The Bioscan 10(1): 323-327, 2015 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

COMPARATIVE ANALYSIS OF YIELD AND QUALITY IN SUGARCANE GENOTYPES UNDER WATERLOGGED AND NORMAL CONDITION

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KEYWORDS
Sugarcane genotypes
Growth
Yield
Quality
Economics
Waterlogged and normal condition

Received on :
22.01.2015

Accepted on :
10.03.2015

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ABSTRACT

A field experiment was conducted from 2009 - 10 to 2010 - 11 at Sugarcane Research Institute, Pusa, Bihar to evaluate 9 sugarcane genotypes for their yield and quality characteristics under waterlogged and normal condition. Among genotypes, BO 147 had significantly higher growth and yield attributes *viz.*, germination (46.0 and 44.2 %), plant population (2, 15600 and 2, 05700/ ha), cane height (232.2 and 254.7 cm), cane diameter (2.06 and 2.23 cm), millable cane (1, 10800 and 1, 23600/ ha), single cane weight (705 and 785 g) and cane yield (76.5 and 91.4 t/ ha) in waterlogged and normal condition, respectively. The genotype CoLk 94184 showed the significantly higher values of brix (19.79 and 20.65 %) and pol per cent (17.48 and 18.47 %) respectively under waterlogged and normal conditions. But, maximum purity per cent (92.20 and 92.55 %) juice was obtained by BO 147. Significantly higher gross return (' 1, 56800 and 1, 87400/ ha), net return, (99,200 and 1, 26500/ ha) and benefit: cost ratio (2.72 and 3.08) was obtained by the genotype BO 147 under waterlogged and normal condition, respectively. This was closely followed by BO 146 which gave the net return of '79800 and 1, 00600/ ha, respectively under waterlogged and normal situation. Overall, genotype BO 147 performed best among all other genotypes may be recommended for waterlogged condition to obtain good yield and economic return.

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrid complex), the most important sugar crop of India as well as world, representing wide range of agro-climatic conditions, has diversified uses as sweeteners for human, feed for livestock, organic manure for crop production and raw material in sugar industrial complex. In India, it is cultivated on an area of 5.06 million hectare, of which Bihar shares only an area of 0.26 million hectare (ISMA, 2014) mainly in the north Bihar. Thus the demand of sugarcane for its varied uses is likely to increase in the coming years, but its productivity is generally decreased by abiotic stresses. Among the abiotic stresses responsible for low productivity, waterlogging are undoubtly one of them, which deteriorate yield and quality to a greater extent (More *et al.*, 2010, Singh, 2013). In Bihar about 30 - 35% of sugarcane areas falls under waterlogged condition. Growing of sugarcane varieties with no waterlogging tolerance pulls down the average productivity of state. Under waterlogged condition the productivity of sugarcane is always lower than normal condition. Losses due to waterlogging depends upon location, depth and duration of waterlogging, flow of water, aerial roots, stage of crop and genotypes etc., which could be minimized mainly through development of improved genotypes. Suitability of genotypes to a particular agro-ecological situation is the most important factor in realizing their yield potential as the productivity under stress condition are depends upon the amount of variability and extent to adaptability present in the particular genotypes (Arya *et al.* 2013). The tolerant varieties elongate faster with early tiller formation showed compensatory mechanism for waterlogging tolerance (Kumar, 2009). As the final yield of sugarcane is greatly depends upon the tillering habit of the genotype (Patel and Patel, 2014). In recent past, many high yielding genotypes of sugarcane have been developed for cultivation, among them identification of suitable genotypes are pre- requisites to harvest economic yield from these areas. Since the information about the response of these new genotypes to waterlogged condition is not available, the present investigation was carried out to evaluate the sugarcane genotypes under waterlogged and normal conditions.

