PHILIPPINE SUGARCANE BREEDING PROGRAM: PHILOSOPHIES AND STRATEGIES

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ABSTRACT
The frequent occurrence of tropical cyclones gives early maturing varieties a great advantage for commercial growing in the Philippines. In such varieties, yield is increased if stages of growth are well partitioned so that tiller survival is high. Of the two approaches being used to influence stages of growth and percentage tiller survival, planting distance seems to show immediate promise.

Selection procedures used in Phase 1 (nobilisation and development of parental material) of the breeding program involve the use of recurrent selection for intra-population or intra-species improvement prior to nobilisation, and the use of highly productive lines for the development of parental material.

The commercial hybrid breeding program (Phase 2) is characterised by the use of highly selected lines as parents and high selection rates.

INTRODUCTION
The production of high yielding varieties has been the major research activity of the Philippine Sugar Institute (Philsugin) since its creation in 1952. The breeding program of the Institute has produced a number of hybrids which occupy about 65% of the present area.14

Varietal improvement in the Philippines is beset by two major problems which could not be remedied by the breeders alone. Firstly, there is a slow adoption of Philippine-bred varieties. Serious breeding work was first undertaken by the Bureau of Plant Industry in 1931,8 but 36 years later Philippine-bred canes still occupied less than 25% of the total area planted. The present 35% planted with Hawaiian, POJ and Co varieties is disappointing after a 42-year breeding project. Secondly, statistics show that while planting of Philippine-bred canes is increasing, the national average sugar yield per hectare is decreasing. At a glance it seems that our breeding work has had little impact on the industry. The above two problems are probably due to the following factors:

1) Lack of an organised sett distribution scheme backed by a stringent system of certification.
2) An inadequate breeding program which cycles every 12 years, and is unable to cope with the problems of land expansion and diseases.
3) Inadequate quarantine procedures.
4) Sugar losses due to harvest of immature canes, the presence of trash and the long interval between cutting and milling.

In 1972, a study was made on the possibility of speeding up the development of new varieties and incorporating resistance to smut, leaf scorch and downy mildew into them. Last year an 84-month commercial hybrid breeding program was adopted and the whole research office of Philsugin was re-organised in an attempt to solve the problems involved in factors 1, 2 and 4.
This paper presents the philosophy that evolved the whole varietal improvement program and the selection and breeding practices used. Because no basic study on selection and breeding methodology has been conducted in the Philippines, the systems of selection and breeding at present used are based on results from other countries. Nevertheless, problems involving the improvement of selection work and breeding strategies are priority areas in our research.

**BASIC BREEDING PHILOSOPHY**

Each year an average of 16 tropical cyclones hit the portion of the Philippines where 90% of sugarcane is grown. Typhoons occur between May and December and are destructive to sugarcane crops as early as 2 months of age. Therefore, it is decidedly advantageous to grow a variety which matures in 8 to 10 months. At present the two most popular varieties are PHIL 56-226 and CAC 57-11, both of which can be harvested at 9 months. Unfortunately they are highly susceptible to smut and are at present being replaced.

Sugarcane planters in the Philippines look for increases in tonnage of cane rather than sugar content in new varieties. This is because no premium is paid for a high sugar content, losses due to deterioration after harvest are not assessed on sucrose, and the purchase of cane by middlemen is entirely based on weight. Because there is no control on varieties that a farmer may grow, our breeding program is compelled to produce 12-month varieties to suit the practices of most farmers. In spite of this, the production of 10-month genotypes is now given priority.

Before sexual maturity, products of photosynthesis are used primarily for tiller formation, elongation and enlargement. Any residue is stored as sucrose. After floral initiation, growth is greatly diminished and sugar storage is increased but a number of environmental factors such as water and nitrogen can cause continuous growth thereby decreasing the amount of sugar stored. To obtain high yields in 10-12-month canes, it is necessary that we have an efficient partitioning of the photosynthate for maximum sugar yield. For us the balance between the number of days for tonnage and for sugar storage is more delicate than for Hawaiian sugarcane growers who harvest cane 24 or more months of age.

For most effective partitioning, cane growth should be divided into the following stages:

<table>
<thead>
<tr>
<th>Stage</th>
<th>10-month crop</th>
<th>12-month crop</th>
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<tbody>
<tr>
<td>Tillering</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Elongation and enlargement</td>
<td>4</td>
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<td>Storage</td>
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Tillering must be limited to the first 3 months, and elongation and enlargement to the next 4 to 5 months to obtain the most effective utilisation of photosynthate. Therefore, under our conditions, stools of sugarcane should produce few tillers, perhaps between 6 and 9, but all of these should become harvestable stalks. This will reduce sugar losses arising from the development of non-harvestable tillers. To effect a significant increase in sugar yield per unit area in the Philippines our breeding program must (1) develop high yielding, disease-resistant, early maturing canes, (2) efficiently partition the 3 major stages of growth, and (3) increase percentage tiller survival.
Breeding work in the Philippines has in the past been directed towards the immediate production of commercial types. Parent material is primarily made up of native and acclimatised noble canes and adapted, introduced hybrids. Examination of our breeding records shows that there is a significant negative phenotypic correlation (−0.40 to −0.60) between brix at 10 months and tons cane per hectare among selected clones in advanced stages of the breeding program. However, clones subjected to mild selection show no such negative correlation. In both populations, correlation between 10 and 12 month brix is positive and significant, with values ranging from 0.75 to 0.85 in mildly selected populations and 0.93 to 0.96 in more severely selected populations. In addition, no unfavorable relationship exists between 10 month brix and number of harvestable tillers. Similarly, no correlation was observed between earliness and rate of growth. Our data are in contrast to those of Brown, et al, that there is a negative correlation between yield per plot and percentage sucrose on dry weight. The disparity might be due to differences in populations used, since theirs was composed mainly of early hybrids with spontaneum. Our practice of selecting seedlings produced in the commercial hybrid breeding program at 8 to 10 months makes it convenient for us to select for earliness. At this stage, only brix and stalk diameter are considered among the components of sugar yield. At present, basic studies are being conducted to improve efficiency in selecting for earliness in the seedling and row tests of our breeding program.

Two approaches were followed in an attempt to control stages of growth and tiller survival. The first is long-term through hybridisation and selection. Since the program was started only in 1972 we expect the first results in October of this year. Emphasis is on the search for indices (genetic, physiological and morphological) that will assist in selection. The short-term approach was made through control of planting distance or plant population.

The usual commercial planting distance in the Philippines is 30 cm between setts in furrows 1 m apart. At such a distance, varieties produce about 10-20 tillers but only 5-10 are harvestable at 12 months. Since tillering is influenced by plant density, we planted test varieties at 75 x 30 cm with a fertilizer rate of 100-70-200:N, P$_2$O$_5$, and K$_2$O. Results showed that, under closer planting, there was a decrease in the number of harvestable stalks, a slight decrease in tons cane per hectare, and an increase in percentage tiller survival and in brix. One test variety CAC 57-11 gave 30% increase in tiller survival and 4% increase in brix. Correlation analysis showed that tiller survival was highly correlated with both tons cane per hectare and brix. We also observed that some varieties gave better cane yields in narrow rows. Tajon and Rosario evaluated the response of 4 varieties under 2 plant distances (75 x 30 cm and 150 x 30 cm). Their experiment showed a significantly higher sugar yield in narrow rows, and this was entirely due to difference in tonnage. Although they observed that the wider rows produced more and heavier stalks per hill, the effects of these 2 yield components was not sufficient to offset the advantage of the greater number of stools (44 44 as against 22 222) in the closer planting distance. In the above experiment the fertilizer application was 300-150-400 of N, P$_2$O$_5$, and K$_2$O. Our data on the effect of distance of planting on cane yields show that, under low fertilizer rates, wider spacing may result in a higher tonnage because the harvestable stalks per stool are more numerous.
and heavier. On the other hand, a variety suited to narrow rows and high plant density may produce more sugar per hectare because of having a higher sugar content. Under high fertilizer rates, number of stools per unit area is more important in determining tonnage than number and weight of stalks per hill. This suggests that nutrition is an important factor in determining stalk number and weight since the fact that the experiments reported were irrigated would eliminate water as a cause of differences in yield.

In 1971, Rosario observed a positive phenotypic correlation between net carbon exchange (NCE) and number of stalks at harvest. He suggested that this might be caused by the greater tillering capacity resulting from more photosynthate, and the reduction of the effect of shading since high NCE capacity was associated with thick, narrow and erect leaves. Such a canopy would afford better light penetration, which promotes the development of late tillers. In the same experiment he observed that plants possessing narrow, thick and erect leaves exhibited rapid early vegetative growth. Visual grading of relative light interception at 4 and 6 months showed that clones with this type of leaf intercepted considerably more light.

Plant density studies in Philsugin, in which only the distance within rows was varied, showed that Philippine-bred varieties can tolerate between 30 to 50 thousand stools per hectare without differences in yield. Other studies in Philsugin showed that equidistant spacing of 50 × 50 cm (40 000 plants per hectare) and 75 × 75 cm (17 777 plants per hectare) gave yields equal to, or better than those for cane planted at 100 × 33 cm (33 333). This seems to suggest that, under our short cycle cane culture, canopies on wide interrows are inadequate at 3–5 months and that shading is excessive at 8–12 months. These are probably significant factors affecting yield but more evidence is needed to associate the canopy of thick, narrow and erect leaves with good performance under high density conditions. Until more conclusive data are obtained, varieties for high density propagation will be evaluated in narrow rows (75 × 30 cm or 44 444 plants per hectare) and with medium applications of fertilizer.

THE BREEDING PROGRAM PROPER

The sugarcane improvement program in the Philippines is divided into two distinct phases. Phase 1 is nobilisation and development of parental materials. The primary goal is to synthesise from the wide germplasm pool of the gene bank, clones that may be used in Phase 2 which is the commercial hybrid breeding program.

Among the wild types, S. spontaneum dominates our nobilisation program followed by S. robustum. Selection work on hybrids between noble canes and wild types is guided by what we know of the meiotic behavior of F1's and the first two backcross generations; the predominance of autosyndetic pairing, genetic action governing inheritance of yield and its components, and genetic correlation among yield components.

