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Variability Studies of Various Traits and Selection of Water Logging Tolerant Clones in Early Generation

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ABSTRACT

An experiment was carried out in January, 2021–December, 22 at Sugarcane Research Institute, Dr. RPCAU, Pusa, Samastipur, Bihar, India to screen the genotypes for tolerance to water-logging from July to September in the early clonal generation of sugarcane. The experimental design followed was augmented design, in which a total of 24 clones were planted together with 2 checks. The degree of genetic variability present in the base population and the heritability of the traits being improved will be key factors in any breeding programme success. For all of the observations, the analysis of variance indicated highly significant differences among the clones. The range of variation in mean value was comparatively wide for number of shoots at 120 DAP, plant height, number of millable canes and cane yield. The traits cane yield and sucrose content play a crucial role in selecting the appropriate clones. Thus, from the studies the clone CoX 20069 recorded the highest mean performance for cane yield. Whereas the genotype CoX 20068 showed the highest mean performance for HR Brix in November, December and January. Based on the brix value, cane yield and morphological performance eight clones namely CoX 20069, CoX 20068, CoX 20055, X 20030, X 20035, CoX 20054, CoX 20056, CoX 20246 can be selected for further utilization in breeding programme under water-logging condition. All the clones in the present study had non-flowering and non-lodging morphological behaviour.

KEYWORDS: Sugarcane, clones, water-logging, cane yield, brix value

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Sugarcane, a member of the Poaceae family is frequently propagated by stem cuttings. The present sugarcane hybrids, representing 2n=100 to 130 chromosomes, are the result of the contributions of both S. officinarum (2n=80) and *S. spontaneum* (2n=40 to 128). Sugarcane has the distinct characteristic of high sugar concentration accumulated in the stalk (Farrag et al., 2019). A large part of the sugarcane grown areas in India is first used to make sugar which is processed using chemicals and sulphur followed by gur (jaggery) and khandsari (unrefined or brown sugar). The country's sugarcane producing area in 2021–22 is estimated to be 5.098 mha, with a yield of 80.03 t ha^{-1} and a production of 430.50 mt. The area used to grow sugarcane in Bihar is estimated to be 0.219 m ha^{-1} in 2021–22, yielding 13.97 m t^{-1} and 66.25 t ha^{-1} in productivity. (Source: DES, Ministry of Agri. & FW). Numerous biotic and abiotic stresses impede the production of sugarcane. Excess moisture stress is one of the abiotic stresses that has a major impact on sugarcane production, productivity, and production quality. When the water table rises to the point where the crop's root zone becomes saturated and aeration is restricted, waterlogging stress is experienced (Chandran et al., 2019). In the country's sugarcane growing areas, waterlogging is affecting about 2.2 lakh hectares of sugarcane. The main causes of water logging include heavy rainfall, poor soil water drainage, flooding from overflowing rivers, and excessive irrigation. Gilbert et al., 2008 reported that when continuous flooding was provided to sugarcane crops for a period of three months, cane yield losses were observed to be between 18 and 37%.

The stress of water logging prevents the growth of tillers, leaves, and stems, as well as alters the direction in which shoots extend. Germination, tillering, and the grand growth period are practically affected by waterlogging stress, which lowers the output and quality of biomass (Leelastwattanagul et al., 2023). Juice quality degrades quickly during the post-water logging phase because of the submergence of canes in water. Such low-quality juice presents significant processing challenges, which impacts sugar recovery. According to reports, early in the season, sugarcane crops that are subjected to waterlogged conditions during the monsoon achieve a higher juice sucrose content (Masri et al., 2022).

As potential sources of tolerance, there are a large number of genotypes that may be exploited which also includes breeding lines, commercial hybrids and taxa that are very distantly related to one another and conventional or biotechnology breeding methods should be used to create varieties with waterlogging resistance (Gomathi et al., 2015). In several locations where sugarcane is grown, the response of the plant to short and long-term waterlogging conditions was examined in terms of growth, physiology, biochemical, yield, and quality. To combat the flooding of the land, a study of the quantitative character changes revealed by sugarcane genotypes following flooding treatment should be carried out (Avivi et al., 2016). Subsequently, sugarcane varieties that exhibit favourable characteristics during floods are chosen to have tolerance. In Bihar, 2/3 of area is under water-logged condition, it reduces the yield, sugar production and also the extraction percentage. Northern Bihar is the primary region for sugarcane cultivation, and during the monsoon season, 35 to 40% of the territory is flooded and that coincides with the crop at its grand growth stage. The yield of cane often declines by 15% to 20% in areas that are heavily flooded. In this context, the current study was undertaken to select genotypes that perform better with respect to cane yield and sucrose content.

