International Journal of Agricultural Sciences
Volume **10** | Issue 1| January, 2014 | 87-91

RESEARCH PAPER

Genetic analysis of sugar content in segregating populations derived from cross between grain sorghum x sweet sorghum

VEMANNA IRADDI*, PARASHURAM PATROTI, SANTOSH PATIL[1],
H.K. MAHADEVA SWAMY AND M. GANESH
Department of Genetics and Plant Breeding, Acharya N.G. Ranga Agricultural University, HYDERABAD (A.P.) INDIA
(Email : vemanraddi@gmail.com)

Abstract : The present investigation on inheritance, correlation and path analysis study was undertaken in the segregating populations derived from cross between grain sorghum and sweet sorghum. An intervarietal cross of sweet sorghum was generated during *Kharif* 2010 by crossing the parents (27 B with NSSV 13) which were contrasting for the trait of interest *i.e.*, sugar content. The F_1 generation was raised during *Rabi* 2010 - 11 and F_2, B_1 and B_2 crosses were anticipated. Based on sugar yield, plants were classified into two distinct groups *i.e.*, high sugar and low sugar content. By employing the chi square test, goodness of fit was tested for the segregation ratio and it was evident that sugar content governed by simple monogenic pattern (3High sugar: 1low sugar) of inheritance with high sugar content being governed by dominant and low sugar by recessive allele. Further, correlation studies in F_2 generation revealed significant and positive association of sugar yield with juice yield, total biomass, brix per cent, total soluble sugars, bioethanol yield, fresh stalk yield, grain yield and juice extraction per cent. While path analysis studies revealed maximum positive direct effect of total soluble sugars and juice yield on sugar yield. These correlated traits can be effectively utilized in formulating indirect selection schemes.

Key Words : Inheritance, Segregating populations, Chi-square test, Monogenic, Dominant, Recessive, Correlation, Path analysis

View Point Article : Iraddi, Vemanna, Patroti, Parashuram , Patil, Santosh, Mahadeva Swamy, H.K. and Ganesh, M. (2014). Genetic analysis of sugar content in segregating populations derived from cross between grain sorghum x sweet sorghum. *Internat. J. agric. Sci.*, **10** (1): 87-91.

Article History : Received : 14.02.2013**; Revised :** 21.09.2013**; Accepted :** 16.10.2013

INTRODUCTION

Sorghum being fifth and foremost important crop among cereals after maize, rice, wheat and barley, cultivated throughout the world for various purposes. In countries of semi-arid tropics like India, it is traditionally cultivated for food under subsistence farming. However, of late demand for sorghum is increasing as it is being utilized in many industries such as poultry feed. Moreover, it is also being used for production of potable ethanol, syrup, starch, cellulose and other industrial products. Ever increasing price of crude oil in the international market has forced the government to amend policy of blending ethanol into petrol. This created grounds to search for an alternative source for ethanol production, as traditional source of ethanol unable to meet the existing and future projected demand. Eventually, sweet sorghum emerged as a potential raw material for fuel-grade ethanol production due to its rapid growth rate, early maturity (four month), greater water-use efficiency and wide adaptability. Economic superiority (high ethanol production) of this crop is attributed to few characters such as green cane yield, sugar content (brix or stalk sucrose percentage), stalk juice extractability, content of reducing and non-reducing sugars and grain yield.

Albeit, the research work on the genetic enhancement of sweet sorghum has got impetus three decades back but results were not so encouraging. In India so far only one sweet sorghum hybrid (CSH 22SS) has been released for general cultivation while few varieties are in pipeline which needs further confirmation for their superiority, adding more woes to the existing problems. Thus, there is an ample scope for the improvement of this crop through both basic and

*** Author for correspondence**

advance studies. The information on inheritance and character association among the important traits such as sugar content is virtually bare minimum. In this regard, information on genetics of sugar content and character association of this trait with other component traits is the need of the hour to facilitate breeding of cultivars with high ethanol yield. Keeping the situation present in the foregoing paragraphs in view, the present investigation was undertaken.

