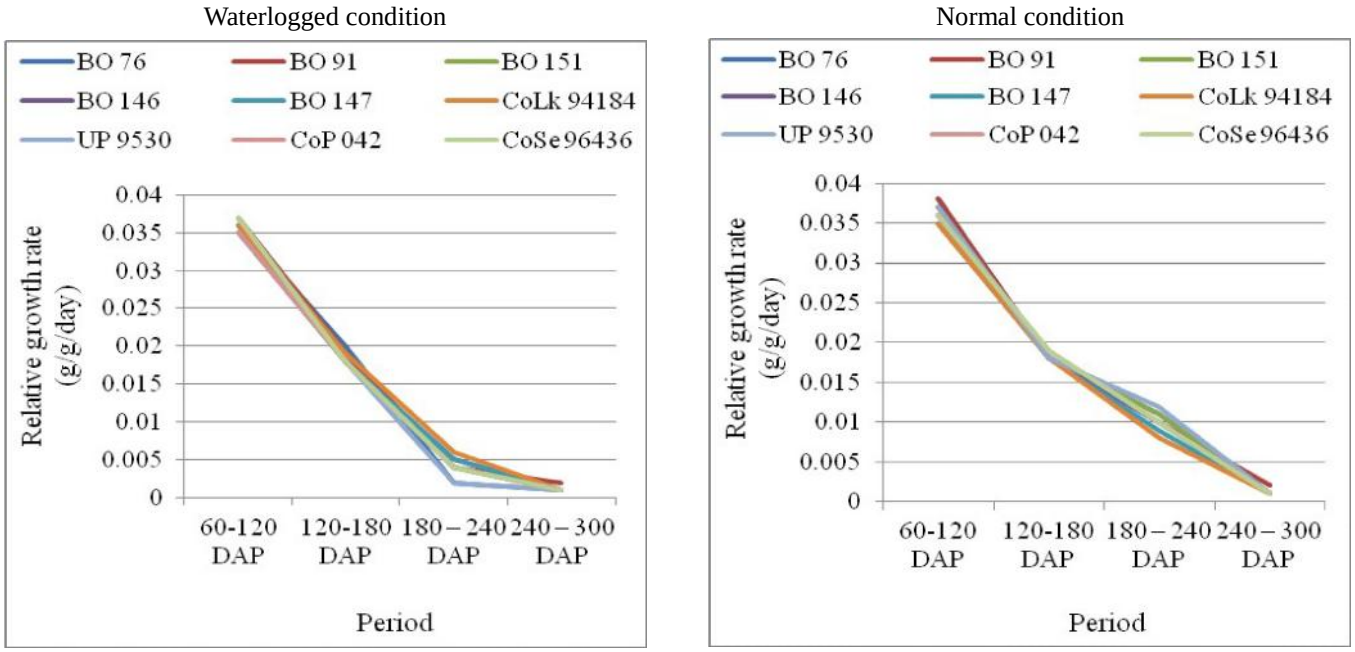

Fig 2 Mean relative growth rate of dry matter of sugarcane (g/ g/ day) as affected periodically by different genotypes under waterlogged and normal conditions

Table 4. Number of internodes, length of internode, number of nodes having aerial roots and sugar yield of sugarcane as influenced periodically by different genotypes under waterlogged and normal condition (pooled data of 2 cropping season)

Genotype	Number of internode per cane	Length of internode (cm)	Number of nodes having aerial roots	Sugar yield (t/ ha)
	Waterlogged condition			
'BO 76'	19	10	8.2	4.60
'BO 91'	20	11	7.5	5.91
'BO 151'	21	10	8.0	5.24
'BO 146'	20	11	7.3	7.12
'BO 147'	20	12	8.0	7.50
'CoLk 94184'	18	12	7.3	6.62
'UP 9530'	19	12	7.3	5.62
'CoP 042'	18	11	6.8	5.63
'CoSe 96436'	19	11	7.6	5.91
Mean	**19**	**11**	**7.6**	**6.02**
SEm ±	0.6	0.5	0.28	0.285
CD (P=0.05)	2	NS	0.8	0.86
Genotype	***Normal condition***			
'BO 76'	23	09	5.7	9.06
'BO 91'	20	12	4.8	8.38
'BO 151'	23	10	5.1	7.22
'BO 146'	22	11	5.5	9.53
'BO 147'	22	12	6.1	10.04
'CoLk 94184'	20	12	5.0	7.99
'UP 9530'	21	11	4.3	8.86
'CoP 042'	19	12	4.2	8.83
'CoSe 96436'	22	11	5.8	9.12
Mean	**21**	**11**	**5.2**	**8.78**
SEm ±	0.6	0.6	0.18	0.424
CD (P=0.05)	2	2	0.5	1.27

Number of nodes having aerial roots/ plant

The maximum number of sprouted buds was recorded under the genotype 'CoP 042' (6.8 and 4.2) under waterlogged and normal condition, respectively (Table 4). The mean per cent increase in number of nodes having aerial roots under waterlogged condition over normal condition was 46 per cent. These findings corroborates with Patil *et al.* (2008).

Sugar yield

On an average the per cent reduction in sugar yield under waterlogged condition was 31.4 per cent as compared to normal condition. Genotypic differences in respect to sugar yield was found to be significant under both the conditions (Table 4) with maximum values of 7.50 and 10.04 t/ ha in 'BO 147' under waterlogged and normal condition, respectively. Sugar yield recorded by the genotype 'BO 147' under waterlogged condition was statistically similar to 'BO 146' (7.12 t/ ha) and significantly superior to the rest of the genotypes. However, values of 'BO 147' under normal condition was significantly superior to 'BO 151' (7.22 t/ ha) and 'CoLk 94184' (7.99 t/ ha) and statistically similar to rest of the genotypes. The higher cane yield contributed greater extent in improving sugar yield than other quality parameters. Kumar *et al.* (2012) have also obtained higher sugar yield with the genotype 'BO 147' under diverse planting season. The differences among genotypes and plant types in sugar accumulation rates may be related to differences in activities of sucrose metabolism enzymes as reported by Zhu *et al*. (2000).

On the basis of results obtained in this experiment it could be concluded that all the sugarcane genotypes under study found to be affected by water logging in later stages of crop growth and there was considerable reduction in growth and sugar yields. However, the genotype 'BO 147' showed the highest plant height and leaf area index with greater partitioning of dry matter during all the stages of crop growth under waterlogged and normal condition. This genotype also recorded highest sugar yield under both the conditions.

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