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Research Article

Evaluation of sugarcane genotypes for theoretical yield of alcohol

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Abstract
Seventy seven genotypes of sugarcane were evaluated in second clonal stage for theoretical yield of alcohol. The genotypes viz., 2010T-72 (14.67 g/100ml), 2010T-16 (14.01 g/100ml) and 2010T-88 (13.93 g/100ml) showed significantly higher performance over the best check Co 7219 (12.80 g/100ml) for theoretical yield of alcohol. Path analysis revealed that the characters viz., total sugars per cent, pol per cent cane and CCS per cent exhibited positive direct effects on theoretical yield of alcohol and the other characters also exhibited their indirect positive effects on theoretical yield of alcohol via total sugars per cent, pol per cent cane and CCS per cent, indicating that these were the major contributing characters to theoretical yield of alcohol in sugarcane.

Key words
Sugarcane, ethanol, path analysis.

Introduction

Sugarcane is an important cash crop and raw material for sugar industry which is the second largest agro based industry of India next to cotton. It assumes an important position in the economy of the country. Its contribution to agricultural GDP is 10% which is significant as the crop is grown in only 2.57% of the gross cropped area in the country (SBI, 2011). Sugarcane crop serves as the major source for a variety of products such as sugar, jaggery, molasses, bagasse, filter cake, out of which sugar and jaggery are obtained for daily use as consumable products while other byproducts have industrial significance. It is realized that sugar production alone will not be able to make the industry profitable and under such circumstances diversification is a necessary consequence for the successful growth of industry.

Sugarcane, which is also considered as an important bio energy crop belongs to the category of C4 plants which converts the solar energy effectively into high quality and low cost raw material for sugar and ethanol (Bruce *et al.* 2005). Molasses and bagasse are the byproducts of sugar industry which form the feedstock for ethanol production and cogeneration respectively. National policy on biofuels proposed to scale up the blending ethanol from 5% to 20% by 2017. The target is difficult to achieve due to limited availability of bioethanol which to a greater extent comes from sugarcane molasses apart from a smaller proportion from grains. This necessitates significant increase in domestic ethanol production by developing varieties which yield higher ethanol. Sugarcane represents one of the most efficient land based system for converting solar energy into biomass. This biomass cane provides both a solid fuel for combustion to process heat, steam or electricity and an easily fermentable juice which may be upgraded to ethanol which is of value as a liquid transport fuel and, in particular, as an octane booster for use in lead free petrol. Sugarcane ethanol requires only a small amount of fossil fuels for its production, thus being a renewable fuel (Jose *et al.*, 2008). The future of the sugar industries depend upon the utilization of the sugarcane for the manufacture of sugarcane based byproducts such as alcohol, power etc. The recent awareness on the advantages of using gasohol to reduce automobile emission has changed the sugar production scenario because varietal needs have started changing. Traditionally, sugarcane is used primarily for sugar production. However, with the energy crisis that has struck the world, the sugarcane plant has emerged as a viable producer of bioenergy. Currently, in Brazil, alcohol is the main product derived from sugarcane and sugar is the principal by-product (Lee and Bressan, 2006). Hence, the breeding programmes must integrate new traits such as high alcohol or high total sugars in addition to yield and juice quality. With these points in view the present investigation was carried out to evaluate the sugarcane genotypes for ethanol production.

Material and Methods

Seventy three genotypes in second clonal stage along with four checks viz., Co 6907, Co 7219, 2003 V46 and Co 86032 were planted in a randomized block design with two replications during April, 2011. Each entry was planted in 2 rows of 5 m length spaced at a distance of 80 cm between rows with 4 three budded setts per meter. Theoretical yield of alcohol was calculated by estimating total sugars and unfermentable sugars.

Juice extracted by crushing a sample of three randomly selected canes at 360 DAP in a three roller power operated crusher was used for estimation of total sugars and unfermentable sugars. The total sugars were estimated by acid hydrolysis and titration with Fehling's solution (Meade and Chen, 1977).

$$\text{Total sugars (g/100ml)} = \frac{32.496 \ x\ 10}{Titre\ Value}$$

Estimation of unfermentable sugars: Filtered juice of 500 ml (diluted to 15% brix where the juice brix was more than 15%) was taken in a 1liter beer bottle and 250 mg of baker's yeast (*Saccharomyces cerevisiae*) was added to it, plugged with cotton and kept in dark. The juice was allowed to ferment till the brix of the fermented juice reached 0% as measured by brix hydrometer. The fermented juice as such was titrated against Fehling's solution to estimate the unfermentable sugars. From the titre value the unfermentable sugars content of the juice was calculated and expressed as g/100ml.

