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Heritability analysis to screen elite sugarcane (*Saccharum* spp.) soma clones under field condition

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Three elite sugarcane varieties were used in this experiment to check the heritability parameters which consist of range, environmental variance, genetic variance, genetic advance and broad sense heritability. Four hundred and five soma clones were observed for phenotypic characters including number of tillers (plant^{-1}), cane height (cm), number of internode (plant^{-1}) and width of internode (cm). Variability range for different characters include number of tillers (plant^{-1}), cane height (cm), number of internode (plant^{-1}) and width of internode (cm) and were also assessed for three auxins. Highest heritability and remarkable genetic advance were recorded for the height of the cane and number of internode (plant^{-1}) was found when 2, 4-D was applied in Murashige and Skoog (MS) media, which directly affected the yield of sugarcane. High heritability and good genetic advance were observed for number of tillers (plant^{-1}) and width of internode (cm) when NAA was applied in the media. In addition to this, increasing concentration of hormones had positive effect on the heritability and genetic advance for phenotypic traits of the sugarcane soma clones. Similarly, it was observed that environmental and genetic variances have optimum effect on the heritability of the sugarcane. Application of 2, 4- D and picloram were recorded as efficient in transference of high heritability and genetic advance to them. On the basis of higher heritability selection made to develop hybrid in sugarcane, higher genetic advancement helped to develop synthetic varieties in sugarcane.

Key words: Heritability, genetic advance, sugarcane (*Saccharum* spp.), auxins, phenotypic character.

INTRODUCTION

Sugarcane (*Saccharum* spp.) hybrids is an important cash crop which belongs to the Poaceae family (Sharma, 2005; Cha-um et al., 2006). Knowledge of the heritability of any phenotypic traits will be very helpful in breeding programs worldwide. So, genetic variability and heritability are useful parameters that can help breeding during different stages of crop improvement (Ali et al., 2014ab). Genotype affected by environment was reported by many researchers (Kimbeng et al., 2002). Environment has significant relation towards genotypes that influence yield

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of sugarcane (Parfitt, 2000; Kimbeng et al., 2002; Janghir et al., 2013; Glaz and Kang, 2008; Qamar et al., 2015). The relationship between the characters is difficult to understand mostly when low heritability occurs (Bakhsh et al., 2006; Silva et al., 2007). Selection of the characters was directly made by understanding the nature of one trait affected by the other (Ali et al., 2013, 2014ab; Butt et al., 2015; Jackson, 1994; Tyagi and Khan, 2010). Phenotypic character has association with the yield components (Jamoza et al., 2013) like number of stalk (plant^{-1}), width of cane (cm), and height of cane (cm) which are helpful for the variety development (Tyagi and Khan, 2010). The function of heritability in genetics was considered to evaluate quantitative traits and qualitative traits which are valuable for economic and used for the breeding programs. Heritability estimation (Hanson et al., 1956) together with genetic advance are most important for selection of yield, and its contributing characters are useful for future selection of superior clones in sugarcane industry (Ahmed et al., 2012).

The improvement of characters will depend mostly on the extents of genetic variability in the base population and heritability. Therefore, the present study is helpful for the assessment of heritability parameters of phenotypic characters like number of tillers (plant^{-1}), number of internodes (plant^{-1}), height of cane (cm) and width of internode (cm). There are many traits which are important for the heritability enhancement, but few are optimized under field condition including those traits that are vital for the selection of character which can be utilized for further improvement of the yield of sugarcane.

MATERIALS AND METHODS

Established plants were transferred to the field from pots for further heritability analysis. Data was recorded for four hundred and five replicates (405) of sugarcane.

Assessments of phenotypic traits

Only 135 stable soma clones were finally evaluated for four phenotypic characters related to yield.

Number of tillers (plant^{-1})

Three randomly selected canes were recorded for the number of tillers from each treatment. Thereafter, their average was noted.

Height of cane (cm)

The height of each selected plant was calculated in centimeters from the surface of soil to the tip of the leaf.

Width of internode (cm)

The stem girth of each plant was recorded in centimeters by vernier caliper, from bottom, mid and top portion and average of the three data was used for data analysis.

Number of internodes (plant^{-1})

Three randomly selected canes from each treatment were counted for number of internode. Thereafter, their average was noted.

