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Utilization and Cause of Higher Cane Yield in Interspecific Hybrids Between *Saccharum Spontaneum* and Commercial Type Hybrids

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サトウキビ実用品種と野生種（*S.spontaneum*）交配系統の多収の原因とその利用

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要　約

サトウキビ野生種を多収性の面から育種利用する場合に、F_1およびBC_1に発現する超多収の原因および関連形質について論じた。

超多収は収量構成要素の広い変異におけるその最適組合によって生じ、その際収量構成要素間の負の相関関係は打ち破られた。

物質生産の面からは葉数の増加によるＬＡＩの増大によって超多収は成立した。以上のような観点から育種素材は選抜された。

INTRODUCTION

Nagatomi (1980) collected *Saccharum spontaneum*. This has been the main sources of disease and insect pest resistance, drought resistance, typhoon tolerance and adaptability to ratooning.

Japan is situated in the northern limit for sugarcane production. *S. spontaneum* has been growing in the Southwest Islands which come under harsh environmental conditions, such as typhoons, droughts and heavy rains. Utilization of S. spontaneum was studied by Heinz (1967), Roach (1968, 1971, 1977), Walker (1971), Juang (1966), Sankaranaraynan (1977), Batch and Palanichamy (1977) from the viewpoint of impoving sugarcane varieties.

The purpose of this study is to find methods of selection of interspscific hybrid populations between commercial type hybrids and S.spontaneum; to know a basic mechanism which is related with higher cane yields: and to know how to make small negative correlations between yield components.

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MATERIALS AND METHODS

This study, completed at the Okinawa Prefectural Agricultural Experiment Station, is based on the date of populations of commercial hybrid × *S. spontaneum* hybrid through such routine works of sugarcane breeding programs such as seedling, preliminary line and line selection trials.

Trial 1.

Seedlings were planted in April, 1981 with a planting distance of 1.25 m × 0.15 m, using cross combinations of 22 F_1, 6 BC_2 and 3 commercial crosses. Dosage of fertilizers per hectare was 210 kg N, 90 kg P_2O_5 and 120 kg K_2O. One third of the total amont was applied before planting time while the remaining amount was applied twice during the growth period.

All seedlings from 1.5 m rows in three and four replications were evaluated. The traits measured were stalk length and diameter, number of nodes, weight of one stalk, Brix, number of stalks, number and weight of green leaves, incidence of disease and leaf area index(LAI).

Triel 2.

One-bud cuttings from all clones were planted in March 1982 with a planting distance of 1.25 m × 0.2 m. For the F_1 stage 330 clones of 22 cross combinations were used. For the BC_1 stage 50 clones of 7 cross combinations, BC_2 70 clones or 7 cross combinations, and 130 clones of 13 commercial combinations were used.

Trial 3.

In all, 120 clones were selected from the 7 F_1 stage and were planted in March, 1983 with a planting distance of 1.25 m × 0.3 m. This trail was laid out in a randomized complete block design and replicated twice. Each treatment comprised one row measuring 4 meters long. Parameters measured were the same as in Trial 1.

RESULTS AND DISCUSSION

1) Variation of mean values of economic traits with change from F_1 stage to commercial crosses.

Tables 1 and 2 show the results of trials 1 and 2 respectively. Economic traits that shift from F_1 stage to commercial cross changed gradually; such as small stalk to large stalk diameter, long to short stalks, light to heavy weight of one stalk, low to high Brix, large to small numbers of stalks, heavy to light cane yield, and large to small LAI. These results concur with previous results in foreign countries.

F_1 populations and clones of BC_1 gave higher cane yields than those of clones in BC_2 and commercial crosses, whereas, in trial 2, only F_1 populations had high cane yields. The difference in yield between Trials 1 and 2 was due to planting density. Cane yield is closely related to yield components and are affected by different planting densities.

Shimabuku et al (1977) analyzed cane yields of commercial type hybrids from the viewpoint of the paradox of negative correlation between yield components in an effort to select high yielding varieties. Higher cane yields of F_1 and BC_1 are the result optimum combination of weight of one stalk and number of stalks in the process of change from F_1 to BC_2 stage. Ultimately, high yielding clones of F_1 and BC_1 stages are characterized by the optimum combination of yield components and larger LAI.

