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Expression of heterosis in sugarcane genotypes under moisture stressed condition

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ABSTRACT: Production of sugarcane varieties that would be suitable for the drought prone ecologies has been a major concern in Nigeria. Effect of drought on sugarcane has been one of the limiting factors to its production. To this end, an effort was made to develop varieties that are tolerant to moisture stress through the expression of high vigour (heterosis). Four sugarcane genotypes (2 resistant and 2 susceptible) were planted along with their progenies in moisture stress and non-moisture stress condition for two years using randomised complete block design in each year. Result showed that progenies performed better than their parents in the moisture stress condition of both years with respect to important yield component like stalk height, number of stalks/stool and number of stools/plot. Progenies from tolerant parents also showed positive heterosis over mid-parents. This ranged from 3.21 –32.31%, confirming the presence of dominance. Heterosis over better parents were however mostly negative.

Key Words: Heterosis; Sugarcane varieties; Drought; Moisture stress.

Introduction

Sugarcane is an important cash crop grown mostly in the tropics and sub tropical regions of the world. It consists of 5 major *Saccharum* species (Thuljaram, 1987). However, S. *officinarum* is the most widely cultivated species. Despite great potentials of new sugarcane varieties, the frequent occurrence of drought occasioned by erratic rainfall distribution and cessation of rains is the greatest hindrance to increased sugarcane production (Olaoye, 1999). Sugarcane tolerant varieties have the ability to reduce transpiration losses, while at the same time maintain a fairly adequate absorption of water from the soil. However severe drought can lead to lower output of cane and sugar per unit area as well as low sugar recovery from net weight of cane (Moore 1987).

Breeding for drought tolerance has been a major objective of many national and international research programmes. Breeding for high yield and drought tolerance crop can be done by selecting for characters that decrease yield (Parsons, 1979). Richard (1989) however hypothesized that the best way of incorporating a trait into an existing breeding programme is to use genotypes with desired expression of the trait as parents in the hybridisation phase.

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Selection should also be made under adverse conditions likely to be encountered so that genotypes capable of exploiting limited resources can be identified. Heterosis, as a measure of the superior performance of hybrid relative to the average of the parents is a means of identifying superior genotypes. According to David and Sally (2005), heterosis may result in the crossbred being better than either parental breed or simply better than the average of the two. The main objective of this study is therefore to identify sugarcane genotypes tolerant to moisture stress through the expression of heterosis for morphological characters.

Materials and Methods

Four sugarcane varieties (2 tolerant and 2 susceptible to drought) were crossed using biparental method of hybridisation in the following combination:

KD-01x F141 (resistant x resistant)
KD-01x Co331 (resistant x susceptible)
Co453x F141 (susceptible x resistant)
Co453x Co331 (susceptible x susceptible)

In each of the four crosses, ten progenies were selected at random. The forty progeny clones were evaluated along with the four parents in the field for tolerance to moisture stress.

Ten seedlings per cross along with their parents were planted in a three replicate randomised complete block design on the field. Each plot consisted of 1 row of 2 m long spaced 1m apart and 1.5m between the rows. In the first year planting was done in February 2002. After 10 weeks of growth, moisture stress was imposed for only 4weeks before the commencement of the rains. In the second year however, the experiment was replicated so that moisture stress was imposed on one set while the other received regular watering throughout the duration of the experiment. The same procedure was followed as above. However moisture stress was imposed for 8 weeks after 10 weeks of vegetative growth in one of the fields while the other received normal watering up to maturity period. At maturity (12 MAP), the following data were collected-: stalk length (cm), stalk weight (kg), stalk girth (cm), number of stalks/stool, number of stools/plot, leaf area, brix percent and cane yield.

Statistical analysis

All experiments were subjected to analysis of variance (ANOVA), while heterosis was determined as the percentage difference of progenies from the mid-parental values as well as the better parents, according to Falconer, (1989).

Results

Mean performance of the parents and their progenies with respect to agronomic and yield characteristics in 2002 are presented in Table 1. Significant differences were observed for number stalks/stool, number of stools per plot, leaf area, sugar and cane yield. Progenies of the cross KD-01xF141 had higher number of stalks per stool than the maternal parent (KD-01) but similar to that of paternal parent (F141). However, the value was only significantly different from those of Co331 and progenies of Co453xCo331. Co453 had higher number of stalks per stool than its progenies while Co331 had lower number of stalks per stool than its progenies.