Heritability analysis

Data was statistically analyzed by using Steel et al. (1997) analysis of variance technique. Phenotypic traits were further subjected to heritability analysis. Genetic parameters viz., heritability percentage in broad sense (h^2 b.s), environmental variance (Ve), genetic variance (Vg) and genetic advance (G.A) were calculated as suggested by Falconer and Mackay (1996):

1. Mean $x = \frac{\sum xi}{n}$
2. Variance $S^2 = \frac{s.s}{n-1}$
3. Standard Deviation (SD) $= \sqrt{s2}$
4. Coefficient of variability (CV) = $\frac{S.D}{Mean} \times 100$
5. Genetic variance (Vg) = VC_3- Ve
6. Environmental variance (Ve) = $(VP_1 + VP_2)/2$
7. Heritability percentage in broad sense (h^2 b.s %) = Vg / VC_3 x 100
8. Genetic advance (G A) = K × (H) × SD.

Where, V = variance C_3 third sub culture generation, and p = parent.
S.D = Phenotypic standard deviation
K = Constant (2.06) for selection difference at 5% Selection intensity
Ve = Environmental variance
Vg = Genetic variance
H = Heritability coefficient
Vp_1 = Variance of parent one
Vp_2 = Variance of parent two
VC_3 = Variance of C_3 soma clones
h^2% (b.s) = Heritability percentage in broad sense
(GA) = K × (H) × SD
N = number of replication

RESULTS

Heritability analysis in soma clones of NIA-2012

The results of parents and soma clones for heritability are presented in Tables 1, 2 and 3. Overall variations were observed among soma clones and their parents as a response of different auxins applied. Differential heritability and genetic advance was observed in tested parents and their soma clones. Number of tillers ranged from 1 to 8.5 and height of cane from 110.19 to 126.19. While number of internode ranged from 10 to 24 and width of internode ranged from 1.11 to 1.94 in 2,4-D. High heritability for height of cane (77%) with remarkable genetic advance (8.6) was observed in NIA-2012 while

Table 1. Heritability analysis of sugarcane parental genotype (NIA2012) and their soma clones affected by different concentrations of 2, 4- D.

Character	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	1-85	2.24	1.86	1.439	45
Height of cane	110.19-126.19	6.7335	22.681	8.602	77
No. of internode	10-24	8.41	5.59	3.076	39
Width of internode	1.11-1.94	0.0451	0.0592	0.37	56

Table 2. Heritability analysis of sugarcane parental genotype (NIA2012) and their soma clones affected by different concentrations of Picloram.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	1-7	1.5995	1.0405	1.319	39
Height of cane	110.11-125.12	7.569	15.259	6.563	66
No. of internode	10-19	5.5985	4.752	3.04	45
Width of internode	1.08-1.72	0.0426	0.0471	0.324	52

Table 3. Heritability analysis of sugarcane parental genotype (NIA2012) and their soma clones affected by different concentrations of NAA.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	1-6	1.0085	0.251	0.518	19
Height of cane	109.12-119.15	6.246	3.682	2.401	37
No. of internode	7-17	2.048	1.876	1.95	47
Width of internode	1.11-1.65	0.0118	0.0135	0.174	53

moderate heritability (56%) with less genetic advance (0.37) was recorded for width of internode. Whereas, low heritability was found for number of tillers and number of internodes exhibited with poor genetic advance, while as number of tillers ranged from 1 to 7, height of cane ranged from 110.11 to 125.12, whereas number of internode ranged from 10 to 19 and width of internode ranged from 1.08 to 1.72 in picloram. Moderate heritability for height of cane (66%) with good genetic advance (6.5) was observed in NIA-2012, while low heritability (39%) with less genetic advance for number of internode (plant^{-1}) (45%), and width of internode (cm) (52) was recorded in picloram. As number of tillers (plant^{-1}) ranged from 1 to 6, height of cane (cm) ranged from 109.12 to 119.15. Whereas, number of internode (plant^{-1}) ranged from 7 to 17 and width of internode (cm) ranged from 1.11 to 1.65 in NAA. Low heritability for number of tillers (plant^{-1}) (19%), height of cane (37%), number of internode (47%) and width of internode (cm) (53%) was recorded in NIA-2012. In case of NIA-2012 2, 4-D was the best hormone among tested auxins as it resulted in high genetic vitiations for height of cane (cm), number of internode (plant^{-1}), moderate for width of internode (cm) and poor for number of tillers (plant^{-1}) followed by picloram that induced moderate genetic variations for height of cane and width of internode.