Table 1. Mean values of economic traits in Trial 1

Type of cross	Number of crosses	Stalk dia. (cm)	Stalk length (cm)	No. of nodes	Cane yield (kg/10m²)	Wt.of green leaves kg/10m²	No. of green leaves	LAI	Brix	No. of stalks	Wt. of one stalk	Incidence of leaf scorch(%)
(F_1) Commercial x *S. spontaneum*	22	1.32	211	19.5	76.7	8.8	2107	8.76	12.91	234	328	15.0
(BC_1)Commercial x F_1	7	1.76	209	19.2	77.4	6.2	1425	7.54	15.17	154	503	51.4
(BC_2)Commercial x BC_1	6	1.82	199	19.7	69.1	5.5	991	6.41	16.27	133	520	61.0
Commercial x commercial	3	2.12	186	17.5	69.5	6.3	706	6.30	19.39	105	660	76.7

Table 2. Mean values of economic traits in Trial 2

Type of cross	Number of crosses	Stalk diameter (cm)	Stalk length (cm)	Number of nodes	Weight of one stalk (g)	Brix	Number of stalks	Cane yield (kg/m²)
(F_1) Commercial x *S. spontaneum*	22	1.62	239	22.6	598	15.6	17.5	8.4
(BC_1) Commercial x F_1	5	2.11	209	20.4	977	18.6	9.8	7.7
(BC_2) Commercial x BC_1	7	2.15	182	20.0	924	18.0	9.9	7.3
Commercial x commercial	13	2.35	174	20.0	1,038	20.2	9.1	7.5
NCo 310	-	2.16	156	16.0	830	19.9	11.0	7.3

2) Correlation coefficient between economic traits among F_1, BC_1, BC_2, and commercial crosses

Table 3 shows the matrix of correlation coefficients between ecomomic traits in F_1 and commercial crosses among cross combinations.

Brix had positive correlations with stalk diamater ($r=0.94^{**}$) and incidence of leaf scorch ($r=0.98^{**}$), but negatively correlated with stalk length ($r=-0.78^{**}$), number of nodes ($r=-0.45^{**}$), cane yield ($r=-0.78^{**}$), weight of green leaves ($r=-0.94^{**}$), number of green leaves ($r=-0.98^{**}$) and number of stalks ($r=-0.98^{**}$).

Cane yield had positive correlations with stalk length ($r=+0.86^{**}$), number of nodes ($r=0.39^{*}$), weight of green leaves ($r=0.60^{**}$), number of green leaves ($r=0.83^{**}$) and number of stalks ($r=0.73^{**}$), but negatively correlated with stalk diameter ($r=-0.70^{**}$), incidence of leaf scorch ($r=-0.74^{**}$) and weight of one stalk ($r=-0.69^{**}$).

There was a high negative correlation between weight of one stalk and number of stalks ($r=-0.97^{**}$). The above results show a universal relation between economic traits from F_1 to BC_1 stge. It is most important to weaken negative correlation between weight of one stalk and number of stalks.

3) Higher yielding canes from the viewpoint of a relationship between economic traits in F_1 and BC_1 stages.

Table 4 shows the matrix of correlation coefficients between economic traits among 22 cross

combinations. of F_1 populations.

Brix had positive correlation with stalk diameter (r=0.53＊＊), cane yield (r=0.56＊＊), weight of one stalk (r=0.45＊＊), but negatively correlated with incidence of leaf scorch (r=−0.48＊). Stalk diameter is positively correlated with cane yield (r=0.67＊＊), weight of green leaves (r=0.48＊＊), weight of one stalk (r=0.88＊＊), but negative correlation was noted with incidence of leaf scorch (r=−0.76＊＊).

Cane yield had positive correlation with Brix (r=0.56＊＊), stalk diameter (r=0.67＊＊), weight of green leaves (0r=0.64＊＊), number of stalks (r=0.62＊＊), weight of one stalk (r=0.75＊＊), but negatively correlated with incidence of leaf scorch (r=−0.58＊＊). Low negative correlation values (r=−0.03) between number of stalk and weight of one stalk was also observed in the F_1 stage. These results show negative correlation between yield components is weakened in F_1 populations. Higher yielding clones were selected by overcoming the paradox between yield components because each yield component independently increase.

There was no significant correlation between number of stalks and weight of one stalk in BC_1 ($r=-0.29^{ns}$) (Table 5). A weak correlation coefficient ($r=-0.29^{ns}$) between yield components suggests a possibility of utilizing these values in determining higher cane yields in BC_1 stage.

As shown in Fig. 1, negative correlation values between yield components gradually changed from F_1 stage to commercial crosses.

