Advances in Biological Research 3 (1-2): 48-52, 2009
ISSN 1992-0067

Assessment of Rind Hardness in Sugarcane (*Sachharum* Spp. Hybrids) Genotypes for Development of non Lodging Erect Canes

[1]C. Babu, [1]K. Koodalingam, [2]U.S. Natarajan, [2]R.M. Shanthi and [2]P. Govindaraj

[1]Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, India
[2]Sugarcane Breeding Institute (ICAR), Coimbatore-641 007, India

Abstract: Breeding varieties with high fibre content gaining momentum as it is related to non lodging and increased biomass suitable for mechanical harvesting and feedstock for co-generation. The estimation of fibre content in cane is a tedious and destructive method. An experiment was conducted at Sugarcane Breeding Institute (ICAR), Coimbatore to ascertain whether the rind hardness of cane can be used as an index for fibre content in sugarcane (*Saccharum* spp. hybrids). The results revealed that rind hardness was positively and significantly associated with fibre content (0.444**) hence it can be used as an index of fibre content in sugarcane. The correlation studies also revealed that, it was positively and significantly correlated with major yield and quality traits. Hence rind hardness may be considered as an important parameter during initial stages of selection when the population size is too large to estimate fibre content. This could result simultaneous improvement of yield and quality with optimum level of fibre content benefiting both the farmers and millers. Selection for high rind hardness would indirectly help in developing nonlodging canes, tolerance to internode borer and canes for mechanical harvesting.

Key words: Sugarcane · Rind hardness · Fibre content · Co-generation

INTRODUCTION

Sugarcane is a tropical crop and is the major source of sugar. Cane sugar contributes around 60 per cent of the total sugar produced in the world, the rest being contributed by sugar beet and other sources. Sugarcane is a multi-product crop, every fraction of which finds economic use either as food, fodder, fuel or fibre and plays a major role in the rural economy.

Among the by products in sugarcane, the fibre content is gaining importance nowadays since many sugar factories rely on the fibre (bagasse) as fuel for co-generation. Bagasse forms the raw material for power generation in many sugar industries. As sugar price is fluctuating from year to year, co-generation has become one of the important sources of garnering additional revenue to the industry. This calls for evolving value added varieties with higher fibre level even compromising little reduction in recovery. The overall income generated by this would extremely advantageous to the millers as well as to the farmers in terms of higher yield level [1]. The sugar factories with co-generation facility demand for high fibre varieties upto 16% as it helps in increasing the baggase availability. In the sugarcane improvement programme, selection for fibre content is postponed to lateral generation when the population becomes manageable due to non availability of reliable non destructive canes.

Fibre content is estimated through rapipol extractor, which is time consuming, laborious and destructive. In the early segregating population, number of millable canes will be less per genotypes and hence can not be spared for fibre estimation. Sugarcane Breeding Institute, Coimbatore has developed a simple device called rind hardiness tester which can be used for indirect estimation of fibre content in larger sample in a shorter period. Among the several traits, the only character which could be screened for, at the earliest stages of selection when large unmanageable numbers of genotypes are involved, is the rind hardness, which gives an index of fibre content in sugarcane. Many earlier workers have also attempted to assess the rind hardness using different penetrometers for the initial selection of sugarcane genotypes [2-4]. If the rind hardness is positively associated with the fibre

Corresponding Author: Dr. C. Babu, Associate Professor (PBG), Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, India

content in sugarcane genotypes, then the genotypes possessing other desirable features with appreciable level of fibre content suitable for co-generation purpose also can be evolved. Apart from this, rind hardness is also associated with other desirable features like resistance to inter node borers and evolving non lodging canes and these features would support for easy mechanical harvesting. It is also easy to record using rind hardness tester since a large number of samples can be tested in a day and thus it can be effectively utilized in the initial seedling generations. In view of this, an investigation was made to find out whether the trait rind hardness is associated with fibre content in sugarcane.