In terms of number of stools per plot, Co453 had higher number of stools/plot than its progeny, which was significantly different, from those of KD-01 and its progenies. Co331 also differed significantly from one of its progenies (i.e. KD-01xCo331). This could be due to maternal effect since KD-01 had similar value with the progenies. C0453 was observed to have higher leaf area than its progenies (Co453xF141 and Co453xCo331); KD-01 also had higher leaf surface area than its progenies (KD-01xF141 and KD-01xCo331). In terms of sugar yield, Co453 had higher sucrose content than its progenies regardless of the paternal parent. F141, which was next in sugar yield among the parents, also had higher value than either of its progenies in both cross combinations. KD-01 however had lower sugar yield than its progenies in all cross combinations. Cane yield in progenies involving F141 and the other two maternal parents were intermediate suggesting mid-parent heterosis in those crosses and that the paternal parent was able to transmit genes for cane yield to the progenies. Conversely, progenies of cross KD-01xCo331 yielded higher than either parent while those of progenies of Co453xCo331 yielded lower than either parent.

Table 1: Means for morphological and yield characteristics in four sugarcane parental clones and their progenies subjected to moisture stress under field conditions (2002)

	Stalk length (cm)	**Stalk girth (cm)**	**Single Stalk weight (kg)**	**No. of Stalks/ stool**	**No. of Stool/ plots**	**Leaf Area (cm^2)**	**Brix %**	**Cane Yield/ plot (kg)**
Parents								
KD-01	207.89	2.21	0.70	6.78	4.67	965.96	17.17	12.60
Co453	206.67	2.25	0.83	6.44	6.33	1378.81	19.16	10.80
Co331	189.45	1.91	0.50	5.11	6.00	1057.62	17.83	13.70
F141	171.00	2.12	0.53	7.44	5.67	691.52	18.33	20.83
Progenies								
*KD-01 x F141	197.89	2.12	0.53	7.44	5.33	721.97	17.32	18.78
KD-01 x Co331	232.20	2.07	0.51	5.68	4.13	888.75	17.18	15.09
Co453 x F141	184.31	2.10	0.60	5.99	4.97	910.36	17.27	17.09
Co 453 x Co331	192.80	2.09	0.63	5.19	6.07	940.95	18.51	10.26
	NS	NS	NS	1.76	1.15	143.2	1.41	7.01
LSD (5%)	23.34	10.29	29.90	16.05	13.02	25.98	4.52	26.97
C.V (%)								

* First parent in a cross combination designates female.

Mean performance of the parents and their progenies with respect to agronomic and yield characters in moisture stressed condition for 2003 are presented in Table 2. Significant differences among parents and their progenies existed only for single stalk weight; leaf area and cane yield per plot. However, the parents generally performed better than their progenies, except KD-01×Co331. KD-01 had higher single stalk weight than its progenies. Similarly Co453 had higher single stalk weight than resulting progenies from the two paternal parents (Co453×F141 and Co453×Co331). In terms of leaf area, progenies of cross KD-01×F141 had larger surface area than either parent. However one of the paternal parents (Co331) had higher surface area than its progenies, regardless of the maternal parent. Although there was no significant difference between parents and their progenies for sugar yield, the progenies had higher sugar content than their parents. With respect to cane yield, the parents had higher yield than their respective progenies with progenies of cross Co453×Co331 yielding significantly lower than three of the parents.

Table 3 shows mean agronomic and yield characteristics in non-moisture stress condition in the field. Significant differences were observed for stalk length, stalk girth, single stalk weight, and number of stools per plot. Neither sugar (brix) nor cane yield differed significantly among the genotypes. In terms of stalk length, progenies of cross KD-01×F141 were taller than the maternal parent KD-01 but shorter than the paternal parent. The second maternal parent (Co453) had longer stalks than those of the progenies involving both paternal parents. In terms of stalk girth, Co453 had wider stalk girth than its progenies Co453×F141 and Co453×Co331. The progenies of the cross combinations involving Co331 had similar values to the paternal parent; indicating the paternal influence in stalk girth under normal growing condition. In terms of single stalk weight, all the parents had higher single stalk weight than their progenies except Co331. This also indicates paternal influence for this trait.

