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Variability, Heritability and Genetic Advance for Cane Yield and its Contributing Traits in Sugarcane Clones under Waterlogged Condition

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A B S T R A C T

In a field experiment sixteen sugarcane clones including two checks were planted with three replications in RBD at Paddy Block, RAU, Pusa, Samastipur, Bihar during 2012-13 under low land area where its grand growth phase coincides with water-stagnation depth 40-45 cm for three months to study the variability, heritability and genetic advance of Sugarcane clones under water-logging condition for the traits *viz,* Germination Percentage at 45 days, Number of Shoots at 120 days, Plant Height at 150, 240 and 360 days, Cane diameter, NMC, Single Cane weight, Red Rot Score, Brix at 10,11 and 12 month, Pol at 10, 11 and 12 month, Purity at 10, 11 and 12 month, CCS Per cent at harvest and Cane yield. Highly significant variation was observed for all traits except purity at 10 and 11 month stage and CCS percent at harvest. High heritability coupled with high genetic advance as per cent of mean found for traits *viz.* number of shoots at 120 days, plant height at 240 and 360 days and single cane weight which will in favor of direct selection. Highest GCV and PCV were recorded for number of shoots at 120 days followed by plant height at 240 days and plant height at 360 days, indicating the importance of these traits to evaluate for water-logging tolerance. Comparatively the maximum phenotypic and genotypic variance were exhibited by the traits viz. plant height at 360 and 240 days, number of shoots at 120 days, plant height at 150 days, number of millable canes and cane yield (t/ ha).Number of shoots at 120 days, plant height at 240 days, plant height at 360 days, and single cane weight showed high heritability coupled with high genetic advance. Hence, direct selection can be done through these characters for future improvement of varieties.

Introduction

Varieties differ in degree of tolerance to water-logging based on certain inherent genetic characteristics, age of the crops and other growing conditions. A large difference in varietal response to water-logging in sugarcane has been reported. The varieties which are doing comparatively well under water-logging situation are BO91, BO110 and BO147, therefore only these three varieties cover more than 40% sugarcane cultivated area in Bihar. The recovery of sugarcane in Bihar has been found lower than the other states of India since last 3 decade. Sugar industries in Bihar is facing several challenges and most of the sugarcane industries are closed since last three decade due to various reason, among them major is 35-40 per cent of sugarcane growing area (presently total area

under sugarcane in the state is 3.00 lakh ha) in Bihar is prone to water-logging situation. Low productivity of sugarcane in Bihar has been recorded since last fifty year (approximately 30-50 t/ha.) due to lack of stable high yielder water logging tolerant variety. It is fact that in water-logged areas, cane yield generally declined by 15-20 per cent. If the water-logging is in the early stage of crop growth it affects the germination, tillering and cane growth, which may result in crop failure. Generally, the water-logging coincides with the grand growth phase and may extend up to maturity of the crop and hence, the early planted crop suffers less. For the clonal differences in the response of severe water-logging was studied and found that under artificially created conditions of prolonged water-logging *Saccharum* spp.

Hybrid Complex clones were highly susceptible and did not survive whereas the clones of *Saccharum barberi, Saccharum sinense, Saccharum sclerostachya* and *Saccharum erianthus* survived. Several clones of *Saccharum spontaneum, Saccharum robustum* and *Saccharum narenga* were water-logging tolerant. In the breeding of sugarcane, it has been a general practice to cross the different species with the noble cane, *S. officinarum*, to combine the high sugar yield of the *officinarum* clones with hardiness and disease resistance of the other species, a procedure called *nobilization*. Todays hybrid complexes *i.e. Saccharum spp*. clones with water-logging tolerant genes can do well under water-logging condition which requires systematic study on their comparative tolerance. Although the use of high yielding varieties coupled with moderate to high sucrose and also having water-logging tolerance capacity contribute substantially in sugarcane production and productivity but still there is need to screen sugarcane varieties tolerant to water-logging condition for its better adaptability and to overcome the problem of water-logging areas under sugarcane cultivation which will enhance the productivity as well as recovery of this crop. Therefore present investigation was formulate to study the variability, heritability and genetic advance of Sugarcane clones under water-logging condition for the productive traits which will be helpful for the researches as well as farmers of sugarcane cultivation under such type of water-logging areas of Bihar.