MATERIAL AND METHODS

The material for this experiment comprised of six populations *viz.*, P_1, P_2, F_1, F_2, B_1 and B_2 of an intervarietal sweet sorghum cross *viz.*, 27 B × NSSV 13, developed at Directorate of Sorghum Research farm, Rajendranagar, Hyderabad. During *Kharif* 2010, the F_1 was generated by crossing 27 B with NSSV 13 through hand emasculation and pollination. Later in *Rabi* 2010 - 11, the F_1 plants were selfed to produce F_2 population as well as backcrossed to both the parents to produce B_1 [(27 B × NSSV 13) × 27 B] and B_2 [(27 B × NSSV 13) × NSSV 13] populations. In non-segregating generations *viz.*, parents, check and F_1's, the data were recorded on five randomly tagged plants in each replication, where as in case of segregating populations, the data were recorded on 200 competitive plants in F_2 generation and 50 competitive plants each in B_1 and B_2 generations across three blocks. The inheritance pattern was studied in this cross where all the six generations were available by fitting the genetic ratios for sugar content. The sugar content was classified into two groups, those with high sugar content (more than 13 g / plant) and low sugar content (less than 13 g / plant) in both F_2 as well as backcross generations. The segregation ratios were subjected to chi-square test, which tests the goodness of fit between expected and observed segregation ratios (Snedecor and Cochran, 1967).

Besides sugar content, in F_2 population observations on total biomass, fresh stalk yield, grain yield, brix per cent, juice yield, juice extraction per cent, total soluble sugars, bioethanol yield and sugar yield were recorded on single plant basis. The data were subjected to correlation and path co-efficient analysis of sugar yield and its components traits.

RESULTS AND DISCUSSION

The results of studies on the inheritance of sugar content using six generations of an intervarietal cross *viz.*, '27 B × NSSV 13', have been tabulated in Table 1a and 1b. In the present investigation, all the plants in each of the segregating generation were classified into two groups based on sugar content as high sugar (more than 13 g / plant) and low sugar (less than 13 g / plant) content plants.

All the 15 plants of the female parent '27 B' had low sugar content, while all the 15 plants of 'NSSV 13' had high sugar content. It is for the obvious reason that the chosen female and male parents are grain and sweet sorghum, respectively. In the F_1 generation of this cross, all 15 plants were found to have high sugar content confirming the dominance of high sugar content over low sugar content. Out of 200 F_2 plants studied, 142 plants had high sugar content, while 58 plants had low sugar content, giving a good fit for the monogenic ratio of 3:1 for high sugar vs low sugar content as indicated by low, non-significant Chi-square value of 1.71. In the backcross (B_2) progenies, 42 plants had high sugar content confirming dominance of high sugar content which gives a good fit to the expected backcross ratio of 1:0 for the high sugar content and low sugar content ones, respectively, with a Chi-square value of 1.28. Out of 50 test cross progenies, 20 plants had high sugar content, while 30 plants had low sugar content. Thus, the data give a good fit to

Table 1a : Classification of plants based on sugar content in parents, F_1, F_2 and back cross generations of the cross '27 B × NSSV 13' of sweet sorghum

	Generation	Plants with high sugar content	Plants with low sugar content	Total
Parents	27 B	0	15	15
	NSSV 13	15	0	15
F_1	27 B × NSSV 13	15	0	15
F_2	27 B × NSSV 13	142	58	200
B_1	(27 B × NSSV 13) × 27 B	20	30	50
B_2	(27 B × NSSV 13) × NSSV 13	42	08	50

Table 1b : Observed and expected frequencies of high and low sugar content plants in F_2 and backcross generations of the cross '27 B × NSSV 13' of sweet sorghum along with "Test of goodness of fit"

Cross / Generation	Observed frequency		Expected frequency		Expected ratio	χ^2 value	Probability
	High sugar	Low sugar	High sugar	Low sugar	H : L		
F_2	142	58	150	50	3 : 1	1.71	0.1910
B_1	20	30	25	25	1 : 1	2.00	0.1573
B_2	42	08	50	0	1 : 0	1.28	0.2579

the expected test cross ratio of 1:1 with a Chi-square value of 2.00 which confirm the F_2 monogenic ratio of 3:1.