Table 2: Means for morphological and yield characteristics in four sugarcane parental clones and their progenies under moisture stress conditions in the field (2003)

	Stalk length (cm)	**Stalk girth (cm)**	**Single stalk weight (kg)**	**No. of Stalks/ stool**	**No. of Stools/ plot**	**Leaf Area (cm^2)**	**Brix %**	**Cane Yield Plot (kg)**
Parents								
KD-01	170.60	2.23	0.86	3.33	2.67	900.09	15.90	13.87
Co453	158.33	2.17	0.84	3.33	4.67	1100.20	15.37	10.77
Co331	149.43	2.33	0.71	5.33	4.33	1112.03	16.33	13.53
F141	145.00	2.13	0.67	5.33	6.00	617.83	15.33	14.50
Progenies								
*KD-01 x	165.42	2.15	0.70	5.73	4.47	949.65	16.36	13.00
F141	170.80	2.04	0.65	5.40	4.57	854.04	16.63	11.58
KD-01 x	160.16	2.09	0.77	4.53	4.23	1031.17	16.30	10.55
Co331	152.97	2.09	0.70	4.30	5.57	901.79	16.79	8.68
Co453 x F141								
Co 453 x						107.3		
Co331	NS	NS	0.16	NS	NS		NS	2.04
	11.57	12.32	12.09	34.77	33.13	19.69	7.94	19.14
LSD (5%)								
C.V (%)								

* First parent in a cross combination designates female.

The progenies of crosses KD-01×F141 and Co453×F141 had significantly higher number of stool per plot than their paternal parent (F141). However Co453 had significantly higher value than its progenies. In terms of percent brix (sugar yield), although there was no significant difference, the parents had higher sugar yield than their progenies unlike what was observed under moisture stress condition. KD-01 and F141 had higher sucrose yield than their progenies, KD-01×F141 and Co453×F141. However, Co453 and Co331 had lower sucrose yield than their progenies. With respect to cane yield however, although there was no significant difference, the parents performed better than their progenies, similar to what was observed in moisture stressed condition. The progenies of resistant parents (KD-01and F141) had higher cane yield than the progenies of susceptible parents (Co453 and Co331).

Table 4 shows the heterosis in percentage of mid and better parents. In the first year, it was observed that the progeny clones from either resistant male (F141) or female (KD-01) always had positive heterotic effect over mid-parent values. The opposite was the case of progeny clones with susceptible parent (Co331 or Co453). This shows the preponderance of genetic gain for the hybrid progenies for moisture stress condition. Similarly, in the second year, the hybrids from resistant parents had high and positive values for yield components like number of stalks/stool and number of stools per plot. Heterosis over better parents were mostly negative except in few cases.

Table 3: Means for morphological and yield characteristics of four sugarcane parental clones and their progenies in unstressed field (2003)

	Stalk length (cm)	Stalk girth (cm)	Single stalk weight (kg)	No. of Stalks/ stool	No. of Stools/ plot	Leaf Area (cm^2)	Brix (%)	Cane Yield Plot (kg)
Parents								
KD-01	182.33	2.13	0.80	4.00	5.67	1141.88	19.43	15.60
Co453	197.63	2.20	0.83	3.00	6.67	1278.36	16.87	13.70
Co331	176.67	1.83	0.63	4.00	5.00	1125.06	16.43	13.00
F141	205.57	2.13	0.80	6.00	3.67	932.39	17.33	15.47
Progenies								
*KD-01 x F141	196.28	2.04	0.71	4.93	5.43	979.22	16.11	15.09
KD-01 x Co331	170.86	1.82	0.55	4.43	4.17	968.04	16.68	10.00
Co453 x F141	174.37	2.02	0.69	4.17	4.57	993.46	17.12	11.91
Co 453 x Co331	161.16	1.91	0.66	4.03	4.63	1090.31	18.08	10.92
LSD (5%)	28.60	0.24	0.19	NS	1.85	NS	NS	NS
C.V (%)	8.92	6.87	15.54	33.45	21.26	18.17	7.99	23.67

* First parent in cross combinations designates female.

Discussion

Sugarcane is polyploid and highly heterozygous. Therefore maximum variability is expected from the F_1 of a cross involving two parents of contrasting character (Olaoye, 1996). In the first year where there was no prolonged moisture stress, no desiccation was observed. However, significant differences were observed between the progenies and their parents, which is an indication of the variability, which existed between the different populations (Table 1) and the opportunity for carrying out selection between and within the progenies for drought tolerance. F141 and KD-01 showed high tolerance and as such had higher mean values for yield components like single stalk weight, number of stalks per stool and cane yield.