Theoretical Yield of Alcohol (g/100ml): Theoretically 180.158 g of invert sugar yields 92.138 g of ethyl alcohol. Hence, the theoretical yield of alcohol was calculated using the following formula :

$$\text{Theoretical yield of alcohol (g/100ml)} = \frac{92.138\ x\ (A-B)}{180.158}$$

where, A = Total sugars,
B = Unfermentable sugars

Results and Discussion

Total sugar per cent ranged from 11.46% (2010T-158) to 29.25% (2010T-72) with a mean value of 20.38%). Theoretical yield of alcohol varied from 1.79 g/100ml (2010T-416) to 14.67 g/100ml (2010T-72) with a general mean value of 9.29 g/100ml. Based on the mean performance, the genotypes viz., 2010T-72 (14.67 g/100ml), 2010T-16 (14.01 g/100ml) and 2010T-88 (13.93 g/100ml) showed significantly higher performance than the best check Co 7219 (12.80 g/100ml) for theoretical yield of alcohol.

Character association studies (Table 1) revealed significant negative association of theoretical yield of alcohol with stalk volume (-0.242) and juice extraction per cent (-0.290) while the characters brix (0.389), sucrose (0.440), CCS per cent (0.447), juice purity (0.388), pol per cent cane (0.414), total sugars (0.919) and CCS yield (0.256) were significantly and positively associated with this character. These results are in conformity with the findings of Rakkiyappan and Pandiyan (1992) and Radhamani et al., (2012) with respect to the positive association of ethanol yield with total sugars. No significant positive or negative association of theoretical yield of alcohol was observed with cane yield indicating the possibility of simultaneous improvement of these two characters. Hence a variety meant for ethanol production should contain high total sugars in juice coupled with high cane yield.

The direct and indirect effects of nine characters on theoretical yield of alcohol are presented in Table 2. Stalk volume showed negligible negative direct effect (-0.030) on theoretical yield of alcohol. Its indirect effects through total sugars, CCS per cent (-0.049), pol per cent cane (-0.048), juice extraction (-0.003) and CCS yield (-0.003) were negative resulting in significant negative correlation of this character with theoretical yield of alcohol (-0.242). Brix recorded high negative direct effect (-0.330) on theoretical yield of alcohol and it also exhibited negative indirect effects via sucrose (-0.154), juice purity (-0.076) and CCS yield (-0.011). But the high positive indirect effects through pol per cent cane (0.392), total sugars (0.319) and CCS per cent (0.242) resulted in significant positive correlation of brix with theoretical yield of alcohol (0.389). Sucrose per cent exhibited negative direct effect (-0.159) on theoretical yield of alcohol. The correlation between sucrose per cent and theoretical yield of alcohol was significant and positive (0.440) which was due to high positive indirect effects of sucrose per cent through pol per cent cane (0.404), total sugars (0.368) and CCS per cent (0.260). CCS per cent recorded moderate positive direct effect (0.268) on theoretical yield of alcohol. Its indirect effects via brix per cent (-0.298) and juice purity (-0.124) were negative while its indirect effects via pol per cent cane (0.390) and total sugars (0.366) were high and positive which resulted in significant correlation of CCS per cent with theoretical yield of alcohol (0.447).

Juice purity per cent showed low negative direct effect (-0.171) on theoretical yield of alcohol. Positive and high indirect effects of juice purity per cent on theoretical yield of alcohol was noticed through total sugars (0.351), pol per cent cane (0.266) and CCS per cent (0.193) resulting in significant positive correlation of this character with theoretical yield of alcohol (0.388). Pol per cent cane registered high positive direct effect (0.413) on theoretical yield of alcohol. It also showed positive indirect effects via total sugars (0.336) and CCS per cent (0.252). But its correlation with theoretical yield of alcohol (0.414) was on par with the direct effect of pol per cent cane due to its negative indirect effects through brix (-0.313), sucrose per cent (-0.156), juice purity per cent (-0.110) and CCS yield (-0.011). Juice extraction per cent recorded negligible negative direct effect (-0.062) on theoretical yield of alcohol and its indirect effects were negative through total sugars (-0.249), CCS per cent (-0.016) and stalk volume (-0.002), which resulted in significant negative correlation of this character with theoretical yield of alcohol (-0.290). Total sugars showed the highest positive direct effect (0.887) on theoretical yield of alcohol. Its low positive indirect effects through pol per cent cane (0.157) and CCS per cent (0.110) resulted in total correlation of 0.919. CCS yield direct effect on theoretical yield of alcohol was negligible and negative (-0.026). But its correlation with theoretical yield of alcohol was positive and significant (0.256) due to its positive indirect effects through total sugars (0.241), pol per cent cane (0.180) and CCS per cent (0.096). Residual effect was found to be low (0.374) which indicated that most of the characters contributing to theoretical yield of alcohol were included in study.