2. MATERIALS AND METHODS

2.1. Site of the experiment, topography and climate

The experiment was conducted during spring season of Jan 2021 to Dec 2022 at SRI, Dr. RPCAU, Pusa, Samastipur, Bihar (848125), India situated between 25.97°N latitude and 85.66° E longitude at 51.8 m above MSL. The climate in this area is subtropical, with highs in the summer and lows in the winter. In most years, the monsoon season begins around the third or fourth week of June and lasts all the way through September. The plot selected for experiment was well levelled, but it is set to remain in waterlogging condition for 3 months with the average water depth of 25 to 45 cm.

2.2. Experimental material

The experimental materials consisted of 24 sugarcane clones along with 2 checks which were procured from SRI, Pusa were grown in low land where water could stagnant minimum for three months (Table 1). The experiment was laid out in Augmented Design. 24 clones along with 2 checks were planted in 4 rows, 6m long spaced at 90 cm for the proposed study.

2.3. Analysis of variance

ANOVA for each metric character was conducted and the total variation was divided into components attributable to different sources such as clones (varieties), blocks and unassignable causes (error), according to the model suggested by Federer, 1956:

(i) Block effect $(b_j)=1/e\ (Tb_j-\bar{c}-Tvb_j)$

(j=1 to b)

Counter check $\sum_1^b b_j \approx 0$

(ii) Mean effect $(m)=1/e\ \{GT-(b-1)\bar{c}-\sum_1^b n_j b_j\}$

Where, n_j is the number of 'v' occurring in j^{th} block If n_j is the same in all blocks, then

$M=1/e\ \{GT-(b-1)\ \bar{c}\}$

Table 1: List of experimental material

Sl. No.	Clones	Parentage
1.	X 20008	BO 154 FC
2.	X 20009	BO 154 FC
3.	X 20015	BO 154 FC
4.	X 20022	BO 154 FC
5.	X 20030	BO 154 FC
6.	X 20034	BO 154 FC
7.	X 20035	BO 154 FC
8.	X 20036	BO 154 FC
9.	X 20038	BO 154 FC
10.	X 20039	BO 154 FC
11.	CoX 20041	Co 0238 GC
12.	CoX 20047	CoPb 09181 GC
13.	CoX 20053	BO 91 GC
14.	CoX 20054	Co 09022 x BO 154
15.	CoX 20055	Co 09022 x BO 154
16.	CoX 20056	Co 09022 x BO 154
17.	CoX 20062	Co 09022 x BO 154
18.	CoX 20065	Co 09022 x BO 154
19.	CoX 20067	Co 09022 x BO 154
20.	CoX 20068	Co 09022 x BO 154
21.	CoX 20069	Co 09022 x BO 154
22.	CoX 20076	BO 91 x Co 87268
23.	CoX 20078	BO 91 x Co 87268
24.	CoX 20246	BO 91 GC
25.	Check 1: CoP 16437	CoSe 92423 x Co 1148
26.	Check 2: CoP 2016	CoLk 8102 x HR 83/65

(iii) Check effects (c_j)=$\bar{c}_j$-m(i=1 to c)
(iv) Adjusted means of test varieties (V_i)

2.4. *Analysis of variance and expectation of mean squares*

Table 2.4: ANOVA table for augmented design

Source of variation	d.f	SS	MSS	F
Blocks	b-1	bSS	bMS	bMS/EMS
Entries	e-1	eSS	eMS	eMS/EMS
Checks	c-1	cSS	cMS	cMS/EMS
Varieties	v-1	vSS	vMS	vMS/EMS
Checks vs. Varieties	1	cvSS	cvMS	cvMS/EMS
Error	(c-1) (b-1)	ESS	EMS	
Total	N-1	TSS		

2.5. *Standard error (SE)*

Standard error of mean was computed with the help of error mean square from ANOVA table.

$SE_m=\sqrt{MSe/r}$

3. RESULTS AND DISCUSSION

3.1. Analysis of variance

Each character had their own separate study of variance, with the final result being a breakdown of the overall variance into its component parts. Table 2 displays the results. The result revealed significant MSS due to blocks for the characters *viz.*, germination at 45 DAP, cane diameter at harvest, single cane weight, number of aerial roots node^{-1}, HR Brix in November, December, January and cane yield. MSS due to entries were significant for all the traits. MSS due to checks were significant for all the traits.