Materials and Methods

The present experiment was conducted in the fields located at Paddy Block, RAU, Pusa, Samastipur, Bihar during 2012-2013 with sixteen promising sugarcane clones viz., BO153, BO141, CoSe96436, CoX07067, CoP081, CoP091, CoP02061, CoP111, CoP04181, BO155, BO154, BO146, CoP092 (CoP 9437), Colk94184 including two checks namely BO91 and BO147 under water-logged condition and a minimum of 40-45 cm depth of water is maintained during July-October. All the sixteen clones were grown under field condition in Randomized Block Design (RBD) with three replications follow all agronomical package and practices. In each replication each variety was grown in a plot of 6 rows of 6 meters length each with a spacing of 0.90 meter between rows and plot size is 32.4 m^2.

Observations were record by selecting five random plants per genotype per replication for cane yield and yield attributing characters viz, Germination Percentage at 45 days, Number of Shoots at 120 days, Plant Height at 150, 240 and 360 days, Cane diameter, NMC, Single Cane weight, Red Rot Score, Brix at 10,11 and 12 month, Pol at 10, 11 and 12 month, Purity at 10, 11 and 12 month, CCS Per cent at harvest and Cane yield. Red rot score (0-9 scale) was observed after splitting of five randomly selected plants of each genotype per replication.

Statistical analysis

Estimation of variance components Genotypic and phenotypic components of variance were estimated with the help of following formulae

Genotypic Variance (σ_g^2) = (vMSS – EMSS) x CF
Phenotypic variance (σ_p^2) = σ_g^2 + EMS

Coefficient of variability

Both genotypic and phenotypic coefficient of variability were computed for each character as per method suggested by Burton and De Vane (1953)

Genotypic Coefficient of Variation (GCV) = genotypic standard deviation (σ_g) divided by grand mean of the character x 100

Phenotypic Coefficient of Variation (PCV) = Phenotypic standard deviation (σ_p) divided by grand mean of the character x 100

Heritability (h^2)

It was estimated in broad sense by using following formula as suggested by Lush (1940).

h^2 = Genotypic variances (σ_g^2) divided by Phenotypic variances (σ_p^2) x 100

Genetic advance (GA) for each character was computed by adopting the formulae given by Johnson *et al.,* (1955).

$GA = h^2 .K. \sigma_p$

Where,

h^2= Heritability of the character.
K = Selection differential which is equal to 2.06 at 5 percent intensity of selection (Lush, 1949).

σ_p = Phenotypic standard deviation of the character

Genetic advance as per cent of mean (GAM)

GAM (%)= Genetic advance (GA) divided by General mean of population (Gm) × 100

The estimates of variability parameters that are coefficient of variation at genotypic (GCV), phenotypic (PCV), environmental level (ECV), heritability (%) and genetic advance as percentage of mean. In general the estimated values of PCV were higher than GCV for all the characters studied indicating role of environment on the performance of clones. GCV and PCV values were categorized as low (0-10%), moderate (10-20%) and high (20 and above) as indicated by Sivasubramanian and Menon (1973). The heritability was categorized as low (0-30%), moderate (30-60%) and high (60 and above) as given by Robinson *et al.,* (1949). Genetic advance as per cent mean was categorized as low (0-10%), moderate (10-20%) and high (20 and above) as given by Johnson *et al.,* (1955).

Results and Discussion

Genetic variability is one of the important consideration in any crop improvement which is needed to study in detail. Variability is measure by estimation of genotypic and phenotypic variance (σ^2g and σ^2p), genotypic and phenotypic coefficient of variation (GCV and PCV), heritability, genetic advance and genetic advance as per cent of mean. These parameters help in selection for improvement of desired characters. Environment plays an important role in the expression of phenotype. The phenotypic variability which is observable includes both genotypic (heritable) and environmental variation (non-heritable). Hence, variability can be observed through biometric parameters like GCV, heritability