Similar to what was observed in year 2002, drought tolerant varieties and their progenies were superior for important yield components like stalk height, single stalk weight and number of stools per plot (Table 2). Comparison of performance of the genotypes in moisture stressed (Table 2) and unstressed condition (Table 3) showed that drought tolerant varieties also performed well in non- moisture stressed conditions. This implies that drought tolerant varieties have the potential for higher yield in both moisture stressed and unstressed environments. In other words, although drought effect can be expressed in many forms in different crop varieties, if the effect is not much on the yield attributes, a genotype that is high yielding may also be tolerant to moisture stress environment as well. Clarke *et al* (1992) observed that relative yield performance of genotypes in moisture stress and non-stressed environments should be the starting point in identifying traits related to drought tolerance and selection of desired genotypes. In this study, the varieties selected as tolerant parent clones performed well in both stressed and unstressed condition. The tolerant parents (F141 and KD-01) had similar values for important yield components like stalk height, single stalk weight, number of stalks per plot and number of stools per plot in both stressed (Table 2) and unstressed (Table 3) condition. Therefore they can be used as parents for yield increase in both stress and unstressed environments.

Table 4: Heterosis (%)of the Progeny over Better parent and Mid-parent

Trait	Progenies	Year 1 (stress)		Year 2 (stress)		Year 2 (unstressed)	
		mid-parent	Better parent	mid-parent	Better parent	mid - parent	Better parent
Stalk length	KD-01xF141	4.46	-4.81	4.83	-3.04	1.20	-4.52
	KD-01xCo331	16.89	11.69	6.74	0.12	-4.81	-6.29
	Co453xF141	-2.40	-10.82	5.60	1.16	-13.51	-15.18
	Co453xCo331	-4.82	-6.71	-0.59	-3.39	-13.89	-18.45
Stalk girth	KD-01xF141	-2.27	-4.07	-1.51	-3.58	-4.50	-4.22
	KD-01xCo331	0.34	-6.33	-12.39	-12.44	-8.07	-14.55
	Co453xF141	-4.02	-9.67	-2.79	-3.39	-6.78	-8.18
	Co453xCo331	5.28	-7.11	-7.11	-10.30	-5.45	-13.18
Stalk weight	KD-01xF141	-14.59	-24.29	-8.50	-18.60	-11.63	-11.25
	KD-01xCo331	-15.00	-27.14	-17.78	-24.41	-22.87	-31.25
	Co453xF141	-12.59	-27.71	1.98	-8.33	-15.18	-16.86
	Co453xCo331	-5.55	-24.10	-10.29	-16.67	-10.37	-20.48
No. stalk/stool	KD-01xF141	4.69	0.00	32.31	7.50	-1.34	-17.83
	KD-01xCo331	-4.37	-16.22	24.62	1.31	10.83	10.75
	Co453xF141	-13.77	-19.49	4.62	-15.01	-7.40	-30.50
	Co453xCo331	-10.25	-19.41	-0.76	-19.32	-15.23	0.75
No. stools/plot	KD-01xF141	3.21	-6.00	3.07	-25.50	1.86	-4.23
	KD-01xCo331	-22.52	-31.17	30.49	5.54	-10.71	-26.45
	Co453xF141	-17.22	-21.48	-20.64	-29.50	-11.61	-31.48
	Co453xCo331	-50.26	-4.11	23.71	19.27	-20.58	-30.58
Leaf area	KD-01xF141	-12.88	-25.26	25.12	5.51	-5.58	-14.24
	KD-01xCo331	-12.16	-15.97	-15.11	-23.20	-14.59	-15.22
	Co453xF141	-12.01	-33.97	20.43	-6.27	-10.12	-22.29
	Co453xCo331	-22.76	-31.76	-18.50	-18.91	-9.27	-14.71
Brix(%)	KD-01xF141	-3.20	-5.51	4.74	2.89	-12.36	-17.09
	KD-01xCo331	-1.07	-3.65	3.20	1.84	-6.98	-14.15
	Co453xF141	-1.27	-9.86	6.21	6.05	0.13	-1.21
	Co453xCo331	-6.64	-3.39	5.91	2.82	8.61	7.17
Cane yield	KD-01xF141	12.34	-9.84	-8.35	-10.34	-0.28	-3.27
	KD-01xCo331	14.78	10.14	-15.47	-16.51	-30.05	-35.90
	Co453xF141	8.05	-17.95	-16.50	-27.24	-18.36	-23.01
	Co453xCo331	-16.27	-25.11	-28.70	-35.85	-18.22	-20.29

High and low positive heterosis observed was mainly due to varying genetic composition between parents of different crosses for the component characters (Rajesh and Gulsan, 2001). This indicates that the parents differ significantly for traits controlling moisture stress. Heterosis observed shows that there is dominance for resistance to moisture stress as progenies from resistant parents consistently had positive heterosis. Dominance variance was also significant for these traits (Ishaq 2005). Selection for progenies with hybrid vigour can therefore be practice under moisture stress condition in sugarcane. Progeny clones KD-01XF14 and KD-01x Co331 would give high yield under both moisture and non-moisture stressed conditions.

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