Table 3. Matrix of correlation coefficient between economic traits smong 38 cross combinations in F_2 to commercial crosses

Traits	Stalk diameter	Stalk length	Number of nodes	Cane yield	Weight of green leaves	Number of green leaves	Incidence of leaf scorch	Number of stalks	Weight of one stalk
Brix	0.94＊＊	− 0.78＊＊	−0.45＊＊	−0.78＊＊	−0.94＊＊	−0.98＊＊	+0.98＊＊	−0.98＊＊	0.92＊＊
Stalk diameter		−0.88＊＊	−0.72＊＊	−0.70＊＊	−0.80＊＊	−0.97＊＊	0.99＊＊	−0.99＊＊	0.99＊＊
Stalk length			0.80＊＊	0.86＊＊	0.51＊＊	0.89＊＊	−0.85＊＊	0.83＊＊	−0.89＊＊
Number of nodes				0.39＊	0.16	0.60＊＊	−0.63＊＊	0.59＊＊	−0.76＊＊
Cane yield					0.60	0.83＊＊	−0.74＊＊	0.73＊＊	−0.69＊＊
Weight of green leaves						0.85＊＊	−0.86＊＊	0.89＊＊	−0.76＊＊
Number of green leaves		n=38					−0.99＊＊	0.99＊＊	−0.96＊＊
Incidence of leaf scorch		＊ 5% significance level						0.99＊＊	−0.98＊＊
Number of stalks		＊＊ 1% significance level							−0.97＊＊
Weight of one stalk									

Table 4. Matrix of correlation coefficient between economic traits among 22 cross combinations of F_1 populations in seedlings

Traits	Stalk diameter	Stalk length	Number of nodes	Cane yield	Weight of green leaves	Number of green leaves	Incidence of leaf scorch	Number of stalks	Weight of one stalk
Brix	0.53＊＊	0.07	−0.01	0.56＊＊	0.23	0.28	−0.48＊	−0.37	0.45＊
Stalk diameter		0.14	0.11	0.67＊＊	0.48＊	−0.13	−0.76＊＊	−0.01	0.88＊＊

Stalk length			0.14	0.06	−0.18	0.08	−0.36	0.00	0.01
Number of nodes				0.33	−0.04	0.18	−0.17	0.39	0.14
Cane yield					0.64**	0.20	−0.58**	0.62**	0.75**
Weight of green leaves	n=22					0.20	−0.28	0.49*	0.64**
Number leaves green leaves	* 5% significance level ** 1% significance level						0.14	0.29	0.04
Incidence of leaf scorch								0.13	−0.74**
Number of stalks									−0.03
Weight of one stalk									

Table 5. Matrix of correlation coefficient between economic traits among 7 cross combinations of BC_2 in seedlings

Traits	Stalk diameter	Stalk length	Number of nodes	Cane yield	Weight of green leaves	Number of green leaves	Incidence of leaf scorch	Number of stalks	Weight of one stalk
Brix	0.69	0.04	0.36	0.60	0.16	0.33	0.74**	0.04	0.59
Stalk diameter		−0.44	−0.21	0.31	0.58	−0.51	0.34	0.35	0.50
Stalk length			0.04	0.27	0.28	0.13	0.17	0.42	0.03
Number of nodes				0.49	−0.09	0.48	0.41	0.17	0.45
Cane yield					0.55	−0.09	0.75*	−0.31	0.81*
Weight of green leaves						−0.02	0.07	−0.44	0.74
Number of green leaves		n=7					−0.54	−0.64	0.23
Incidence of leaf scorch		*5% significance level							−0.36
Number of stalks									−0.29
Weight of one stalk									

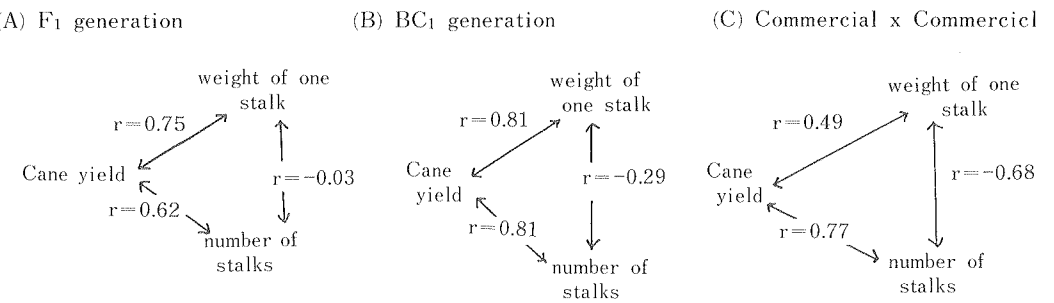

Fig. 1. Change of correlation between yield components with commercialization.