Heritability analysis in soma clones of NIA-105

The data of parents and soma clones for heritability are depicted in Tables 4, 5, 6 and 7 number of tillers (plant^{-1}) ranged from 1 to 9 and height of cane (cm) from 111.19 to 126.14. While number of internode (plant^{-1}) ranged from 10 to 28 and width of internode (cm) ranged from 1.13 to 2.34 in 2, 4-D. High heritability for number of internode (plant^{-1}) (83%) with considerable genetic advance (4.95) was observed in NIA-105 while moderate heritability (58%) with less genetic advance (0.33) was recorded for width of internode whereas, low heritability for number of tillers (plant^{-1}) and height of cane were revealed with reduced genetic advance. While as number

Table 4. Heritability analysis of sugarcane parental genotype (NIA-105) and their soma clones affected by different concentrations of 2, 4- D.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	1-9	2.847	0.0885	0.1062	3
Height of cane	111.1 4-126.14	14.3	4.404	2.091	23
No. of internode	10-28	9.204	15.395	4.95	83.4
Width of internode	1.13 -2.34	0.0335	0.0465	0.335	58

Table 5. Heritability analysis of sugarcane parental genotype (NIA-105) and their soma clonesaffected by different concentrations of Picloram.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	2-8	1.101	0.993	1.413	47
Height of cane	18.12-126.16	5.427	5.822	2.367	51
No. of internode	10-26	2.177	7.420	4.94	77
Width of internode	1.11-2.24	0.0206	0.0218	0.218	51

Table 6. Heritability analysis of sugarcane parental genotype and their (NIA-105) soma clones affected by different concentration NAA.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	1-9	1.885	1.782	1.91	48
Height of cane	108.24-127.18	13.417	8.023	3.569	37
No. of internode	10-28	17.785	14.032	4.056	61
Width of internode	1.18-2.34	0.0318	0.065	0.433	67

Table 7. Heritability analysis of sugarcane parental genotype (Gulabi-95) and their somaclones affected by different concentrations of 2,4-D.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	2-9	2.154	0.664	1.0671	30
Height of cane	111.23 -127.87	18.7	5.98	2.479	24
No. of internode	12-28	11.35	9.05	4.093	44
Width of internode	1.13-2.54	0.0460	0.046	0.0309	50

of tillers ranged from 1 to 9, height of cane ranged from 108.24 to 127.18. Whereas number of internode (plant^{-1}) ranged from 10 to 28 and width of internode ranged from 1.18 to 2.34 in picloram. Moderate heritability for number of internode (61%) with remarkable genetic advance (4.05) was found in NIA-105. Moderate heritability for width of internode (67%) with low genetic advance (0.433) was observed in picloram. Low heritability for number of tillers (plant^{-1}) (48%) and height of cane (37%) was recorded in NIA-105. While as number of tillers (plant^{-1}) ranged from 2 to 8, height of cane ranged from 109.12 to 126.16. Whereas, number of internode (plant^{-1}) ranged from 10 to 26 and width of internode (cm) ranged from 1.11 to 2.24 in NAA while high heritability for number of internode (plant^{-1}) (77%) with good genetic advance was recorded in NIA-105. Low heritability for number of tillers (plant^{-1}), height of cane and width of internode was obtained in NAA. In case of NIA-105 2, 4-D

Table 8. Heritability analysis of sugarcane parental genotype (Gulabi-95) and their somaclones affected by different concentrations of Picloram.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	1-9	1.885	1.782	1.91	48
Height of cane	108.24-127.18	13.417	8.023	3.569	37
No. of internode	10-28	17.785	14.032	4.056	61
Width of internode	1.18-2.34	0.0318	0.065	0.433	67

Table 9. Heritability analysis of sugarcane parental genotype (Gulabi-95) and their soma clones affected by different concentrations of NAA.

Characters	Range	Environmental variance	Genotypic variance	Genetic advance	Heritability h^2bs (%)
No. of tillers	2-8	1.101	0.993	1.413	47
Height of cane	18.12-126.16	5.427	5.822	2.367	51
No. of internode	10-26	2.177	7.420	4.94	77
Width of internode	1.11-2.24	0.0206	0.0218	0.218	51

was the best hormone among tested auxins as it results in high genetic vitiations for number of internode (plant^{-1}), moderate for width of internode and poor for number of tillers (plant^{-1}) followed by picloram that induced moderate genetic variations for height of cane and width of internode.