ANOVA revealed highly significant differences among the clones for all the parameters under water-logging condition. This reflected the presence of considerable extent of variability among the clones of sugarcane. Similar reports were also noted by several researchers for respective characters *viz.*, Kumar and Kumar (2014); Negi and Koujalagi (2018); Farrag et al. (2019); Sanghera and

Table 2: Analysis of variance for eleven quantitative characters in sugarcane under water-logging condition

Characters	Mean sum of squares			
	Blocks	Checks	Entries	Error
	3	1	23	3
Germination at 45 DAP (%)	3.87**	16.76**	2.56**	0.48
No. of shoots at 120 DAP (000 ha^{-1})	14.30	460.86**	74.81**	9.42
Plant height at harvest (cm)	81.86	290.04*	520.92**	157.20
Cane diameter at harvest (cm)	0.371**	0.053**	0.282*	0.016
Single cane weight (kg)	0.019**	0.041**	0.021**	0.002
No. of millable canes at harvest (000 ha^{-1})	72.96	629.95**	114.58**	32.20
No. of aerial roots node^{-1}	23.33*	104.84**	20.13*	11.26
HR Brix in NOV	6.52**	18.00**	4.55**	0.81
HR Brix in DEC	6.11**	16.25**	4.60**	1.39
HR Brix in JAN	5.21**	15.13**	4.96**	1.9
Cane Yield (t ha^{-1})	28.68**	55.02**	41.36**	4.58

*, ** significant at p=0.05 and 0.01 level, respectively

Jamwal, (2019); Singh et al. (2019); Sholeh et al. (2020). The range of variation in mean value was comparatively wide for number of shoots at 120 DAP, plant height, NMC and cane yield. Characters which had high range of variation have a positive scope of improvement through simple selection. While for rest of the characters, range of difference was comparatively narrow indicates lesser extent variability among the clones for these traits. Similar results were consistent with Kumar and Kumar (2014) and Singh et al. (2010).

3.2. Mean performance of clones

Clone CoX 20069 recorded highest mean performance for cane yield. Similarly, CoX 20068 showed highest mean performance for HR Brix in November, December and January. Clone CoX 20246 recorded highest mean performance for germination % at 45 DAP as well as for plant height at harvest. Clone X 20034 showed highest mean performance for number of shoots at 120 DAP and clones namely X 20030, CoX 20054, CoX 20067, CoX 20055 showed highest mean performance for cane diameter at harvest, single cane weight, number of millable canes at harvest, number of aerial roots per node respectively. Higher mean performance of clones indicates high variability that was reported by Palachai (2019); Singh et al. (2019); Bamrungrai et al. (2021) and Yadav et al. (2023). Table 3 displays overall mean performance of all the clones under study.

Table 3: Overall mean performance of 24 clones along with 2 checks in 4 blocks for eleven quantitative characters in sugarcane under water-logging condition

Sl. No.	Characters/ Clones	G%	S120	PH	CD	SCW	NMC	NAR	B% NOV	B% DEC	B% JAN	CY
	CoX20067	34.85	91.64	274.62	2.13	0.95	98.04	29.71	14.80	15.20	16.00	94.24
1.	CoX20076	31.81	84.46	300.33	1.73	0.89	96.86	21.48	12.4	13	13.6	87.11
2.	CoX20069	32.44	93.43	249.86	2.84	1.15	82.41	26.83	18.4	19.6	20.4	95.98
3.	CoX20053	33.57	94.61	320.12	1.93	1.05	84.95	31.22	16.4	16.8	17.8	88.21
4.	X20038	32.22	79.33	260.79	1.54	1.1	71.01	32.65	14	14.8	15.4	77.24
5.	CoX20078	32.89	86.41	301.69	1.84	0.94	85.87	22.51	12.6	13.4	13.8	81.47
6.	CoX20068	33.29	95.76	267.49	1.21	1.01	87.2	31.79	20	21.2	21.8	87.12
7.	X20039	34.45	98.64	299.33	2.05	1.05	91.79	25.53	15.4	16.2	17	95.34
8.	X20022	34.26	89.52	298.16	1.27	1.15	81.97	27.47	18.6	18.8	19.8	93.39
9.	X20009	31.64	80.56	276.97	1.62	1.3	70.89	33.63	16.4	17.2	18	89.52
10.	CoX20062	35.39	92.42	285.23	1.75	1.1	81.48	25.35	15.4	15.8	16.2	90.41
11.	CoX20047	32.52	77.56	297.57	1.42	1.22	70.4	27.48	17.6	17.8	18.4	86.72
12.	CoX20055	35.46	97.47	303.72	1.87	0.96	88.98	37.23	19.8	20	20.6	86.52
13.	X20015	34.83	89.73	294.43	1.91	1.05	79.62	28.98	17.8	18	18.4	88.64
14.	X20034	36.22	102.56	246.13	1.21	0.9	91.84	30.42	14	14.6	15.2	83.59
15.	X20030	34.68	89.54	277.54	2.97	1.21	74.54	35.97	18.4	18.8	20	91.72
16.	X20036	31.24	75.36	262.62	1.67	1.1	65.74	23.48	17.8	18.2	19	73.31
17.	X20035	35.97	101.63	307.69	1.47	0.9	91.65	27.84	18.8	19.4	20.2	83.57
18.	X20008	31.89	98.66	247.16	1.76	0.85	90.12	35.42	15.6	16.4	16.8	74.61
19.	CoX20041	32.24	76.86	282.28	1.84	1.34	64.81	25.97	16.8	18.3	18.6	85.84
20.	CoX20054	32.66	79.12	271.93	2.68	1.38	65.2	24.32	18.4	19	19.6	91.27
21.	CoX20056	34.81	98.62	276.82	2.78	0.98	94.43	29.54	18	19.2	20	94.59
22.	CoX20065	33.72	76.72	306.78	1.72	1.2	65.45	36.72	16.8	17.4	18.2	77.54
23.	CoX20246	36.76	91.67	332.17	2.83	1.08	81.93	28.79	18.8	19.4	20.4	89.49
24.	CoP16437	32.63	81.24	267.16	1.81	1.06	72.21	24.55	19.3	20	20.8	76.88

