Received: 18 Jul 2024 | Revised: 24 Jan 2025 | Accepted: 27 Jan 2025

Electronic Journal of Plant Breeding

Research Article

Genetic evaluation of climate resilient sugarcane clones under waterlogged condition

K. Karthik*, S. Rakshitha and D.N. Kamat

Department of Genetics and Plant Breeding, Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar
***E-Mail:**karthikkuncha9914@gmail.com

Abstract
Waterlogging, an abiotic stress situation, affects sugarcane yields by 15-20 percent. The present study sought to identify sugarcane clones suitable for waterlogging conditions. Fifteen climate resilient sugarcane clones and three standard check varieties were evaluated under waterlogged as well as normal conditions at Kalyanpur Research farm, RPCAU, in a alpha lattice. Variance analysis revealed that the studied characters differ significantly among resilient sugarcane clones under waterlogging conditions. High variability was found for cane height at maturity. Commercial Cane Sugar(t/ha) had high GCV and the trait, number of nodes with aerial roots had higher PCV under waterlogged conditions. Less variability was observed for all quality traits such as brix, purity, and sucrose percent at 10 and 12 months, CCS%, Pol percent cane and juice extraction percent at harvest. High to moderate heritability along with moderate genetic advance was found for majority of the traits indicating that the choice of these characters will be suitable for successful crop improvement. Commercial cane sugar (t/ha) had high heritability and high genetic advance which suggests that direct selection for this character can be indicator under waterlogged conditions.

Keywords: Sugarcane, Climate Resilience, Waterlogging, Heritability, GCV, PCV, Genetic Advance

INTRODUCTION

Sugarcane is major sugar yielding crop grown in tropics and subtropics of the world including Indian sub-continent. Waterlogging, an abiotic stress condition that has shown severe impact on sugarcane survival, drastically decreases cane production to the tune of 15 – 20 % (Agrawal *et al*., 2017). The sugarcane yield depends on environmental conditions, developmental stage, and the duration of the stress. Waterlogging results in anaerobic conditions limiting the oxygen supply to the roots and inhibiting the expansion of leaf and stem, number of tillers and causes changes in the direction of shoot extension. Aerial roots, the growth phase of the clone, environmental fluctuations including biotic and abiotic stress during active growth circumstances, and the duration of inundation significantly influence cane output and juice quality. Identification of climate resilient types and use of them in development of improved genotypes can mitigate these effects. Enhancing plant's ability to adjust to shifting climatic conditions and reducing their susceptibility to abiotic and biotic stressors are essential (Anna Durai and Kuruppaiyan,2023). Genotypic ability to withstand waterlogging and achieve high yields with medium to high sucrose concentrations may substantially improve sugarcane productivity. It is a challenge for the plant breeders to develop sustained sugarcane clones towards climate resilience.

In order to address the issue of waterlogging in areas where sugarcane is grown, it is crucial to evaluate the adaptation of sugarcane varieties that can withstand such conditions for the purpose of replacing old or outdated clones, which would also improve sugarcane productivity and production. The current research focuses on identifying sugarcane clones able to tolerate water logging and attain satisfactory yields.

Table 1(a): Analysis of Variance for 23 yield and quality governing traits under waterlogging conditions.

S. No.	Source of Variation	Replication (DF = 1)	Genotype (DF = 17)	Blocks (DF= 4)	Error (DF= 13)
1	Germination at 45DAP	7.84	27.89*	4.82	10.24
2	Tillers at 90DAP (000/ha)	2.60	78.62**	21.03	12.07
3	No. of shoots before waterlogging (000/ha)	143.88	117.56*	43.25	46.66
4	No. of shoots after waterlogging (000/ha)	19.77	61.89*	20.05	24.62
5	Cane height before waterlogging (cm)	112.22	109.56*	65.03	41.76
6	Cane height after waterlogging (cm)	1658.93	563.21*	178.50	153.99
7	Cane height at maturity (cm)	1915.52	612.75*	214.72	171.32
8	Cane diameter at harvest (cm)	0.03	0.14**	0.02	0.02
9	Single Cane weight at harvest (Kg)	0.01	0.01**	0.004	0.001
10	NMC at harvest (000/ha)	112.00	76.39**	9.43	12.50
11	No. of Nodes with aerial roots	1.65	1.50*	0.21	0.46
12	Brix % at 10 months	0.01	3.34**	0.53	0.51
13	Brix % at 12 months	0.59	2.30**	0.61	0.17
14	Purity% at 10 months	0.78	2.90**	0.55	0.40
15	Purity% at 12 months	1.44	1.55**	0.46	0.25
16	Sucrose % at 10 months	0.07	3.65**	0.76	0.28
17	Sucrose % at 12 months	0.54	1.51**	0.57	0.14
18	CCS% at Harvest	0.11	0.71**	0.17	0.09
19	Fiber % at harvest	0.09	0.32*	0.08	0.12
20	Pol % cane at harvest	0.37	1.01**	0.45	0.10
21	Juice extraction%	1.05	2.71*	1.24	0.94
22	Cane yield at harvest(t/ha)	240.30	68.66**	12.52	12.69
23	CCS(t/ha) at harvest	3.99	1.38**	0.12	0.24