Critical analysis of the results by path analysis revealed that the characters viz., total sugars per cent, pol per cent cane and CCS per cent exhibited positive direct effects on theoretical yield of alcohol and the other characters also exhibited their indirect positive effects on theoretical yield of alcohol via total sugars per cent, pol per cent cane and CCS per cent, indicating that these are the major contributing characters to theoretical yield of alcohol in sugarcane. Further, these three characters showed significant positive correlations among themselves indicating that selection for any one of these traits would improve the remaining two traits simultaneously. Hence, a variety meant for ethanol production should have high total sugars or pol per cent cane or CCS per cent coupled with high cane yield.

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Table 1. Phenotypic correlation coefficients between theoretical yield of alcohol and its component characters in sugarcane

	No. of millable canes	Single cane weight	Fibre content	Brix %	Sucrose %	Commercial cane sugar %	Juice puritiy %	Pol % cane	Juice extraction %	Total sugars %	Biomass per cane	Fibre yield	Commercial cane sugar yield (g)	Cane yield (g)	Theoretical yield of alcohol (g/100 ml)
	NMC	SCW	FC	BRIX	SUC	CCS	JP	P%C	JE	TS%	BM	FY	CCSY	CY	TYA
SV	0.119	0.165	-0.215	-0.134	-0.154	-0.182	-0.126	-0.116	0.053	-0.225*	0.540**	0.083	0.113	0.241*	-0.242*
NMC		-0.201	-0.141	-0.002	-0.062	-0.107	-0.195	-0.029	0.291*	0.138	-0.215	0.507**	0.526**	0.618**	0.079
SCW			-0.194	-0.063	-0.072	-0.117	-0.038	-0.035	-0.238*	-0.068	0.376**	0.459**	0.533**	0.632**	-0.064
FC				0.095	0.106	0.144	0.060	-0.099	-0.388**	0.188	-0.147	0.389**	-0.174	-0.253*	0.135
BRIX					0.967**	0.903**	0.444**	0.948**	-0.054	0.359**	-0.196	0.011	0.411**	-0.048	0.389**
SUC						0.970**	0.654**	0.979**	-0.052	0.415**	-0.170	-0.038	0.397**	-0.104	0.440**
CCS							0.723**	0.943**	-0.061	0.412**	-0.187	-0.080	0.357**	-0.170	0.447**
JP								0.643**	-0.006	0.396**	-0.017	-0.153	0.202	-0.189	0.388**
P%C									0.027	0.379**	-0.148	-0.116	0.436**	-0.051	0.414**
JE										-0.281*	-0.052	-0.207	-0.021	0.035	-0.290*
TS%											-0.187	0.176	0.272*	0.052	0.919**
BM												0.008	0.015	0.129	-0.165
FY													0.686**	0.779**	0.107
CCSY														0.846**	0.256*
CY															0.011

*,** Significant at 5 and 1% level respectively

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Table 2. Direct and indirect effects of component characters on theoretical yield of alcohol at phenotypic level in second clonal stage of sugarcane

Characters	Stalk volume	Brix per cent	Sucrose per cent	Commercial cane sugar per cent	Juice purity per cent	Pol % cane	Juice extraction per cent	Total sugars per cent	Commercial cane sugar yield (g)	Theoretical yield of alcohol (g/100 ml)
	SV	BRIX %	SUC %	CCS %	JP %	P%C	JE %	TS %	CCSY	TYA 'r'
SV	**-0.030**	0.044	0.024	-0.049	0.022	-0.048	-0.003	-0.200	-0.003	-0.242*
BRIX %	0.004	**-0.330**	-0.154	0.242	-0.076	0.392	0.003	0.319	-0.011	0.389**
SUC %	0.005	-0.319	**-0.159**	0.260	-0.112	0.404	0.003	0.368	-0.010	0.440**
CCS %	0.005	-0.298	-0.154	**0.268**	-0.124	0.390	0.004	0.366	-0.009	0.447**
JP %	0.004	-0.147	-0.104	0.193	**-0.171**	0.266	0.000	0.351	-0.005	0.388**
P%C	0.003	-0.313	-0.156	0.252	-0.110	**0.413**	-0.002	0.336	-0.011	0.414**
JE %	-0.002	0.018	0.008	-0.016	0.001	0.011	**-0.062**	-0.249	0.001	-0.290*
TS %	0.007	-0.118	-0.066	0.110	-0.068	0.157	0.017	**0.887**	-0.007	0.919**
CCSY	-0.003	-0.136	-0.063	0.096	-0.035	0.180	0.001	0.241	**-0.026**	0.256*

Residual effect = 0.374
Figures in bold indicates direct effect