(broad sense) and genetic advance. The analysis of variance (Table 1) revealed highly significant variation among the varieties for all the 19 traits studied except purity at 10 month stage, purity at 11 month stage and CCS per cent at harvest under water-logging condition. This indicated that there was presence of sufficient variability in the material studied under water-logging condition because of the fact that these clones were derived from parents having different 'backgrounds' geographical one. In other words further analysis of water-logging tolerance is meaningful as indicated by significant mean sum of squares under water-logging condition *i.e.*, stress condition. Many earlier workers, Tyagi and Singh (1998), Kadian *et al.*, (1997), Kumar and Singh (1999), Gupta and Chatterjee (2002), Thippeswamy *et al.*, (2001), Puneet *et al.*, (2001), Hapase and Repale (2004), Doule and Balasundaram (2003), Singh *et al.*, (2010) and Nair and Somarajan (1986) reported high variability for different traits in sugarcane. Thus, it is implied that there was reasonably sufficient variability in material used for their study, which provides ample scope for selecting superior and desire clone by the plant breeder for further improvement. The phenotypic variances for all the traits under studied were higher than the genotypic variances (Kadian *et al.*, (1997). This may be due to the non-genetic factor which played an important role in the manifestation of these characters. A perusal of table 3 revealed that phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits under investigation. The narrow difference between PCV and GCV were recorded for most of the traits. High phenotypic coefficient of variability was recorded for number of shoots per hectare at 120 days after planting (20.91) followed by plant height at 240 days after planting (20.09), plant height at 360 days after planting (17.97), number of millable canes (15.72), cane yield (15.06), Almost same trend has been recorded for genotypic coefficient of variability with maximum value for number of shoots per hectare at 120 days after planting (18.29), followed by plant height at 240 days after planting (17.86), plant height at 360 days after planting (15.48). The characters having moderate phenotypic coefficient of variability were CCS per cent at harvest (14.69), single cane weight (13.97), plant height at 150 days (13.90), germination percent at 45 days (12.56), cane diameter at harvest (12.18), pol at 10 month stage (11.87), brix at 10 month stage (11.69), pol at 12 month stage (10.78) and pol at 11 month stage (10.30). Moderate genotypic coefficient of variability were exhibited by the characters namely, single cane weight (13.77), number of millable canes (12.00), cane yield (10.77) and plant height at 150 days (10.40). Low phenotypic coefficient of variability was recorded for brix at 11 month stage (9.19), brix at 12 month stage (8.92), purity at 12 month stage (6.03), purity at 11 month stage (4.96) and purity at 10 month stage (4.38). Similarly, low genotypic coefficient of variability were shown by the characters namely, pol at 10 month stage (9.01), brix at 10 month stage (8.79), cane diameter at harvest (7.58), pol at 12 month stage (7.48), CCS per cent at harvest (7.28), pol at 11 month stage (6.76), germination per cent at 45 days (6.75), brix at 11 month stage (5.05), brix at 12 month stage (4.83), purity at 12 month stage (3.58), purity at 10 month stage (2.01) and purity at 11 month stage (0.62).Wide ranges of variance (phenotypic and genotypic) were observed in the experimental material for all the characters under investigation. The maximum phenotypic and genotypic variance exhibited by the traits, plant height at 360 days, plant height at 240 days, number of shoots at 120 days, number of millable canes, cane yield, and germination percentage at 45 days under water-logging condition. These findings were in accordance with the result of Kumar and Singh (1999),

Gupta and Chatterjee (2002), Thippeswamy *et al.,* (2001), who also observed high variance for yield and yield component traits among sugarcane genotypes. The assessment of heritable and non-heritable components in the total variability observed is indispensable in adopting suitable breeding procedure. The heritable portion of the overall observed variation can be ascertained by studying the components of variation such as GCV, PCV, heritability and genetic advance as per cent of mean.

The genotypic and phenotypic coefficient of variation (Table 3) found to be high for traits *viz.* number of shoots per hectare at 120 days, followed by plant height at 240 days, plant height at 360 days, single cane weight and number of millable canes. These results are in agreement with Kumar and Singh (1999) for all the characters cited above. The results showed high GCV and PCV for number of shoots at 120 days, indicating the importance of this trait in evaluation of clones for water-logging tolerance and selecting the varieties for water-logging tolerance. These findings were clearly indicated that selecting genotypes through the traits *viz.* number of shoots per hectare at 120 days, followed by plant height at 240 days, plant height at 360 days, single cane weight, and number of millable canes will be effective for water-logging tolerance. It is interesting to note that the differences between GCV and PCV values were minimum implying least influence of environment and additive gene effects indicating genotypes can be improved and selected for these characters under stress condition for improvement of water-logging tolerance. Heritability is a measure of the extent of phenotypic variation caused by the action of genes. It is a good index of the transmission of characters from parents to their offspring (Falconer, 1989). For making effective improvement in the characters for which selection is practiced, heritability has been adopted by large number of workers as a reliable indicator. The estimates of heritability help plant breeder in selection of elite genotypes from diverse genetic population. The estimates of heritability are more advantageous when expressed in terms of genetic advance. Hanson (1963) stated that heritability and genetic advance are two complementary concepts. However it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al.,* 1955a).The heritability in broad sense and genetic advance as per cent of mean was worked out for all the characters, have been presented in table 3 and their performance adjudged on the basis given by Robinson *et al.,* (1949) for heritability and Johnson *et al.,* (1955a) for genetic advance as per cent of mean.