* - At 5% significance level ** - At 1% significance level

MATERIALS AND METHODS

The research activity was carried out with 15 promising sugarcane clones namely, 96 WL 1206, WL 09-965, WL 09-678, WL 10-62, WL 10-3, WL 10-85, WL 10-18, WL 10-83, WL 10-105, WL 11-2534, WL 12-509, WL 12-182, WL 12-300, Co 99006 and three check varieties, are BO 154, BO 91 and CoSe95422. These clones were sourced from the Sugarcane Breeding Institute in Coimbatore. The varieties BO 154 and BO 91 are tolerant and CoSe95422 is susceptible to waterlogging. This research was conducted in the year 2023, at the Kalyanpur research farm, Dr. RPCAU, Bihar, in an Alpha lattice design with two replications, three blocks, and six treatments per block. Each clone was grown in a plot of 2 rows of 6 meters length with a spacing of 0.90 meter between rows. A minimum of 40-50 cm depth of waterlogging water is maintained during formative stage, (June-September).Observations were recorded by selecting five random plants per genotype per replication for cane yield and yield attributing traits *viz.*, germination at 45 days after planting (DAP), number of tillers at 90 DAP, number of shoots before and after waterlogging, cane height before, after and at maturity under waterlogging, cane diameter at harvest, single cane weight at harvest, number of millable canes at harvest, brix percent, sucrose percent and purity% at 10 and 12 months cane yield at harvest, CCS (Commercial Cane Sugar) percent at harvest, fiber percent at harvest, Pol (total soluble sugars) percent cane at harvest, number of nodes with aerial roots and juice extraction percent at harvest. Significance of the data was evaluated by Analysis of Variance (ANOVA) as outlined by Panse and Sukhatme, 1967, under waterlogged and normal conditions provided in **Table 1a and 1b**. Mean, standard error, critical difference and coefficient of variation for each trait was calculated the same is furnished in **Tables 2a and 2b.** Phenotypic and genotypic coefficient of variation were calculated according to the method suggested by Burton and De Vane (1953) and categorized as low (<10 %), medium (11-20 %) and high (>20 %). Heritability in broad sense was calculated according to Lush, 1940 and classified as low (<30 %), medium (30 – 60 %) and high (> 60 %) as suggested by Johnson *et al*. (1955). Genetic advance as percent of mean was estimated according to Johnson *et al*. (1955) and categorized as low (<10 %), medium (11-20 %) and high (>20 %). All the statistical analyses were carried out by using R-software Version 4.3.1.

Table 1(b): Analysis of Variance for 23 yield and quality governing traits under normal conditions