MATERIALS AND METHODS

Experimental site and meteorological information

A field experiment was conducted during spring seasons of 2009-10 and 2010-11 under waterlogged and normal condition at Sugarcane Research Institute, Pusa, Bihar located at 25°59' N latitude 85°40'E longitude and at an altitude of 52.1 m above mean sea level. The climate of the experimental site is sub humid, sub tropical with moderate rainfall, hot dry

Table 1: Germination, plant population, millable cane height and cane diameter of sugarcane genotypes under waterlogged and normal condition (pooled data of 2 cropping seasons)

Genotype	Germination % at 45 DAP			Plant population (x10^3/ha) at120 DAP			Millable cane height (cm)			Cane diameter (cm)		
	W	N	% DN	W	N	% DN	W	N	% DN	W	N	% DN
BO 76	24.5	26.8	8.6	120.0	119.7	-0.3	197.7	217.8	9.2	1.51	2.07	27.1
BO 91	30.41	30.5	0.3	188.9	179.6	-5.2	224.2	243.3	7.9	1.70	1.82	6.6
BO 151	27.1	28.1	3.6	137.5	104.2	-32.0	205.3	237.1	13.4	1.59	1.91	16.8
BO 146	34.2	39.9	14.3	152.7	146.6	-4.2	228.9	248.8	8.0	2.01	2.17	7.4
BO 147	46.0	44.2	4.1	215.6	205.7	-4.8	232.2	254.7	8.8	2.06	2.23	7.6
CoLk 94184	23.3	26.0	10.4	139.5	117.2	-19.0	221.6	242.9	8.8	1.81	2.04	11.3
UP 9530	28.9	29.3	1.4	148.0	129.2	-14.6	219.3	238.6	8.1	1.64	2.02	18.8
CoP 042	29.7	27.4	-8.4	118.7	108.8	-9.1	201.2	225.2	10.7	1.80	2.08	13.5
CoSe 96436	29.0	28.6	-1.4	151.4	134.3	-12.7	212.8	234.8	9.4	1.85	2.09	11.5
Mean	30.3	31.2	2.74	152.5	138.4	-11.3	215.9	238.1	9.4	1.77	2.05	13.4
SE m +	1.71	1.86		10.94	10.17	-	9.71	10.25	-	0.069	0.085	-
CD (P=0.05)	5.1	5.6		32.8	30.5	-	29.1	30.8	-	0.21	0.25	-

W: Waterlogged condition, N: Normal condition, % DN: Percent deviation from normal condition.

Table 2: Influence of genotypes on mortality per cent of tillers, millable canes, single cane weight and yield of sugarcane under waterlogged and normal condition (pooled data of 2 cropping seasons)

Genotypes	Mortality % of tillers			Millable canes (X 10^3/ha)			Single cane weight (g)			Cane yield (t/ha)		
	W	N	% DN	W	N	% DN	W	N	% DN	W	N	% DN
BO 76	34.1	16.7	-104.2	79.1	99.7	20.7	547	751	27.2	46.0	73.6	37.5
BO 91	45.6	39.1	-16.6	102.7	109.3	6.0	522	630	17.1	54.1	67.6	20.0
BO 151	45.0	15.8	-184.8	75.6	87.7	13.8	564	656	14.0	43.6	57.2	23.8
BO 146	38.9	25.9	-50.2	93.3	108.7	14.2	680	783	13.2	67.0	78.8	15.0
BO 147	48.6	39.9	-21.8	110.8	123.6	10.4	705	785	10.2	76.5	91.4	16.3
CoLk 94184	39.8	24.1	-65.1	84.0	88.9	5.5	678	726	6.6	54.7	63.4	13.7
UP 9530	46.0	23.5	-95.7	79.9	98.8	19.1	541	738	26.7	49.0	71.3	31.3
CoP 042	36.0	14.5	-148.3	76.0	93.0	18.3	674	781	13.7	51.8	72.5	28.6
CoSe 96436	44.3	25.1	-76.5	84.3	100.6	16.2	680	782	13.0	56.1	75.8	26.0
Mean	42.0	25.0	-84.8	87.3	101.1	13.8	621	737	15.7	55.4	72.4	23.6
SE m +	2.15	1.13	-	5.75	5.01	-	34.7	36.9	-	4..31	5.07	-
CD (P=0.05)	6.5	3.4	-	17.2	15.0	-	104	111	-	13.0	15.2	-