4) Higher yielding clones and optimum combination of yield components.

Figure 2 shows the scatter diagram of cane yield from the viewpoint of relationship between the weight of one stalk and the number of stalks in F_1.

Clones with individual stalk weights ranging from 500g to 700g had 14 to 19 stalks per square meter. Many clones with these stalk weights yielded more than 100 tons per hectare.

The future plan of sugarcane breeding is to produce high yielding varieties with good ratooning capacities. This can be accomplished by selecting vigorous hybrids with many stalks, higher LAI and good quality juice. These are clones characterized or selected with high yield levels at the F_1 and BC_1 stages. These clones or varieties have smaller stalks (1.8-2.0cm), and produces 140,000 to 190,000 stalks per hectare with large LAI and high sugar content.

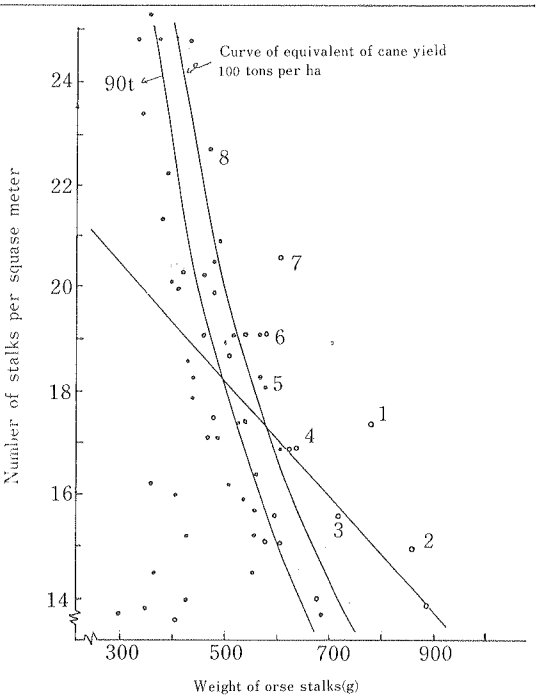

Fig.2. scattering of cane yield from the viewpoint of relation between weight of one stalk and number of stalks in F_1 populations

Note: Planting distance was 1.25 m x 0.3 m
1 is NCo 310 x JW35
2 is RK 67-8 x US 56-15
3 is KF 71-143 x US 56-15-8
4 is IRK 67-1 x US56-15-8
5 is N52-219 x US56-15-8
6 is IRK 67-1 x Glagha
7 is IRK 67-1 x JW 44

It was found that there is a positive correlation between LAI and cane yield in F_1 and BC_1 population. Higher yielding clones with optimum combination of yield components have higher LAI which keep many green leaves. Hybrid vigor in F_1 and BC_1 generation is characterized by a large number of stalks, small diameter, long stalk, many green leaves and large LAI.

CONCLUSIONS

This study was carried out to find the method of utilization of vigor of interspecific hybrid populations between Saccharum spontaneum and commercial type hybrids from the viewpoint of higher yields.

F_1 populations and clones of BC_1 had higher cane yields than those of clones of BC_2 and commercial crosses because of optimum combination of yield components and larger LAI.

There was a high negative correlation ($r=-0.97^{**}$) between weight of one stalk and number of stalks among F_1 populations, clones of BC_1, BC_2, and commercial crosses. It is most important to know the method or mechanism which weaken this negative correlation for high yielding varieties.

The negative correlation was weak between number of stalks and weight of one stalk in the F_1 and BC_1 stages.

Vigorous hybrids can be obtained independently increasing each yield component because negetive correlation between yield components is weakened in F_1 and BC_1 populations.

The future plan of sugarcane breeding is to produce high yielding varieties with good

ratooning capacities. This can be accomplished by selecting vigorous hybrids with many stalks, higher LAI and good quality juice. These are clones characterized or selected with high yield leaves at the F_1 and BC_1 stage. These clones or varieties have smaller stalks (1.8–2.0 cm), and produce 140,000 to 190,000 stalks per hectare with larger LAI and high sugar content.

SUMMARY

Interspecific hybrids of F_1 and BC_1 stages between commercial hybrids and *Saccharum spontaneum* showed vigorous growth and higher cane yield. This was characterized by the optimum combination of yield components with many stalks with a larger leaf area index because negative correlation between yield components became smaller or none.
Vigorous hybrids of F_1 stage were selected for breeding materials.

Keywords: *Saccharum* spp., sugarcane, high yield, LAI, *spontaneum*

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