MATERIALS AND METHODS

Experimental Material: The experimental material consisted of 1950 progenies obtained from 39 biparental crosses involving 11 pollen parents and 34 pistil parents of sugarcane. Thirty six seedlings per replication per cross were planted in a randomized block design @ 12 seedlings per row of 6m length along with the parents. This present study was conducted at Sugarcane Breeding Institute (ICAR), Coimbatore, India (latitude; 11° North; longitude; 78°.8' East; altitude; 426.72 m MSL) during 2002-2003.

Biometrical Observations: Out of the thirty six progenies from a family, twenty five seedlings were randomly selected for recording biometrical observations and analysis. The biometrical observations such as number of millable canes (NMC) at 300 and 360 days after planting, hand refractometer brix (HRB) at 240 and 300 days after planting, stalk diameter (STD) at 360 days after planting, leaf area (LAR) and number of green leaves (NGL) at 300 days after planting and stalk height (SHT), single stalk weight (SSW), number of internodes (INT), internode length (INL), sucrose per cent (SUC) and stalk yield per clump (YLD) at 360 days after planting were recorded apart from rind hardness and fibre content. Normal package of practices were adopted with respect to manuring, irrigation, earthing up *etc*. Forty five parental clones were also planted simultaneously in randomized block design for comparison.

Rind Hardness (RHD): The 'Rind hardness tester' as contrived from Sugarcane Breeding Institute (ICAR), Coimbatore, India [5] was used for this purpose (Fig. 1). It measures the force required by the tester to pierce the

Fig. 1: Rind hardness tester

rind. The rind hardness (RHD) was measured using this tester on the main stalk as single stalk per clump at middle of the stalk at 300 days.

Fibre Content (FIB): Fibre (FIB) content was estimated only in parents in order to find out its relationship with rind hardness. This correlation was studied in the parental clones and it could not be estimated in the progenies due to insufficient number of canes in individual progenies. However, the rind hardness is tested in all the progenies and interrelationship was worked out with other economic traits. Three canes randomly selected from the canes harvested at 360 days were further subsampled to include top, middle and bottom portion from each cane. These three pieces of cane were subjected to electrically operated high efficient cane shredder. The resultant product after thorough mixing was subsampled and 250 g was taken in cloth bags for the estimation of fibre per cent. The samples were washed repeatedly in fresh water to remove the juice present in the fibre and dried to remove the moisture content and to attain a constant weight.

Fibre per cent was calculated as per the formula given by Thangavelu and Rao [6].

$$\text{Fibre per cent} = \frac{A-B}{C} \times 100$$

Where:

A = Dry weight of bag + bagasse after drying (g)
B = Dry weight of bag alone (g)
C = Fresh weight of cane (g)

RESULTS AND DISCUSSION

The mean performance of the parents for the traits rind hardness and fibre per cent is presented in the Table 1. The rind hardness was the highest in the parent Co 94008 (12.04),while the lowest was recorded in the parent 984819 (4.28). For fibre per cent in cane, the parent Co 94008 which recorded the highest rind hardness also registered the highest mean value for fibre per cent (16.73%). The variety Co 98003 registered the lowest fibre value of 11.35 % and a total of 18 parents recorded statistically significant and superior values to parental grand mean (13.94%).

The results of analysis of variance within families for rind hardness are furnished in the Table 2. Three families