Heritability analysis in soma clones of Gulabi-95

The results of parents and soma clones for heritability are compiled in Tables 7, 8 and 9. Overall variations were observed among soma clones and their parents as a response of varying auxins applied. Number of tillers (plant^{-1}) ranged from 2 to 9, height of cane from 111.23 to 127.87. While number of internode (plant^{-1}) ranged from 12 to 28 and width of internode ranged from 1.13 to 2.54 in 2,4-D. Whereas, low heritability for number of tillers (plant^{-1}) (30%), height of cane (24%) and width of internode (50%) with less genetic advance was found in Gulabi-95. Low heritability for number of internode (plant^{-1}) (44) with remarkable genetic advance (4.09) was recorded in 2, 4-D. While as number of tillers (plant^{-1}) ranged 1 to 9, height of cane (cm) from 108.24 to 127.18. Whereas number of internode ranged from 10 to 28 and width of internode ranged from 1.18 to 2.34 in picloram. Moderate heritability for number of internode (plant^{-1}) (61%) with good genetic advance (4.05) was found in Gulabi-95. Moderate heritability for width of internode (67%) with low genetic advance (0.433) was recorded in Gulabi-95. Whereas low heritability for number of tillers (plant^{-1}) (48%), height of cane (cm) (37%) and with less genetic advance was obtained in Gulabi-95. Number of tillers (plant^{-1}) ranged from 2 to 8, height of cane from 118.12 to 127.16. While number of internode (plant^{-1}) ranged from 10 to 26 and width of internode ranged from 1.11 to 2.24 in NAA. High heritability for number of internode (plant^{-1}) (77%) with good genetic advance (4.94) was found in Gulabi-95. Whereas low heritability for number of tillers (plant^{-1}) (47%), height of cane (51%) and width of internode (51) with less genetic advance was obtained in Gulabi-95 when NAA was applied. For Gulabi-95 × somaclones 2,4-D do not stimulate genetic variation rather Picloram and NAA generated moderate genetic variations for number and width (plant^{-1}) of internode and number of tillers (plant^{-1}) while low variations for height of cane.

DISCUSSION

Heritability exploration in NIA-2012

High heritability coupled with good genetic advance and high environmental variance in NIA- 2012 × soma clones for height is also reported earlier in some other varieties of sugarcane all around the world (Zhou et al., 2005, 2011). The results indicate existence of considerable genetic vitiations induced through callus culture. Moderate heritability with poor genetic advance for number of tillers (plant^{-1}) and number of internode (plant^{-1}) was consistent with the findings of Khan et al. (2009) and Raza et al. (2014). High heritability with low genetic advance and environmental effects found for thickness of cane is supported by Hoy et al. (2003) who observed smaller cane diameter in the plants regenerated from callus culture. Generally width of internode (cm) is negatively correlated with yield of sucrose (Pandey, 1989; Butterfield and Nuss, 2002) therefore low genetic advance for this character is in favor of the present genetic improvement strategy. It can be inferred from over all heritability analysis that 2, 4-D and picloram are effective among tested auxins towards soma clonal variation as compared to NAA.

Heritability exploration in NIA-105

Good genetic advance and high heritability coupled with and low environmental variance for number of internode (plant^{-1}) is supported by the work of Bull (2000) and who also elaborated environmental effect on number of internode (plant^{-1}) directly correlated to the yield of sugarcane. It is obvious from results that this character is largely influenced by growth hormones not by environmental effects so selection for improvement of that characters must be useful. High heritability with low genetic advance was recorded for width of internode (cm) indicating non-additive effect of gene. Similar results of higher number of internodes, greater length of internodes contributing height of cane and smaller width of cane (cm) was also reported by Sood et al. (2006). Low heritability with less genetic advance and environmental variance for number of tillers is also reported by many workers dealing with same type of auxins (Sani and Mustapha, 2010; Ahmed et al., 2012; Riaz et al., 2016). It can be inferred from overall heritability analysis of NIA-105 × soma clones that more genetic changes were induced by 2,4-D followed by NAA, than Picloram.

Heritability exploration in Gulabi-95

It is evident from the result that moderate heritability with fine genetic advance and high environmental variance for number of internode (plant^{-1}) selection of that character is possible for further improvement. Low heritability coupled with less genetic advance for number of tillers (plant^{-1}) was recorded in clones of Gulabi-95 parents. Moderate heritability with low genetic advance for number of height of cane (cm) (high environmental effect) in picloram showed that this character was selected for future advancement of this phenotypic character. Similar results are consistent with Rajeswari et al. (2009). The results suggest increasing the duration and numbering of subcultures to get high genetic advance for number of internode (plant^{-1}) and number of tillers (plant^{-1}) before the selection of soma clones as a new cultivar. It can be inferred from over all heritability analysis in Gulabi-95 × soma clones that more genetic changes were induced by Picloram and NAA, respectively in spite of 2,4-D.

Conclusion

Increasing concentration of hormones in the MS (media) has positive effect on the broad sense heritability. Genetic advance of sugarcane soma clones for phenotypic traits was improved. Although effect of each auxin on the heritability of sugarcane is variety dependent but 2, 4-D, the only general growth hormone, created remarkable genetic variation in the progeny of the sugarcane. Standardization of the type of auxin must be made for each genotype separately for heritability analysis and for better result. Besides heritability, environmental variance play important role in the phenotype character of the sugarcane varieties.

Conflict of interest

The authors have not declared any conflict of interest.

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