summer and cold winter. Generally south west monsoon sets in third or fourth week of June and continues up to September. The average annual rainfall is 1270 mm out of which nearly 80 % of the total rainfall is received during the south west monsoon season (July-September). The period between last week of December and first half of January receives occasional winter showers. May and early part of June happens to be the hottest month. December-January is the coldest month of the year with an average winter maximum and minimum temperature of 23.2°C and 7.9°C, respectively. During monsoon the average maximum temperature is above 33°C and average minimum temperature is about 25.3°C. 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 during 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. The soil of the experimental plot under both the conditions was sandy loam with pH 8.1 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 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 pH and EC of experimental site was determined through 1: 2 soil and water suspension method (Jackson, 1973). Free $CaCO_3$ was measured by rapid titration method (Piper, 1950). Walkely and Black method (Jackson, 1973), Alkaline permanganate method (Subbiah and Asija, 1956), Olsen's method (Jackson, 1973) and Flame photometric method (Jackson, 1973) were used for the determination of organic carbon, available N, P_2O_5 and K_2O, respectively.

Technical programme

The nine genotypes of sugarcane viz., BO 76, BO 91, BO 151, BO 146, BO 147, CoLk, 94184, UP 9530, CoP 042, CoSe 96436 were evaluated in randomized block design and replicated thrice.

Experimental materials used and cultural operations

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 basally 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 year. Urea, diammonium phosphate and muriate of potash were used as sources of nitrogen, phosphorus and potassium. Before planting, desired quantity of farm yard manure was broadcasted and mixed with tractor drawn cultivator and field was levelled by planking. After that three budded setts were placed bud to bud horizontally in 90 cm apart furrow opened by tractor drawn furrow opener and the amount of fertilizers to be applied in furrow beneath cane setts. Before covering

Table 3: Effect of genotypes on quality constraints of sugarcane under waterlogged and normal condition at 330 DAP (pooled data of 2 cropping seasons)

Genotypes	Brix % juice			Pol % juice			Purity % juice			CCS % juice			Fibre % cane		
	W	N	% DN	W	N	% DN	W	N	% DN	W	N	% DN	W	N	% DN
BO 76	17.36	20.14	13.80	14.75	17.79	17.09	84.97	88.33	3.80	10.01	12.31	18.68	16.5	16.4	-0.61
BO 91	18.81	20.07	6.28	16.54	17.86	7.39	87.93	88.99	1.19	10.92	12.39	11.86	13.1	12.2	-7.38
BO 151	19.64	20.61	4.71	17.36	18.24	4.82	88.39	88.50	0.12	12.01	12.62	4.83	15.0	14.4	-4.17
BO 146	18.26	19.80	7.78	16.11	17.49	7.89	88.23	88.33	0.11	10.63	12.09	12.08	15.3	15.0	-2.00
BO 147	17.44	18.13	3.81	16.08	16.78	4.17	92.20	92.55	0.38	9.81	10.99	10.74	13.1	12.8	-2.34
CoLk 94184	19.79	20.65	7.82	17.48	18.47	5.36	88.33	89.44	1.24	12.10	12.61	4.04	15.2	14.6	-4.11
UP 9530	18.84	20.18	6.64	16.62	17.92	7.25	88.22	88.80	0.65	11.47	12.43	7.72	16.9	16.6	-1.81
CoP 042	18.06	19.63	8.00	15.79	17.53	9.93	87.43	89.30	2.09	10.87	12.18	10.76	14.0	13.2	-6.06
CoSe 96436	17.56	19.76	11.13	15.32	17.41	12.00	87.24	88.11	0.99	10.53	12.03	12.47	16.5	15.7	-5.10
Mean	18.42	19.89	7.77	16.23	17.72	8.43	88.10	89.15	1.17	10.93	12.18	10.35	15.1	14.5	-3.73
SE m +	0.261	0.315	-	0.247	0.247	-	1.480	1.484	-	0.171	0.169	-	0.243	0.247	-
CD (P=0.05)	0.78	0.94	-	0.74	0.74	-	4.44	NS	-	0.51	0.51	-	0.73	0.74	-

the setts with soil, 15 kg/ha thimet 10 G was applied over setts to control early shoot borer. The different genotypes of sugarcane were planted in second fortnight of February and harvested in first fortnight of January during both the year. All recommended agronomic practices were followed throughout the cropping period.

Data collection and analysis

The data were recorded on growth, yield attributes, yield and quality of sugarcane following the standard procedures. Whole cane samples were taken at the time of harvest and cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955). Fibre per cent cane was estimated by rapi pol extractor. The economics was worked out based on pooled yield data and considering price of input and output of the last year of study. The net realization was calculated by deducting the total cost of cultivation from the gross realization for each genotype. The benefit: cost ratio was calculated as ratio of gross realization to cost of cultivation. Finally the data were analysed as per the standard statistical methods.