Table 1: Mean performance of the parents for rind hardness and fibre content

S.No.	Parents	Rind hardness	Fibre content (%)
1	Co 775	4.56	14.07
2	Co 1148	7.33	13.38
3	Co 62198	7.77*	14.00
4	Co 8371	7.49	13.21
5	Co 85002	6.62	13.71
6	Co 86010	7.48	14.71*
7	Co 86249	7.48	14.27*
8	Co 87002	4.91	12.44
9	Co 88028	8.22*	14.07
10	Co 93009	5.61	11.38
11	Co 94008	12.04*	16.73*
12	Co 98003	8.24*	11.35
13	Co 98006	7.71	13.78
14	CoA 7602	8.01	13.07
15	CoC 671	5.57	14.82*
16	CoH 76	6.11	12.34
17	CoH 110	7.26	13.21
18	CoJ 72	7.38	14.47*
19	CoM 9220	8.43*	14.78*
20	ISH 1	6.55	13.69
21	87 A 298	6.37	14.47*
22	RS 93-2182	6.66	13.58
23	970311	10.26*	16.66*
24	971235	4.29	14.90*
25	971236	9.18*	15.85*
26	971862	5.78	12.61
27	973402	7.27	14.85*
28	9844195	6.51	13.97
29	984727	7.52	11.78
30	984819	4.28	13.59
31	984843	4.51	13.68
32	985040	5.66	14.66*
33	985094	7.32	11.96
34	985735	6.54	14.02
35	985931	8.52*	14.75*
36	986046	6.34	13.71
37	986095	6.93	15.23*
38	986140	7.24	15.70*
39	986179	8.18*	12.98
40	9869110	8.09*	15.22*
41	987001	7.95*	16.52*
42	987032	7.66	13.31
43	987080	5.85	12.90
44	987124	8.09*	11.83
45	9871144	8.44*	15.42*
	GM	7.11	13.94
	S.E	0.20	0.06
	C.D (5%)	0.57	0.16

* Significantly superior to the grand mean

Table 2: Results of analysis of variance within families for rind hardness

	Sv	Family	df	MSS-Rind hardness
1	Between families	-	38	27.05**
2	Within families	-	1948	4.80
	Family 1	Co 8371 x 971862	49	4.06
	2	Co 85002 x 971862	49	4.27
	3	Co 86010 x Co 775	49	6.20
	4	Co 86249 x Co 775	49	3.46
	5	Co 87002 x 986179	49	3.28
	6	Co 88028 x Co 775	49	3.83
	7	Co 98003 x 971862	49	3.60
	8	Co 98006 x 987001	49	4.38
	9	CoC 671 x Co 94008	49	3.30
	10	CoH 76 x 985094	49	7.40
	11	CoH 110 x 984843	49	3.74
	12	CoH 110 x 986179	49	4.86
	13	CoJ 72 x Co 62198	49	4.12
	14	CoM 9220 x 984843	49	2.76
	15	CoM 9220 x 987001	49	4.90
	16	ISH 1 x Co 94008	49	5.79
	17	RS 93-2182 x Co 93009	49	3.09
	18	87A298 x Co 1148	49	6.87
	19	970311 x 986179	49	10.19
	20	971235 x Co 1148	49	3.43
	21	971235 x Co 62198	49	8.06
	22	971236 x Co 62198	49	8.51
	23	973402 x Co 775	49	4.14
	24	9844195 x Co A 7602	49	4.44
	25	984727 x 984843	49	2.63
	26	984819 x Co 1148	49	7.49
	27	985040 x Co 1148	49	5.69
	28	985735 x Co 62198	49	3.17
	29	985931 x Co 775	49	4.98
	30	986046 x Co 775	49	3.66
	31	986095 x Co 62198	49	7.82
	32	986095 x Co 94008	49	5.86
	33	986140 x Co 1148	49	3.43
	34	9869110 x Co 1148	49	3.62
	35	9869110 x Co 62198	49	3.69
	36	987032 x Co 93009	49	5.04
	37	987080 x Co 1148	49	3.50
	38	987124 x Co 775	49	2.36
	39	9871144 x Co 775	49	8.51

viz., 970311 x 986179, 971236 x Co 62198 and 9871144 x Co 775 recorded high variances for rind hardness, while the lowest (2.36) was registered by the family 987124 x Co 775. Mean performance of crosses with respect to rind hardness is given in the Table 3. Among the crosses, only two crosses *viz*., 971236 x Co 62198 (7.91) and 971235 x Co 62198 (7.77) recorded significantly superior values for rind hardness as compared to the grand mean (5.96). The cross 984727 x 984843 (4.78) registered very low mean value for rind hardness (Table 3).