Category	Heritability (broad sense)	Genetic Advance as per cent of mean
High	> 60 %	> 20 %
Moderate	30 %-60 %	10 % - 20 %
Low	< 30 %	< 10 %

On the basis of this characterization it was clear from table 3 that maximum heritability (broad sense) was observed for single cane weight (97) followed by plant height at 240 days (79), number of shoots at 120 days (76) and plant height at 360 days (74). Moderate heritability (broad sense) was observed for the characters *viz.* pol at 10 month stage and number of millable canes (58) followed brix at 10 month stage (57), plant height at 150 days (56), cane yield (51), pol at 12 month stage (48), pol at 11 month stage (43), cane diameter at harvest (39), germination percent at 45 days (38), purity at 12 month stage (35) and brix at 11 month stage (30). Low heritability (broad sense) were observed for the characters brix at 12 month stage (29), CCS per cent at harvest (25), purity at 10 month stage (21) and purity at 11 month stage (20).

Table.1 Analysis of variance for nineteen characters of sixteen sugarcane varieties under water-logging condition

Sr. No.	Characters	Mean sum of squares		
		Replications n (d.f.=2)	Treatments (d.f. = 15)	Error (d.f.=30)
1	Germination % at 45 days After Planting	0.02	31.19**	10.94
2	Number of Shoots at 120 days (000/ha)	15.32	1849.83**	171.95
3	Plant Height at 150 days (cm)	10.96	1135.86**	235.79
4	Plant Height at 240 days (cm)	15.59	4388.67**	356.97
5	Brix at 10 Month Stage (%)	0.28	9.39**	1.91
6	Pol at 10 Month Stage (%)	0.10	7.45**	1.47
7	Purity at 10 Month Stage (%)	13.05	8.56	17.86
8	Brix at 11 Month Stage (%)	0.14	4.57**	1.99
9	Pol at 11 Month Stage (%)	0.08	5.00**	1.53
10	Purity at 11 Month Stage (%)	1.93	18.00	18.88
11	Brix at 12 Month Stage (%)	0.37	4.04**	1.80
12	Pol at 12 Month Stage (%)	0.36	5.50**	1.46
13	Purity at 12 Month Stage (%)	0.65	47.12**	17.86
14	CCS Per cent at Harvest	0.57	3.65	1.85
15	Plant Height at 360 days (cm)	24.14	4518.52**	468.80
16	Cane Diameter at harvest (cm)	0.0009	0.17**	0.06
17	Single Cane Weight (kg)	0.0003	0.04**	0.0003
18	Number of Millable Canes (000/ ha)	4.98	574.26**	110.60
19	Cane Yield (tonne/ ha)	3.59	314.37**	75.93

** and * indicates significant level at 1 % and 5 %, respectively

Table.2 Mean, range and coefficient of variance for nineteen characters of sixteen sugarcane varieties under water-logging condition

Sr. No.	Characters	Symbol	Mean ± SEM	C.V.	Range	
					Min	Max
1	Germination % at 45 Days After Planting	G%	33.49±1.85	11.25	28.72	39.79
2	Number of Shoots at 120 days (000/ha)	S120	129.30±7.33	5.06	101.66	180.16
3	Plant Height at 150 days (cm)	PH150	166.57±8.58	6.36	134.66	202.30
4	Plant Height at 240 days (cm)	PH240	205.27±10.56	5.56	157.00	301.33
5	Brix at 10 Month Stage (%)	B%10	17.96±0.77	3.87	14.73	21.97
6	Pol at 10 Month Stage (%)	P%10	15.68±0.68	4.65	12.54	18.60
7	Purity at 10 Month Stage (%)	PU%10	87.65±2.36	2.11	85.25	91.77
8	Brix at 11 Month Stage (%)	B%11	18.36±0.79	3.48	15.73	20.00
9	Pol at 11 Month Stage (%)	P%11	15.91±0.69	3.76	13.14	17.75
10	Purity at 11 Month Stage (%)	PU%11	86.88±2.43	2.77	81.54	89.69
11	Brix at 12 Month Stage (%)	B%12	17.88±0.75	3.86	15.73	20.47
12	Pol at 12 Month Stage (%)	P%12	15.53±0.67	4.99	13.31	17.97
13	Purity at 12 Month Stage (%)	PU%12	87.17±2.36	2.94	82.64	93.87
14	CCS Per cent at Harvest	CCS%	10.65±0.76	9.52	9.01	12.39
15	Plant Height at 360 days (cm)	PH360	237.33±12.10	3.44	185.53	327.37
16	Cane Diameter at harvest (cm)	CD	2.57±0.14	4.17	2.16	2.92
17	Single Cane Weight (kg)	SCW	0.81±0.01	7.09	0.59	0.98
18	Number of Millable Canes (000/ ha)	NMC	103.56±5.88	9.16	83.12	130.43
19	Cane Yield (tonne/ ha)	CY	82.78±4.87	7.24	62.81	97.08