The above segregation pattern indicates that parent (NSSV 13) possessing high sugar have homozygous dominant alleles for high sugar (SS), while, the other parent (27 B) would therefore, have homozygous recessive allele (ss) for low sugar content. The cross between these two parents would result in heterozygous progeny having both dominant and recessive allele (Ss) and since dominant allele is contributing for high sugar content, all the plants in F_1's had high sugar content. In F_2 generations, the segregation process lead to form three genotypes, one with homozygous dominant allele (SS), two dominant heterozygous (Ss) and one homozygous recessive (ss) in 1SS : 2Ss : 1ss ratio. Since, the high sugar content is governed by dominant allele, both homozygous dominant and heterozygous types yielded high sugar plants, thereby confirming to 3:1 ratio in F_2 for high sugar and low sugar, respectively. Hence, it can be inferred from this study that, the high sugar content was inherited through dominant gene (SS) and low sugar content through recessive gene (ss).

The genetic ratio obtained is just an indication, since sugar yield is a complex quantitative trait, is likely to be governed by many genes. Hence, present study needs further confirmation by analyzing larger segregating population of more number of crosses involving other diverse genotypes as parents with respect to this trait.

Moreover these quantitative characters of economic importance are often associated with one another either positively or negatively. Hence, the selection for yield on the basis of *per se* performance alone may not be as effective as that is based on the component characters whose association with yield are biometrically determined by correlation and path co-efficient analysis. The indirect selection schemes concentrate on correlation between characters to improve a highly complex trait like yield. The efficiency of indirect selection depends on the direction and magnitude of association between yield and its component characters. Therefore, study of relationships among the quantitative traits is important for assessing feasibility of joint selection of two or more traits. Further, understanding the association between the component traits and their relative contribution to the target trait is essential to bring out a rational improvement in the desired trait as they may be differently correlated. In this regard, the correlation co-efficients among all the characters related to sugar yield in F_2 populations of sweet sorghum cross were estimated; results were tabulated in Table 2 and briefly described in the

Table 2 : Correlation coefficients of sugar yield with its attributing characters in F_2 generation of the cross '27 B × NSSV 13' in sweet sorghum

Characters	Total biomass (g / plant)	Fresh stalk yield (g/plant)	Grain yield (g/plant)	Brix per cent	Juice yield (g / plant)	Juice extraction per cent	Total soluble sugars (%)	Bioethanol yield (ml / plant)	Sugar yield (g / plant)
Total biomass (g / plant)	1.000	0.977**	0.888**	0.896**	0.971**	0.534**	0.896**	0.897**	0.972**
Fresh stalk yield (g / plant)		1.000	0.830**	0.843**	0.934**	0.394**	0.843**	0.845**	0.940**
Grain yield (g / plant)			1.000	0.916**	0.909**	0.741**	0.916**	0.918**	0.894**
Brix per cent				1.000	0.947**	0.755**	1.000**	0.995**	0.958**
Juice yield (g / plant)					1.000	0.685**	0.947**	0.948**	0.995**
Juice extraction per cent						1.000	0.755**	0.754**	0.653**
Total soluble sugars (%)							1.000	0.995**	0.958**
Bioethanol yield (ml/plant)								1.000	0.957**
Sugar yield (g / plant)									1.000

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 3 : Path analysis indicating direct and indirect effects of component characters on sugar yield in F_2 generation of the cross '27 B × NSSV 13' in sweet sorghum