The results from the correlation studies showed that, there was a high and significant positive correlation (0.444**) between rind hardness and fibre content in the parents. Davidson [2] used a modified soil-penetrometer to measure rind hardness and also reported a high correlation coefficient (0.50-0.60) between rind hardness and per cent fibre. Skinner [3] evaluated a portable penetrometer consisting of six flat rods for determining rind hardness and found a high correlation coefficient (0.70-0.90) between rind hardness and per cent fibre. Kang *et al*. [4] reported that maize rind-penetrometer would be a useful device for measuring rind hardness in sugarcane which adequately differentiated the genotypes for selection. Walker [7], used a cane softness score (visual rating 1 = hard to 5 = soft) and found a correlation coefficient of-0.55 between softness score and fibre content.

The correlation coefficients estimated on the 1856 progenies are presented in Table 4. Correlation coefficients values between the characters were mostly significant.

Very low as well as very high correlations were observed in the study. In general, the character association was predominantly positive. The correlation studies showed that, rind hardness is associated with major yield and quality components. It had significant positive relationship with leaf area, stalk height, number of internodes, single stalk weight, internode length, clump yield, H.R. brix and sucrose. However the correlation coefficients with stalk height (0.277) and single stalk weight (0.239) were found to be high. Thus selection for rind hardness would indirectly improve yield and quality in the population. Rind hardness apart from its positive association with fibre content also has other advantages like tolerance to internode borer and selection of erect non lodging canes suitable for mechanical harvesting. White *et al*. [8] reported that rind hardness and fiber content were more closely associated with resistance to sugarcane borer, *Diatraea saccharalis* (F.) than pith. They also reported that, phenotypic selection in the early stages of variety development for low insect damage may result in varieties with high fiber content and rind hardness and possibly with higher levels of pith. Martin *et al*. [9] reported a highly significant negative correlation (r = -0.97) between internode hardness measured with a porometer and per cent insect-bored internodes.

Table 3: Mean performance of crosses with respect to rind hardness

S.No.	Crosses	Rind hardness
1.	Co 8371 x 971862	5.69
2.	Co 85002 x 971862	5.39
3.	Co 86010 x Co 775	5.96
4.	Co 86249 x Co 775	5.67
5.	Co 87002 x 986179	5.38
6.	Co 88028 x Co 775	5.90
7.	Co 98003 x 971862	5.22
8.	Co 98006 x 987001	6.02
9.	CoC 671 x Co 94008	6.39
10.	CoH 76 x 985094	5.95
11.	CoH 110 x 984843	5.18
12.	CoH 110 x 986179	5.98
13.	CoJ 72 x Co 62198	6.68
14.	CoM 9220 x 984843	5.89
15.	CoM 9220 x 987001	6.19
16.	ISH 1 x Co 94008	5.99
17.	RS 93-2182 x Co 93009	5.76
18.	87A298 x Co 1148	5.73
19.	970311 x 986179	7.25
20.	971235 x Co 1148	5.82
21.	971235 x Co 62198	7.77*
22.	971236 x Co 62198	7.91*
23.	973402 x Co 775	6.00
24.	9844195 x Co A 7602	5.49
25.	984727 x 984843	4.78
26.	984819 x Co 1148	6.58
27.	985040 x Co 1148	6.48
28.	985735 x Co 62198	5.03
29.	985931 x Co 775	6.79
30.	986046 x Co 775	5.33
31.	986095 x Co 62198	6.96
32.	986095 x Co 94008	7.04
33.	986140 x Co 1148	5.61
34.	9869110 x Co 1148	4.81
35.	9869110 x Co 62198	5.50
36.	987032 x Co 93009	5.56
37.	987080 x Co 1148	5.76
38.	987124 x Co 775	4.99
39.	9871144 x Co 775	6.04
	GM	5.96
	S.E	0.54
	C.D (5%)	1.51

* Significantly superior to the grand mean

Table 4: Correlation coefficient of rind hardness with different yield and quality traits in sugarcane progenies