RESULTS AND DISCUSSION

Growth studies

The data on germination, plant population, millable cane height are presented in Table 1. The genotypic difference in respect to germination percentage under both the land situations was significant. The higher germination per cent (46.0 and 44.2 %), were recorded due to the genotype BO 147 which was closely followed by BO 146 (34.2 and 39.9 %) under waterlogged and normal condition. Significantly higher plant population were recorded under the genotype BO 147 (215.6 and 205.7 thousand/ha) and it was on a par with BO 91 (188.9 and 179.6 thousand/ha), under waterlogged and normal condition, respectively and significantly superior over other genotypes. However, the mean plant population recorded under waterlogged condition was 10.2 % higher over the normal condition. The increase in plant population count under waterlogged condition over normal condition was due to higher fertility status and moisture availability to root zone depth of soil during early formative stage to sugarcane increasing cell division and cell expansion which in turn increased plant population. BO 147 recorded significantly higher millable cane height (232.2 and 254.7 cm) under waterlogged and normal condition, respectively. Though, 8.8 % deviation was recorded for waterlogged condition. On an average 9.4 % deviation in millable cane height under waterlogged condition over normal was recorded under the study. The reduction in millable cane height was associated with a decline in the cell enlargement and more leaf senescence under waterlogged condition.

Yield attributes and cane yield

The significantly higher cane diameter (2.06 and 2.23 cm) was recorded in BO 147 under waterlogged and normal conditions respectively. The highest percent reduction for cane diameter under waterlogged condition was recorded in BO 76 (27.1%) followed by UP 9530 (18.8 %). However, BO 91 (6.6 %) was least affected for cane diameter under waterlogged condition, indicating its greater adaptability to environment.

Table 4: Economic analysis of sugarcane genotypes under waterlogged and normal condition (Pooled data of 2 cropping seasons)

Genotypes	Gross return (X 10^3 ‘/ha)			Net return (X10^3 ‘/ha)			Benefit : cost ratio		
	W	N	% DN	W	N	% DN	W	N	% DN
BO 76	94.3	150.9	37.5	36.7	90.0	59.2	1.64	2.48	33.9
BO 91	110.9	138.6	20.0	53.3	77.7	31.4	1.93	2.28	15.4
BO 151	89.4	117.3	23.8	31.8	56.4	43.6	1.55	1.93	19.7
BO 146	137.4	161.5	14.9	79.8	100.6	20.7	2.39	2.65	9.8
BO 147	156.8	187.4	16.3	99.2	126.5	21.6	2.72	3.08	11.7
CoLk 94184	112.1	130.0	13.8	54.5	69.1	21.1	1.95	2.13	8.5
UP 9530	100.5	146.2	31.3	42.9	85.3	49.7	1.74	2.40	27.5
CoP 042	106.2	148.6	28.5	48.6	87.7	44.6	1.84	2.44	24.6
CoSe 96436	115.0	155.4	26.0	57.4	94.5	39.3	2.00	2.55	21.6
Mean	113.6	148.4	23.6	56.0	87.5	36.8	1.97	2.44	19.2
SE m +	6.39	8.18	-	2.97	4.43	-	0.102	0.129	-
CD (P=0.05)	19.2	24.5	-	8.9	13.3	-	0.31	0.39	-

Cost of cultivation; Waterlogged condition: ‘ 57,634/ha, Normal condition: ‘ 60,685/ha, Selling price of sugarcane: ‘ 2050/tones