Characters	Total biomass (g / plant)	Fresh stalk yield (g / plant)	Brix per cent	Juice yield (g / plant)	Juice extraction per cent	Total oluble sugars (%)	Bioethanol yield (ml / plant)	'r' with Sugar yield
Total biomass (g / plant)	0.0604	-0.3873	-6.1659	1.1805	-0.1507	6.4136	-0.0032	0.9473**
Fresh stalk yield (g / plant)	0.0590	-0.3965	-5.8020	1.1352	-0.1111	6.0350	-0.0030	0.9168**
Brix per cent	0.0541	-0.3342	-6.8825	1.1503	-0.2131	7.1587	-0.0035	0.9298**
Juice yield (g / plant)	0.0586	-0.3704	-6.5149	1.2153	-0.1932	6.7765	-0.0033	0.9686**
Juice extraction per cent	0.0322	-0.1560	-5.1967	0.8319	-0.2823	5.4051	-0.0027	0.6316**
Total soluble sugars (%)	0.0541	-0.3342	-6.8825	1.1504	-0.2131	7.1587	-0.0035	0.9298**
Bioethanol yield (ml / plant)	0.0542	-0.3351	-6.8491	1.1515	-0.2129	7.1240	-0.0035	0.9291**

Residual effect = 0.1669

* and ** indicate significance of values at P=0.05 and 0.01, respectively

following paragraphs.

Association of sugar yield with its component characters:

Association between sugar yield was positive and highly significant with juice yield per plant, total biomass per plant, brix per cent, total soluble sugars, bioethanol yield per plant, fresh stalk yield per plant, grain yield per plant and juice extraction per cent. The results of the present investigation are in corroborative with Patel *et al.* (1993); Jadhav *et al.* (1994); Mallikarjun *et al.* (1998); Hapase and Repale (1999); Verma *et al.* (1999); Singh and Khan (2004); Kadian and Mehta (2006) and Unche *et al.* (2008).

Association among sugar yield attributing characters:

The association of total biomass with fresh stalk yield per plant, juice yield per plant, bioethanol yield per plant, brix per cent, total soluble sugars, grain yield per plant and juice extraction per cent; fresh stalk yield per plant with juice yield per plant, bioethanol yield per plant, brix per cent, total soluble sugars, grain yield per plant and juice extraction per cent; grain yield per plant with bioethanol yield per plant, brix per cent, total soluble sugars, juice yield per plant and juice extraction per cent; brix per cent with total soluble sugars, bioethanol yield per plant, juice yield per plant and juice extraction per cent; juice yield per plant with bioethanol yield per plant, total soluble sugars and juice extraction per cent; juice extraction per cent with total soluble sugars and bioethanol yield per plant; total soluble sugar with bioethanol yield per plant were positive and significant. The reports of Verma *et al.* (1988); Selvi and Palanisamy (1989); Ma *et al.* (1992); Jadhav *et al.* (1994); Ganesh *et al.* (1995); Singh and Khan (2004); Kadian and Mehta (2006); Kachapur and Salimath (2009); Unche *et al.* (2008) and Sandeep *et al.* (2010) were in agreement with the above results.

The results on association of sugar yield with its attributing traits indicated importance of juice yield, total biomass, brix per cent, total soluble sugars, bioethanol yield, fresh stalk yield, grain yield and juice extraction per cent in improving sugar yield as these traits had direct relation with sugar yield and hence, improvement in these traits eventually ends with improved sugar yield. Hence, the above correlated traits can be effectively utilized in formulating indirect selection schemes.

However, these correlation results are the sum total of direct effect and indirect effects of an independent character on a dependent character and it is quite obvious that the correlation (positive or negative) may be of small magnitude and non-significant in spite of its direct effect and/or some of the indirect effects are operating in the opposite direction. Therefore, path analysis is required to partition the correlation value of independent characters on dependent character into direct and indirect effects so as to get a correct picture of the association of characters. In this regard, path co-efficient analysis was carried out to know the direct and indirect effects of the component characters on sugar yield and the results of the same were tabulated in Table 3 and briefly discussed below.

The results of path analysis for sugar yield indicated maximum positive direct effect of total soluble sugars and juice yield whereas brix per cent and fresh stalk yield per cent had high and moderate negative direct effect, respectively on sugar yield. However, all the traits exhibited high positive indirect effect *via* total soluble sugars and juice yield. The indirect effect *via* juice brix per cent, fresh stalk yield and juice extraction per cent is very high, high and low, respectively in negative direction. The reports of Selvi and Palanisamy (1989); Patel *et al.* (1993); Mallikarjun *et al.* (1998); Hapase and Repale (1999) and Kachapur and Salimath (2009) were in corroborative with the above results. It was evident from the above cited results that, the indirect contribution of all characters *via* total soluble sugars and juice yield was very high resulting in positive association with sugar yield.