S. No	Source of Variation	Replication (DF = 1)	Genotype (DF = 17)	Blocks (DF= 4)	Error (DF= 13)
1	Germination at 45DAP	3.61	32.58*	7.37	8.73
2	Tillers at 90DAP (000/ha)	79.74	65.68**	128.64	11.00
3	No. of shoots before waterlogging (000/ha)	117.18	115.94*	18.18	44.73
4	No. of shoots after waterlogging (000/ha)	16.98	79.14*	33.35	31.41
5	Cane height before waterlogging (cm)	149.41	131.33*	150.80	52.47
6	Cane height after waterlogging (cm)	378.82	365.66*	246.58	137.76
7	Cane height at maturity (cm)	442.40	445.31*	173.87	163.55
8	Cane diameter at harvest (cm)	0.0038	0.11**	0.0078	0.02
9	Single Cane weight at harvest (Kg)	0.025	0.011**	0.0028	0.0023
10	NMC at harvest (000/ha)	27.52	90.37**	7.61	15.06
11	No. of Nodes with aerial roots	0.11	1.52**	0.43	0.37
12	Brix % at 10 months	5.44	1.52*	0.51	0.53
13	Brix % at 12 months	3.61	1.51*	0.73	0.48
14	Purity% at 10 months	2.25	3.53***	0.33	0.29
15	Purity% at 12 months	0.69	1.28*	0.28	0.34
16	Sucrose % at 10 months	5.27	1.35*	0.36	0.42
17	Sucrose % at 12 months	2.99	1.40*	0.64	0.41
18	CCS% at Harvest	1.46	0.74*	0.33	0.21
19	Fiber % at harvest	0.0006	0.25*	0.017	0.095
20	Pol % cane at harvest	1.92	0.97*	0.43	0.28
21	Juice extraction%	0.00007	2.33*	0.89	0.88
22	Cane yield at harvest(t/ha)	241.75	78.78**	25.52	19.41
23	CCS(t/ha) at harvest	6.66	1.73**	0.64	0.33

* - At 5% significance level ** - At 1% significance level

RESULTS AND DISCUSSION

The efficiency of choosing and recognizing better genotypes relies on the extent of inherent diversity for the trait of interest. Therefore, it is essential to examine the measures of genetic characteristics like the genotypic and phenotypic coefficient of variability, broad-sense heritability, and genetic advancement as fundamental steps (Agrawal *et al.,* 2017 and Patel *et al.,*2024).

For all the traits studied in both waterlogged and controlled conditions, the phenotypic variance (σ_p^2) surpasses the genotypic variance (σ_g^2). This disparity in variance arises from non-heritable and non-genetic factors that significantly contribute to the expression of these traits. Similar results were reported by Kadian *et al.* (1997).

High variability has observed for cane height at maturity, cane height before and after waterlogging, number of tillers at 90 DAP, number of millable canes at harvest and cane yield at harvest among the quantitative traits. Relatively narrow range of variability was noticed for all the qualitative traits such as brix, purity, sucrose percent at 10 and 12 months, commercial cane sugar percent at harvest, fibre, and Pol percent cane at harvest. The degree of variability, as assessed through PCV and GCV, provides insights into the comparative level of variation across distinct traits studied by Agrawal *et al.*(2001) and Divya Chaudhary *et al.*(2023). For all the traits under examination, the coefficient of phenotypic variability exceeded the coefficient of genotypic variability. There was a minimal disparity observed between GCV and PCV for the majority of the traits **(Tables 3a and 3b**).

High PCV was observed in the case of number of nodes with aerial roots under both the environments. In case of GCV, high value was observed for number of nodes with aerial roots and commercial cane sugar (t/ha) at harvest under normal and waterlogging conditions respectively (**Tables 3a and 3b**). The traits having the moderate phenotypic variability were germination at 45DAP, cane yield at harvest, number of millable canes, single cane weight and cane diameter at harvest but number of tillers at 90 DAP has moderate PCV under waterlogging condition only. Almost same trend was recorded in GCV with moderate value for number of nodes with aerial roots, germination at 45DAP, number of millable canes, cane yield (t/ha) and commercial cane sugar (t/ha) at harvest. Low PCV and GCV was observed in case of number of

Table 2: Mean performance of 18 clones for yield and yield attributing traits under waterlogging and normal conditions

2a. Waterlogged conditions:

S. No	Parameters	Mean	SE(m)	CD	CV
1	Germination at 45DAP	31.43	2.26	6.57	10.18
2	Tillers at 90DAP (000/ha)	66.98	2.46	7.17	5.18
3	No. of shoots before waterlogging (000/ha)	124.18	4.83	14.07	5.50
4	No. of shoots after waterlogging (000/ha)	100.29	3.51	10.22	4.95
5	Cane height before waterlogging (cm)	140.54	4.57	13.30	4.60
6	Cane height after waterlogging (cm)	240.28	8.77	25.54	5.16
7	Cane height at maturity (cm)	255.50	9.26	26.96	5.12
8	Cane diameter at harvest (cm)	2.57	0.10	0.28	5.52
9	Single Cane weight at harvest (Kg)	0.80	0.02	0.05	5.10
10	NMC at harvest (000/ha)	61.56	2.50	7.27	5.74
11	No. of Nodes with aerial roots	6.02	0.48	1.40	11.32
12	Brix % at 10 months	18.08	0.50	1.44	3.94
13	Brix % at 12 months	19.26	0.30	0.86	2.17
14	Purity% at 10 months	85.38	0.45	1.30	0.75
15	Purity% at 12 months	87.05	0.35	1.01	0.57
16	Sucrose % at 10 months	15.42	0.38	1.09	3.48
17	Sucrose % at 12 months	16.79	0.27	0.78	2.24
18	CCS% at Harvest	11.56	0.22	0.64	2.72
19	Fiber % at harvest	12.54	0.25	0.72	2.84
20	Pol % cane at harvest	13.83	0.22	0.64	2.30
21	Juice extraction%	55.47	0.68	1.98	1.75
22	Cane yield at harvest(t/ha)	49.37	2.52	7.33	7.21
23	CCS(t/ha) at harvest	5.71	0.35	1.01	8.65

2(b) Normal conditions:

S. No	Parameters	Mean	SE(m)	CD	CV
1	Germination at 45DAP	32.87	2.10	6.12	8.99
2	Tillers at 90DAP (000/ha)	66.58	2.35	6.86	4.98
3	No. of shoots before waterlogging (000/ha)	126.70	4.71	13.72	5.25
4	No. of shoots after waterlogging (000/ha)	112.62	3.96	11.54	4.97
5	Cane height before waterlogging (cm)	141.32	5.12	14.91	5.12
6	Cane height after waterlogging (cm)	263.49	8.30	24.18	4.65
7	Cane height at maturity (cm)	280.40	9.04	26.35	4.76
8	Cane diameter at harvest (cm)	2.56	0.10	0.29	5.58
9	Single Cane weight at harvest (Kg)	0.83	0.034	0.10	5.88
10	NMC at harvest (000/ha)	66.00	2.75	8.03	5.88
11	No. of Nodes with aerial roots	4.80	0.43	1.26	12.67
12	Brix % at 10 months	19.37	0.52	1.52	3.79
13	Brix % at 12 months	20.10	0.50	1.44	3.47
14	Purity% at 10 months	86.19	0.39	1.13	0.63
15	Purity% at 12 months	87.83	0.41	1.12	0.66
16	Sucrose % at 10 months	16.69	0.46	1.34	3.87
17	Sucrose % at 12 months	17.64	0.46	1.34	3.64
18	CCS% at Harvest	12.15	0.32	0.93	3.78
19	Fiber % at harvest	12.09	0.22	0.64	2.55
20	Pol % cane at harvest	14.65	0.38	1.11	3.66
21	Juice extraction%	57.34	0.66	1.92	1.64
22	Cane yield at harvest(t/ha)	54.61	3.11	9.06	8.06
23	CCS(t/ha) at harvest	6.65	0.41	1.12	8.70

Table 3. Genetic analysis for yield and yield attributing traits in 18 genotypes in sugarcane under waterlogged and controlled conditions

3(a) Waterlogged Condition:

S. NO	TRAITS	RANGE	Vg	Vp	Ve	h^2	GCV	PCV	GA	GAM
1	Germination at 45DAP	15.35	8.82	19.06	10.24	46.28	10.00	13.89	4.16	13.24
2	Tillers at 90DAP (000/ha)	27.78	33.27	45.35	12.08	73.36	8.61	10.05	10.17	15.19
3	No. of shoots before waterlogging (000/ha)	26.49	35.45	82.12	46.67	43.16	4.79	7.29	8.05	6.48
4	No. of shoots after waterlogging (000/ha)	20.20	18.63	43.25	24.62	43.08	4.70	6.55	5.83	5.82
5	Cane height before waterlogging (cm)	28.22	33.90	75.66	41.76	44.80	4.14	6.19	8.02	5.71
6	Cane height after waterlogging (cm)	50.93	204.61	358.60	153.99	57.05	5.95	7.88	22.25	9.26
7	Cane height at maturity (cm)	55.40	220.71	392.03	171.32	56.30	5.81	7.75	22.96	8.98
8	Cane diameter at harvest (cm)	1.04	0.06	0.08	0.02	75.00	9.53	11.00	0.43	17.00
9	Single Cane weight at harvest (Kg)	0.32	0.0052	0.0068	0.0016	76.47	9.01	10.30	0.12	16.23
10	NMC at harvest (000/ha)	21.74	31.94	44.64	12.50	71.87	9.18	10.83	9.87	16.03
11	No. of Nodes with aerial roots	3.20	0.51	0.97	0.46	52.82	11.92	16.40	1.07	17.84
12	Brix % at 10 months	4.25	1.42	1.92	0.50	73.96	6.59	7.66	2.11	11.68
13	Brix % at 12 months	4.20	1.06	1.23	0.17	86.23	5.35	5.77	1.97	10.25
14	Purity% at 10 months	5.15	1.24	1.64	0.40	75.68	1.30	1.50	1.20	2.34
15	Purity% at 12 months	3.10	0.57	0.97	0.40	58.97	0.87	1.13	1.12	1.37
16	Sucrose % at 10 months	4.73	1.68	1.96	0.28	85.75	8.41	9.09	2.47	16.05
17	Sucrose % at 12 months	3.58	0.68	0.82	0.14	83.03	4.93	5.41	1.55	9.25
18	CCS% at Harvest	2.43	0.30	0.40	0.01	75.52	4.78	5.50	0.98	8.56
19	Fiber % at harvest	1.78	0.09	0.22	0.13	42.22	2.46	3.78	0.41	3.29
20	Pol % cane at harvest	2.93	0.45	0.55	0.10	81.98	4.87	5.38	1.25	9.09
21	Juice extraction%	4.70	0.88	1.82	0.94	48.35	1.69	2.43	1.34	2.42
22	Cane yield at harvest(t/ha)	27.15	27.98	40.67	12.69	68.80	10.71	12.91	9.03	18.31
23	CCS(t/ha) at harvest	3.75	0.57	0.81	0.24	69.95	13.12	15.78	1.298	22.74

3(b) Normal Condition

S. NO	TRAITS	RANGE	Vg	Vp	Ve	h^2	GCV	PCV	GA	GAM
1	Germination at 45DAP	16.79	11.92	20.65	8.73	57.73	10.50	13.82	5.40	16.44
2	Tillers at 90DAP (000/ha)	18.87	27.34	38.34	11.00	71.30	7.85	9.30	9.09	13.66
3	No. of shoots before waterlogging (000/ha)	25.61	35.80	80.13	44.73	44.68	4.72	7.06	8.23	6.50
4	No. of shoots after waterlogging (000/ha)	24.03	23.86	55.27	31.41	43.17	4.73	6.60	6.61	5.87
5	Cane height before waterlogging (cm)	27.61	39.43	91.90	52.47	42.90	4.64	6.78	8.47	5.99
6	Cane height after waterlogging (cm)	47.82	113.95	251.71	137.76	45.27	4.05	6.02	14.79	5.61
7	Cane height at maturity (cm)	47.90	140.88	304.63	163.55	46.27	4.23	6.22	16.63	5.93
8	Cane diameter at harvest (cm)	0.89	0.04	0.06	0.02	69.23	8.28	10.00	0.36	14.20
9	Single Cane weight at harvest (Kg)	0.295	0.004	0.006	0.002	65.41	7.94	10.00	0.10	13.23
10	NMC at harvest (000/ha)	23.46	37.65	52.72	15.07	71.41	9.30	11.00	10.68	16.18
11	No. of Nodes with aerial roots	3.00	0.58	0.95	0.37	61.05	15.86	20.3	1.22	25.53
12	Brix % at 10 months	3.00	0.49	1.03	0.54	47.57	3.61	5.24	0.99	5.13
13	Brix % at 12 months	3.15	0.51	1.00	0.49	51.24	3.57	4.98	1.05	5.26
14	Purity% at 10 months	6.20	1.61	1.91	0.30	84.73	1.47	1.60	2.40	2.79
15	Purity% at 12 months	2.90	0.47	0.81	0.34	58.02	0.78	1.02	1.07	1.22
16	Sucrose % at 10 months	3.12	0.46	0.88	0.42	52.54	4.08	5.63	1.01	6.10
17	Sucrose % at 12 months	3.24	0.49	0.90	0.41	54.69	3.99	5.39	1.07	6.07
18	CCS% at Harvest	2.39	0.27	0.48	0.21	56.25	4.27	5.70	0.80	6.60
19	Fiber % at harvest	1.58	0.08	0.17	0.09	44.92	2.30	3.43	0.38	3.17
20	Pol % cane at harvest	2.63	0.34	0.63	0.29	53.96	3.98	5.42	0.88	6.03
21	Juice extraction%	3.65	0.72	1.60	0.88	45.17	1.48	2.20	1.17	2.05
22	Cane yield at harvest(t/ha)	27.47	29.68	49.01	19.33	60.46	9.97	12.83	8.72	15.98
23	CCS(t/ha) at harvest	3.91	0.70	1.03	0.33	67.96	12.58	15.26	1.42	21.36