As in most countries, our selection work in the nobilisation program is hampered by lack of reliable information on the type of gene action governing important components of sugar yield. Roach 1968 observed that, in officinarum × spontaneum hybrids, heterosis is exhibited by stalk length and weight per unit area. Stooling and sucrose yield per acre were greater in the hybrids than
in the mid-parent; and stalk thickness and percentage sucrose were of mid-parental value. Although such studies give us some information on the type of gene action, there is a need for much better information based on first order statistics (generation mean analysis) where standard errors are low.4

In our nobilisation program the following populations are being developed:

N1. Recurrent selection program in S. officinarum: the aim is to develop a noble cane population of wide potential to be used in nobilising spontaneums. High sugar content, low fiber, and high tonnage (diameter and tiller number) are the bases for selection.

N2. Recurrent selection program in S. spontaneum: the objective is to develop a spontaneum population of wide potential, with desired disease resistance, habit of growth, tillering and hardiness. There is no selection for sugar content because there is no evidence of the value of genes governing sugar content in spontaneum.

N3. Recurrent selection program on commercial hybrids of known breeding value - this population is being developed also for crossing with S. spontaneum and S. robustum. We hope that this will produce parent material at a faster rate for use in Phase 2.

Design was used in mating 8 noble canes for population 1, and 10 spontaneum and commercial hybrids for populations 2 and 3. Both populations N2 and N3 have been completed and will be randomly mated for 4 generations before any form of selection. All matings were accomplished by using the hot water emasculation technique. Population N1 was not completed last year because of inadequate pollen supply. Selection progress in these populations will be evaluated for generations 0 to 4 using appropriate field tests.

Our parental development program will start this year and it involves the synthesis of:

P-1 A population of distinct commercial hybrids with high general combining ability, based on actual crossing records.

P-2 A population of commercial hybrids bred in the Philippines, to be selected on tests for general and specific combining ability.

P-3 A population that will be developed, using reciprocal full-sib selection on N3, and a nobilised population (N4).

P-4 A population that will be developed using reciprocal full-sib selection between 2 wide-potential commercial hybrids.

While P-1 and P-2 will be used to mate with genotypes developed in the nobilisation program, P-3 and P-4 are designed to test whether improvements in variety hybrids developed in successive cycles are of value. We are also planning to test the value of one cycle of inbreeding in the utilisation of P-1 and P-2. Most of these studies will be done in the College of Agriculture, University of the Philippines.

Parents for crossing in the second phase, the commercial hybrid breeding program, are chosen for their breeding value. Canes with a mediocre yielding potential are not used as parents, even if they have special characteristics such as disease resistance. Clones for crossing are at least of medium tonnage and sugar yield, and are not susceptible to more than one important disease. Hybridisation in this phase is made to effect the interplay of favorable genes governing yield components, so that it may be possible to produce progenies that surpass the parents. Populations P-1 and P-2 are an integral part of this
program. Especially with the use of computer facilities P-1 will probably be the most important population in this phase since its composition is dynamic. Since there will be no intermating in this phase, efficiency will be guided entirely by the repeatability of quantitative measurements and the control of genotype × environment effects. Because our parents are highly selected, selection pressure at this stage will not be too much of a problem. This suits our loose ecological testing system, where varieties disappear from test plots and, without undergoing certification, are propagated by planters.

This phase is composed of the following 7 stages:

Stage 1 Pollination and seedling care
Stage 2 Plan A 261 seedling plot test
Stage 3 Plan A 262 row test
Stage 4 Plan A 263 preliminary yield test
Stage 5 Plan A 264 intermediate yield test
Stage 6 Plan A 265 ecological test
Stage 7 Agronomic and commercial test.

After Stage 6, clones are released by the breeding stations and are entered in agronomic and commercial tests. After Stage 7 clones are released for propagation of certified sets which are supplied to farmers in the following year.

REFERENCES
EL PROGRAMA DE MEJORAMIENTO VARIETAL DE LA CAÑA DE AZÚCAR EN FILIPINAS: FILOSOFÍA Y ESTRATEGIA

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RESUMEN

La ocurrencia frecuente de ciclones tropicales en Filipinas, sitúa a las variedades de maduración temprana en un lugar de ventaja para las plantaciones comerciales. En tales variedades los rendimientos se maximizan si los estadios de crecimiento son bien particionados de manera que la supervivencia de tallos sea elevada. De las dos aproximaciones utilizadas para influenciar estadios de crecimiento y número porcentual de tallos sobrevivientes, la distancia de plantación parece ser la más promisoria.

Los procedimientos de selección usados en la Fase I (nobilización y desarrollo de material de progenitores) del programa de mejoramiento, involucran el uso de selección recurrente para mejoramiento intrapoblacional ó intra especie previo a la nobilización, y el uso de líneas de buena aptitud combinatoria para el desarrollo de progenitores.

El programa de mejoramiento para híbridos comerciales (Fase II), se caracteriza por el uso de líneas altamente seleccionadas como progenitores, y altas presiones de selección.