Acknowledgement:

First author conveys whole hearted thanks to the technical and non - technical staff of Directorate of Sorghum Research, Hyderabad for providing the necessary service and materials during entire research endeavor and to the Indian Council of Agricultural Research (ICAR), New Delhi, who supported me financially during this tenure by awarding Senior Research Fellowship.

REFERENCES

Ganesh, S., Khan, A.K.F., Suresh, M. and Senthil, N. (1995). Character association for alcohol yield in sweet sorghum. *Madras Agric. J.*, **82** (5) : 361 - 363.

Hapase, R.S. and Repale, J.M. (1999). Variability, correlation and path analysis in sugarcane. In: Proceedings of the 61st Annual Convention of the Sugar Technologists Association of India, New Delhi, India, 7-9 September: pp. 130 - 141.

Jadhav, M.M., Chaugule, B.A., Charan, U.D. and Adsule, R.N. (1994). Assessment of juice quality in the improved sweet sorghum varieties. *J. Maharashtra Agric. Univ.*, **19** : 233 - 235.

Kachapur, R.M. and Salimath, P.M. (2009). Genetic studies on correlation and character association in sweet sorghum [*Sorghum bicolor* (L.) Moench]. *Green Frmng.*, **2** (6) : 343 - 346.

Kadian, S.P. and Mehta, A.S. (2006). Correlation and path analysis in sugarcane. *Indian J. Agric. Res.*, **40** : 47 - 51.

Ma, Z.H., Li, D., Ning, X.B. and Wang, S.W. (1992). Relationship between brix degree and total sugar content in juice of sweet sorghum stem. Agricultural engineering and rural development proceedings of a conference held in Beijing, China, 12-14 October, 1992, Vol. I: 204 - 207.

Mallikarjun, H., Khanure, S.K. and Kachapur, M.D. (1998). Correlation and path analysis for juice quality parameters in sweet sorghum genotypes. *Madras Agric. J.*, **85** (3/4) : 207 - 208.

Patel, M.M., Patel, H.S., Patel, A.D. and Patel M.P. (1993). Correlation and path analysis in sugarcane. *Indian Sugar*, **43** (6) : 365 - 368.

Sandeep, R.G., Gururaja Rao, M.R., Chikkalingaiah and Shivanna, H. (2010). Association and path analysis for ethanol yield in sweet sorghum [*Sorghum bicolor* (L.) Moench]. *Mysore J. Agric. Sci*., **44**: 28 - 30.

Selvi, B. and Palanisamy, S. (1989). Partitioning analysis of quality characters in sweet sorghum. *Annals Agric. Res*., **10** (2) : 204 - 206.

Singh, S.P. and Khan, A.Q. (2004). Inter-relationship and path analysis in sugarcane (*Saccharum* spp. Complex). *Environ. & Ecol*., **22** (4) : 903 - 911.

Snedecor, G.W. and Cochran, W.G. (1967). *Statistical methods*. 6th ed., Oxford and IBH Pub. Co., New Delhi, INDIA.

Unche, P.B., Misal, M.B., Borgaonkar, S.B., Chavan, B.D. and Sawant, D.R. (2008b). Correlation studies in sweet sorghum [*Sorghum bicolor* (L.) Moench]. *Internat. J. Plant Sci*., **3** (1) : 69 - 72.

Verma, P.S., Dhaka, R.P.S. and Singh, H.N. (1988). Genetic variability and correlation studies in sugarcane. *Indian J. Genetics & Plant Breed*., **48** (2) : 213 - 217.

Verma, P.S., Shri Pal and Karma, N.K. (1999). Genetic variability and correlation studies in sugarcane. *Indian Sugar*, **49** (2) : 125 - 128.