https://doi.org/10.37992/2025.1601.002

shoots before and after waterlogging, cane height before and after waterlogging and at maturity, brix, purity, sucrose percent at 10 and 12 months, CCS % at harvest, fibre percent % at harvest under both the conditions. Limited variability was observed in the case of quality traits due to the same maturity group of all the clones in study.

Germination at 45 DAP, number of millable canes, the number of nodes bearing aerial roots, yield at harvest and the production of commercial cane sugar (in t/ha) at harvest exhibited a moderate level of PCV and GCV. These results were in accordance with Belwal and Ahmed (2020), Ghosh and Singh (1996) for all the traits. These results indicated that choosing genotypes according to traits such as count of nodes with aerial roots, cane yield, commercial cane sugar (t/ha), quantity of canes suitable for milling during harvesting, and germination at 45 days after planting would be a successful strategy for enhancing waterlogging tolerance. The close proximity between the GCV and the PCV suggests minimal environmental impact on these traits as the genotypes selected for these characters can be improved under stress condition for the waterlogging tolerance.

The concept of heritability measures the degree of variation in observable traits that arises from the influence of genes. It functions as a valuable indicator for assessing the transmission of traits from parents to their offspring, as indicated by Falconer (1989). A substantial number of breeders have considered heritability as a dependable tool for enhancing traits subject to selection. This criterion is widely used to refine the selection of superior genotypes from a diverse genetic pool. The benefits of expressing heritability estimates in terms of genetic progress are notable. Heritability and genetic progress, outlined as interconnected phenomena by Hanson (1963), mutually complement each other. It is important to recognize, however, that a trait with a high heritability value is not always accompanied by a significant genetic advancement, as demonstrated by Johnson *et al*. (1955).

Moderate to high heritability was observed for all the traits studied in this investigation suggesting that selection of clones for these parameters will be effective, as demonstrated by Gowda *et al.* (2016). The characters, number of tillers at 90DAP, cane diameter, single cane weight, number of millable canes, cane yield and commercial cane sugar (tons/hectare) at harvest, purity percent at 10 months recorded high heritability in broad sense under both the climatic conditions. The results of the investigation agreed with Chaudhary (2001) and Tadesse and Dilnesaw (2014). High heritability in broad sense was observed for brix%(86.23), sucrose percent at 10 and 12 months(85.75 and 83.03), CCS % at harvest(75.52), and pol percent cane at harvest(81.98) under waterlogging condition whereas the trait number of nodes with aerial roots had broad heritability (61.05) in normal conditions only. Moderate heritability was observed in the case of germination at 45 DAP(57.73,46.28), cane height before(42.90,44.80) and after waterlogging(45.27,57.05) and at maturity (46.27,56.30), fibre percent(44.92,42.22) and juice extraction percent at harvest(45.17,48.35) and purity percent at 12 months(58.02,58.97) under normal as well as under waterlogging conditions suggest that simple selection would be effective for these characters. Similar results were also reported by Krishna and Kamat (2018).