Table.3 Genotypic variance (σ2g), phenotypic variance (σ2p), genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability broad sense (h2) and genetic advance as per cent of mean (GA) for 19 characters of 16 sugarcane clones under water-logging condition

Sr. No.	Characters	σ^2_g	σ^2_p	GCV	PCV	h^2 (Broad sense) %	GA as % of Mean
1	**Germination % at 45 Days After Planting**	6.75	17.69	6.75	12.56	38	9.87
2	**Number of Shoots at 120 days (000/ha)**	559.29	731.24	18.29	20.91	76	32.95
3	**Plant Height at 150 days (cm)**	300.02	535.81	10.40	13.90	56	16.03
4	**Plant Height at 240 days (cm)**	1343.90	1700.87	17.86	20.09	79	32.70
5	**Brix at 10 Month Stage (%)**	2.49	4.40	8.79	11.69	57	13.63
6	**Pol at 10 Month Stage (%)**	1.99	3.46	9.01	11.87	58	14.07
7	**Purity at 10 Month Stage (%)**	3.10	14.76	2.01	4.38	21	1.90
8	**Brix at 11 Month Stage (%)**	0.86	2.85	5.05	9.19	30	5.71
9	**Pol at 11 Month Stage (%)**	1.16	2.69	6.76	10.30	43	9.14
10	**Purity at 11 Month Stage (%)**	0.29	18.58	0.62	4.96	20	1.16
11	**Brix at 12 Month Stage (%)**	0.75	2.55	4.83	8.92	29	5.40
12	**Pol at 12 Month Stage (%)**	1.35	2.80	7.48	10.78	48	10.68
13	**Purity at 12 Month Stage (%)**	9.76	27.61	3.58	6.03	35	4.39
14	**CCS Per cent at Harvest**	0.60	2.45	7.28	14.69	25	7.44
15	**Plant Height at 360 days (cm)**	1349.91	1818.70	15.48	17.97	74	27.47
16	**Cane Diameter at harvest (cm)**	0.04	0.10	7.58	12.18	39	12.45
17	**Single Cane Weight (kg)**	0.01	0.01	13.77	13.97	97	27.98
18	**Number of Millable canes (000/ ha)**	154.55	265.16	12.00	15.72	58	18.88
19	**Cane Yield (tonne/ ha)**	79.48	155.41	10.77	15.06	51	15.87

A perusal of genetic advance as per cent of mean (Table 3) revealed that it ranges from 1.16 (purity at 11 month stage) to 32.95 (number of shoots at 120 days). The result showed that four attributes namely number of shoots per hectare at 120 days (32.95), plant height at 240 days (32.70), single cane weight (27.98) and plant height at 360 days (27.47) were exhibited high genetic advance as per cent of mean (> 20%). Although, the traits number of millable canes (18.88), plant height at 150 days (16.03), cane yield (15.87), pol at 10 month stage (14.07), brix at 10 month stage (13.63), cane diameter at harvest (12.45) and pol at 12 month stage (10.68) showed medium genetic advance as per cent of mean (10% -20%). However, the traits germination percent at 45 days (9.87), pol at 11 month stage (9.14), CCS per cent at harvest (7.44), brix at 11 month stage (5.71), brix at 12 month stage (5.40), purity at 12 month stage (4.39), purity at 10 month stage (1.90) and purity % at 11 month stage (1.16) were exhibited low genetic advance as percent of mean (< 10%). Comparatively the maximum phenotypic and genotypic variance were exhibited by the traits viz. plant height at 360 and 240 days, number of shoots at 120 days, plant height at 150 days, number of millable canes and cane yield (t/ ha).Number of shoots at 120 days, plant height at 240 days, plant height at 360 days, and single cane weight showed high heritability coupled with high genetic advance. Hence, direct selection can be done through these characters for future improvement of varieties.

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