The minimum mortality percent (34.1 %) under waterlogged condition was recorded in the genotype BO 76. However, maximum mortality percent (48.6 and 39.9 %) was found in the genotype BO 147 under waterlogged and normal condition, respectively. In general, BO 147 had higher number of plant population showed compensatory mechanism for water logging tolerance. Similar results were also reported by Kumar (2009). The higher millable cane (110.8 and 123.6 thousand/ha) were recorded in BO 147 under waterlogged and normal conditon, respectively with 10.4 % loss under waterlogged condition. The most affected genotype was BO 76 which showed 20.7 % reduction under waterlogged condition. Though, CoLk 94184 had shown only 5.5 % reduction for millable cane over normal condition. Significantly higher millable cane in BO 147 under waterlogged condition was also reported by Kumar (2009). Genotypic differences in respect to cane weight was found to be significnt under both the condition with maximum value of 705 and 785 g in BO 147 and minimum in BO 91 (522 and 630 g) under waterlogged and normal condition, respectively. The mean reduction in single cane weight was 15.7 % under waterlogged condition over normal condition. The maximum reduction (27.2 %) in single cane weight was recorded in BO 76, whereas CoLk 94184 had shown least deviation (6.6 %) under waterlogged condition. The better sink capacity of the genotype was the natural outcome of the vigorous vegetative growth of the particular genotype. Singh *et al.* (2013) also reported similar trend. Genotypic differences in respect to cane yield was varied significantly under both the conditions (Table 2) with maximum cane yield of 76.5 and 91.4 t/ha in BO 147 was statistically similar to BO 146 (67.0 and 78.8 t/ha), respectively under waterlogged and normal condition. The mean percentage reduction in cane yield under waterlogged condition was 23.6 % over normal condition. The highest per cent reduction for cane yield under waterlogged condition was found in BO 76 (37.5 %) followed by UP 9530 (31.3 %) and Cop 042 (28.6%). Genotype CoLk 94184 was least affected for cane yield under waterlogged condition. Little variation in yield of varieties under waterlogged condition indicates their genetic behaviour towards environment. The higher cane yield under BO 147 was due to similar trend in all the growth and yield attributes under the study. The results are in close conformity with the findings of Kumar (2009), More *et al.* (2009) and Patil *et al.* (2008).

Quality parameters

The genotype CoLk 94184 recorded higher brix (19.79 and 20.65 %) and pol per cent (17.48 and 18.47 %) juice at 330 days after planting was closely followed by BO 151 under waterlogged and normal condition, respectively. The mean reduction in brix percentage due to waterlogging was 7.77 %. However, it was 8.43 % in case of pol per cent juice. Similar finding were also reported by More *et al.* (2010) and Sujata and Jyothi (2013). The significantly higher purity per cent juice was recorded due to the genotype BO 147 (92.20 and 92.55%) under waterlogged and normal conditions, respectively with 0.38% reduction under waterlogged condition. Genotypic differences in respect to CCS % juice was found to be significant under both the conditions with maximum value of 12.10 % was recorded due to the genotype CoLk 94184 followed by BO 151 (12.01 %) under water logged condition. However, under normal condition maximum CCS % juice was recorded due to the genotype BO 151 (12.62 %) was closely followed by CoLk 94184 (12.61 %). The mean reduction for CCS per cent juice was 10.35 % under waterlogged condition over normal condition. The highest deviation in CCS per cent juice was recorded in BO 76 (18.68 %) over normal condition. However, least affected genotype for CCS per cent under waterlogged condition was CoLk 94184 (4.04 %). Similar results were also reported by Ramesh (2000) and Kumar *et al.* (2002) under moisture deficit condition. The genotype BO 91 recorded lower fibre (13.1 and 12.2 %) was statistically similar to BO 147 (13.1 and 12.8 %) and significantly superior to rest of the genotypes. The mean fibre per cent under waterlogged condition (15.1 %) was slightly higher than the normal condition (14.5 %).

Economic analysis

There was significant variation among the genotypes for gross return, net return and benefit: cost ratio (Table 4). Genotype BO147 recorded significantly higher gross return (‘ 1, 56800 and 1, 87400), net return (‘ 99,200 and 1, 26500) and benefit: cost ratio (2.72 and 3.08), respectively, under waterlogged and normal conditions. The mean percentage reduction in gross return, net return and benefit: cost ratio under waterlogged condition over normal condition was to the tune of 23.6, 36.8 and 19.2 %, respectively. The genotype BO 76 recorded highest reduction for gross return (37.5 %), net return (59.2 %) and benefit : cost ratio (33.9 %) under waterlogged condition in comparison to normal condition, whereas lowest reduction in terms of gross return (13.8 %), net return (21.1 %) and benefit : cost ratio (8.5 %) were observed in CoLk 94184. Kumar *et al* (2012) have also found highest net return and benefit: cost ratio with the genotype BO 147 under diverse planting season.

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