High genetic advance as percent of mean was noticed in the case of commercial cane sugar (t/ha) at harvest in both the experimental condition. This is similar to results reported by Behou and Pene, 2019; Anbanandan and Eswaran, 2018. High genetic advance was noticed for the trait number of nodes with aerial roots under normal conditions only. Quality traits such as brix percent at 10 and 12 months and sucrose percent at 10 months had moderate genetic advance under waterlogging but they had low genetic advance as percent of mean in normal conditions. This could be due to the varied expression level of genes under both the ecosystems. Quantitative traits like germination at 45DAP, number of tillers at 90DAP, cane diameter, single cane weight, number millable canes and cane yield at harvest recorded moderate genetic advance in waterlogging and normal conditions. A modest increase in genetic advance as percent of mean, highlights the influence of dominant gene effects on the development and enhancement of these traits. These results are in conformity with the observations of Belwal & Ahmad (2020), Kumar *et al.* (2018) and Gowda *et al.* (2016) for the characters cane yield, number of millable canes and cane diameter at harvest. Ranjan and Kumar (2017) also reported similar results for germination at 45DAP and cane height at harvest. Low genetic advance as percent of mean was observed for the trait purity percent at 10 and 12 months, sucrose % at 12 months, CCS %, fibre percent, pol percent cane and juice extraction percentage at harvest under waterlogged conditions. Low genetic advance as percent of mean values were reported for the trait, purity% (Gowda *et al.,* 2016).

The investigation also revealed that commercial cane sugar (t/ha) at harvest recorded high broad sense heritability coupled with high genetic advance as percent of mean in both the climatic conditions indicating additive gene action for the trait and reliable selection could be carried out based on the phenotypic expression of this trait in the individual plants. This result agreed with the results of Tolera *et al.* (2023). On the other hand, the trait number of nodes with aerial root recorded high broad heritability coupled with high genetic advance as percent of mean (GAM) under normal condition only. Selection based on this trait also will be effective under normal conditions. Characters such as cane yield, cane weight and number of millable canes at harvest, number of tillers at 90 DAP, cane diameter at harvest, had high heritability along with moderate genetic advance as percent of mean under waterlogged as well as normal conditions. The high heritability in conjunction with moderate genetic advance as percent of mean for all these traits revealed that these traits can be improved through effective selection process (Singh *et al.,* 2016). The results of high heritability along with high genetic advance as percent of mean for the traits, number of tillers at 90 DAP and cane diameter were reported by (Belwal and Ahmed (2020), Kumar *et al.* (2018), which agreed with the present investigation result. However, germination percent at 45DAP and number of nodes with aerial roots had moderate heritability and GAM values indicating that, phenotypic expression for these traits were controlled by non-additive gene action and hence selection cannot be exercised for these traits which are as well governed by both non-genetic and environmental factors.

The research definitively indicates that characteristics such as commercial cane sugar yield (t/ha) at harvest demonstrate considerable heritability and notable genetic improvement as a percentage of the mean. A wide range of heritability, from high to moderate, is shown by other characteristics such as cane yield (t/ha) at harvest, the number of millable canes at harvest, single cane weight at harvest, sucrose % in cane at harvest, and other qualities. Additionally, these variables show moderate to low values for genetic advance as a percentage of the mean, phenotypic coefficients of variation (PCV), and genetic coefficients of variation (GCV). Ultimately, this study showed that certain genotypes can be suggested for additional breeding programs and selection in the event of waterlogging.

REFERENCES

Agrawal, Rupesh Kumar and Balwant Kumar. 2017. Variability, heritability and genetic advance for cane yield and its contributing traits in sugarcane clones under waterlogged condition. *International Journal of Current Microbiology and Applied Sciences,* **6** (6): 1669-1679.

Agrawal, A. P., Patil, S. A., and Math, P. S. 2001. Variability, heritability and genetic advance of some quantitative characters over the seasons in soybean. *Madras Agricultural Journal*, **88**(1/3): 36-39. [Cross Ref]

Anbanandan, V. and Eswaran. R. 2018. Association analysis in sugarcane (*Saccharum officinarum* L.). *Journal of Pharmacognosy and Phytochemistry,* 71S : 2675-2677.

Anna Durai, A. and Karuppaiyan. R. 2023. Potential parents for developing climate-resilient sugarcane varieties in India: A Breeding Perspective. In *Agro-industrial Perspectives on Sugarcane Production under Environmental Stress*, pp. 57-83. Singapore: Springer Nature Singapore. [Cross Ref]

Béhou, M. Y. and Péné, C. B. 2019. Genetic variability and heritability among sugarcane genotypes in plant crop for some agronomic traits under tropical dry climate of Ferké, Ivory Coast. *Journal of Experimental Agriculture International,* **3**: 1-14. [Cross Ref]

Belwal, Vikas and Sarfraz Ahmad. 2020. Estimation of variability parameters in sugarcane under water logging conditions. *International Journal of Agriculture Sciences, ISSN* : 0975-3710.