Table 3: Continue...

Sl. No.	Characters/ Clones	G%	S120	PH	CD	SCW	NMC	NAR	B% NOV	B% DEC	B% JAN	CY
C1	CoP2061	35.52	96.42	279.2	1.89	0.92	89.95	31.79	16.3	17.15	18.05	82.13
C2	Gen Mean	33.77	89.23	284.15	1.91	1.07	81.51	29.1	16.87	17.53	18.23	86.4
	Check mean	34.08	88.83	273.18	1.85	0.99	81.08	28.17	17.8	18.58	19.43	79.51
	Min	31.24	75.36	246.13	1.21	0.85	64.81	21.48	12.4	13	13.6	73.31
	Max	36.76	102.56	332.17	2.97	1.38	98.04	37.23	20	21.2	21.8	95.98
	CD (p=05)	2.41	10.63	43.44	0.44	0.15	19.66	11.63	3.12	4.09	4.09	7.41

3.3. *Selection based on mean data of productive traits and morphological performance*

In the present study consisting of 24 clones, their HR Brix in November, December, cane yield and morphological performance under water-logging condition were presented in Table 4. Clone CoX 20246 showed best performance for plant height at harvest and germination % at 45 DAP. Stem was non lodging and there was no flowering. Clone CoX 20068 showed best performance for brix % in November, December, and January. Stem was non lodging and there was no flowering. Clone CoX 20069 showed best performance for cane yield. Stem was non lodging and there was no flowering.

In the present study, eight clones could be selected based on the brix value, cane yield, morphological performance under water-logging condition. Eight clones namely CoX 20069, CoX 20068, CoX 20055, X 20030, X 20035, CoX 20054, CoX 20056, and CoX 20246 were found superior under water-logging condition. In all the clones, cane was non flowering and non-lodging. These eight clones were found water-logging tolerant with high brix value and cane yield. Similar findings were reported by Chandran et al., 2019; Avivi et al., 2020; Misra et al., 2020; Nisha et al., 2023. These clones can be selected for further utilized in breeding programme to enhance the recovery and productivity under water-logging condition.

Table 4: Selection based on mean data of productive traits and morphological performance under water logging condition

Clones	HR Brix in NOV	HR Brix in DEC	Cane yield (t ha^{-1})	Flowering behaviour	Stem condition
CoX 20069	18.4	19.6	95.98	NF	NL
CoX 20068	20	21.2	87.12	NF	NL
CoX 20055	19.8	20	86.52	NF	NL
X 20030	18.4	18.8	91.72	NF	NL
X 20035	18.8	19.4	83.57	NF	NL
CoX 20054	18.4	19	91.27	NF	NL
CoX 20056	18	19.2	94.59	NF	NL
CoX 20256	18.8	19.4	89.49	NF	NL

NF: Non-Flowering; NL: Non-Lodging

4. CONCLUSION

Wide genetic variability among the tested genotypes for growth and yield characters. Moreover, the results showed Analysis of variance was highly significant among the clones for all the parameters. Based on the brix value, cane yield and morphological performance eight clones namely CoX 20069, CoX 20068, CoX 20055, X 20030, X 20035, CoX 20054, CoX 20056, CoX 20246 can be selected for further utilization in breeding programme under water-logging condition. In all the clones, cane was non flowering and non- lodging.

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