Character	NMC300	HRB240	NMC360	HRB300	LAR	NGL	STD360	SHT	INT	SSW	INL	SUC	YLD	RHD
RRS	0.054	0.019	0.020	0.004	-0.066*	0.000	0.025	-0.065*	0.060	-0.031	-0.110**	-0.031	-0.019	-0.067*
NMC 300		-0.031	0.883**	-0.088*	-0.083**	0.035	-0.255**	0.169**	0.084**	-0.151**	0.074*	-0.092**	0.656**	0.008
HRB 240			-0.086**	0.690**	-0.089**	-0.023	-0.027	0.096**	0.109**	0.009	-0.005	0.516**	-0.078*	0.115**
NMC 360				-0.126**	-0.056	0.034	-0.241**	0.129**	0.075*	-0.160**	0.047	-0.121**	0.750**	-0.011
HRB 300					-0.062*	0.008	-0.008	0.143**	0.113**	0.081**	0.031	0.603**	-0.058	0.135**
LAR						-0.010	0.229**	-0.028	-0.020	0.219**	-0.009	-0.072*	0.086**	0.098**
NGL							-0.039	0.039	0.101**	0.024	-0.048	-0.044	0.045	0.066*
STD 360								-0.059	0.158**	0.597**	-0.199**	0.039	0.171**	0.027
SHT									0.436**	0.517**	0.519**	0.060	0.412**	0.277**
INT										0.374**	-0.521**	0.000	0.284**	0.095**
SSW											0.127**	0.065*	0.470**	0.239**
INL												0.051	0.111**	0.167**
SUC													-0.060	0.093**
YLD														0.133**

*/** Significant at 5 and 1% respectively

RHD = Rind hardness, RRS = Red rot resistance score, NMC = Number of millable canes, HRB = Hand Refractometer brix (%), LAR = Leaf area (cm^2), NGL = Number of green leaves, STD = Stalk diameter (cm), SHT = Stalk height (cm), INT = Number of internodes, SSW = Single stalk weight (kg), INL = Internode length (cm), SUC = Sucrose per cent, YLD = Clump yield (kg)

In the present study, rind hardness is positively associated with major yield and quality components such as LAR, number of green leaves, stalk height, number of internodes, single stalk weight, internode length, clump yield, H.R brix and sucrose per cent. However, the correlation between rind hardness and red rot resistance was negative as entry and development of red rot pathogens into the cane is independent of the hardness of stem. These results indicated that, rind hardness could be considered as an important parameter during selection in the early generation population for the simultaneous improvement of yield and quality with optimum level of fibre content which would equally benefit the farmers and millers.

REFERENCES

1. Natarajan, U.S., 2000. Breeding for quality improvement in sugarcane. Paper presented in the Winter School on Sugarcane Breeding and Genetics in Retrospect and Prospects, pp: 16-21.
2. Davidson, L.G., 1969. Correlation of rind hardness and fiber in sugarcane. Mem. Int. Soc. Sugar Cane Technol., 13: 1723-1728.
3. Skinner, J.C., 1974. Rind hardness and fibre content. Mem. Int. Soc. Sugar Cane Technol., 15: 153-167.
4. Kang, M.S., O. Sosa Jr. and J.D. Miller, 1990. Genetic variation and advance for rind hardness, flowering and sugar yield traits in sugarcane. Field Crops Res., 23: 69-73.
5. Balasundaram, N., 2002. Personal communication.
6. Thangavelu, S. and K. Chiranjivi Rao, 1982. Comparison of Rapi pol extractor and Cutex cane shredder methods for direct determination of fibre in *Saccharum* clones. Proc. Ann. Conv. Sug. Tech. Assoc. India., 46: 15-21.
7. Walker, D.I.T., 1971. Cane hardness and fibre content. Sug. Breed. Newslett., 28: 10-14.
8. White, W.H., T.L. Tew and E.P. Richard Jr., 2006. Association of sugarcane pith, rind hardness and fiber with resistance to the sugarcane borer. J. American Soc. Sugar Cane Technol., 26: 87-100.
9. Martin, F.A., C.A. Richard and S.D. Hensley, 1975. Host resistance to *Diatraea saccharalis* (F.): Relationship of sugarcane internode hardness to larval damage. Environ. Entomol., 4 (5): 687-688.