Burton, Glenn, W. and de EH De Vane. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal,* **45:** 478-81. [Cross Ref]

Chaudhary, Rewati, R. 2001. Genetic variability and heritability in sugarcane. *Nepal Agric. Res. J* ., **4** (5) : 56-59. [Cross Ref]

Divya Chaudhary, Swati, Anil Kumar and Basu Sudhakar Reddy. 2023. Genetic variability and character association studies in bread wheat (*Triticum aestivum* L.) under two different water regimes. *Electronic Journal of Plant Breeding,* **14**(4): 1330-1336. [Cross Ref]

Falconer, D. S. 1989. Introduction to quantitative genetics. 3rd edition Longman. New York

Ghosh, J. and Singh, J. R. P. 1996. Variability in early maturing clones of sugarcane (*Saccharum* spp.). *Cooperative sugar,* **27***(5):* 341-344.

Gowda, S.N Swamy, Saravanan, K. and Ravishankar, C. R. 2016.Genetic variability, heritability and genetic advance in selected clones of sugarcane. *Plant Archives,* **16***(2)*: 700-704.

Hanson, W. D. 1963. Statistical Genetics and Plant Breeding NAS-NRC Publication **982**: 125-139.

Johnson, Herbert, W., Robinson, H. F. and Comstock, R. E.1955. Estimates of genetic and environmental variability in soybeans. *Agronomy Journal,* **47**: 314-18. [Cross Ref]

Krishna, Bal and Dharm Nath Kamat. Evaluation of sugarcane (*Saccharum officinarum* L.) mid-late clones under waterlogging conditions of Bihar (India). *Applied Biological Research,* **20** (1): 55-61. [Cross Ref]

Kadian, S. P., Chander Kishor Chander Kishor, and Sabharwal, P. S. 1997. Genetic variability and heritability in sugarcane. *Indian sugar,* **46***(12):* 973-975.

Kumar, Praveen, S. S. Pandey, Balwant Kumar, D. N. Kamat, and Mahesh Kumar. Genetic variability, heritability and genetic advance of quantitative traits in sugarcane. *International Journal of Chemical Studies,* **6** (3): 3569-3572.

Lush, Jay, L.1940. Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. *Journal of animal science*, (1): 293-301.

Panse, V.G. and Sukhatme, P.V. 1967. Statistical Methods of Agricultural Workers. 2nd Endorsement, ICAR Publication, New Delhi, India, pp: 381.

Patel, Ujjaval, Harshal Patil, Vipul Parekh, Gopal Vadodaria, and Alok Shrivastava. 2024. Genetic variability, heritability and genetic advance in finger millet (*Eleusine coracana* L.) genotypes. *Electronic Journal of Plant Breeding,* **15** (2): 471-477. [Cross Ref]

Ranjan, Relisha and Balwant Kumar. 2017. Study of genetic variability for cane yield and its component traits in early maturing sugarcane." *International Journal of Current Microbiology and Applied Sciences,* **6** (10): 1739-1748. [Cross Ref]

Sanghera, Gulzar Singh, Aishwarya Saini, and Lenika Kashyap. 2022. Physiological and biochemical traits associated with waterlogged tolerance in sugarcane (*Saccharum* spp. hybrid complex). *Plant Physiology Reports,* **27** (1): 44-55. [Cross Ref]

Singh, S. P., Munna Shahi, Suchita Singh, Lal, M. and Sharma, B. L. 2016. Performance of sugarcane varieties under water logging condition in Eastern Uttar Pradesh. *Agrica,* **5** (2) : 145-147. [Cross Ref]

Tadesse, F. and Dilnesaw, Z. 2014. Genetic variability, heritability and character association of twelve sugar cane varieties in Finchaa Sugar Estate West Wolega Zone Oromia Region of Ethiopia. *Int. J. Adv. Res. Biol. Sci.,* **1** (7): 131-137.

Tolera, Belay, Andargachew Gedebo, and Esayas Tena. 2023. Variability, heritability and genetic advance in sugarcane (*Saccharum* spp. hybrid) genotypes. *Cogent Food & Agriculture,* **9**(1): 2194482. [Cross Ref]