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BREEDING MAIZE IN SURINAM
Considerations and results

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SUMMARY

Maize is grown on a very limited scale in Surinam. It is thought, however, that this crop may play an important part, in the governmental schemes for the spreading of agriculture and the diversification of agricultural production. A pre-requisite for the promotion of maize growing is the availability of varieties with high yielding capacity and other desirable agronomic traits.

After considering the different possibilities of variety improvement, viz. selection in local land varieties, importation or local production of hybrids, development of synthetic varieties, an outline is given of breeding work at the Centre of Agricultural Research in Surinam (CELOS). This includes a survey of breeding objectives, selection criteria, the available breeding stock, the breeding methods applied and the results obtained.

To conclude, some reflections are given with respect to the continuation of the breeding work.

MOTIVATION

The production of maize in Surinam is very limited. It is mainly grown as a catch crop on fresh-cleared forest land and as a second crop after rice. Total acreage was about 250 ha in 1974. Generally use is made of local land varieties of unknown origin. These are very heterogeneous and have a low production capacity. Average kernel yields are at a rate of 1200 kg/ha.

Attempts to stimulate maize production by improving the yielding capacity have been undertaken repeatedly by the Suriname Agricultural Experiment Station and other governmental institutions since the early decades of this century. As early as 1930 maize varieties originating from Java were imported to Surinam and grown in observation plots in different parts of the country. Other introductions, amongst them hybrid varieties, followed, but proved far from successful since in a manual on the growing of maize (issued in 1956) it is stated that "no exotic varieties have been found so far which perform better than the local blends". From 1960 onward the experiments with maize were intensified. Particular attention was paid to hybrid varieties and synthetics with good performance in tropical areas, especially the Caribbean region and tropical America.

At the 7th Annual Meeting of the CFCS Huiswoud et al. (1969) reported that in an orientation trial comparing a number of introductions with the local variety, the hybrid variety X332A appeared to be most productive with a converted yield of 3.9 metric tons/ha versus 1.5 t/ha for the local population.

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In 1964 the Suriname Agricultural Experiment Station started an inbreeding programme with local, Central American and North American materials aiming at the development of synthetic varieties. The last were eliminated soon by *Puccinia sorghi,* but inbred lines were produced of the local (I_8) and of the Central American (I_6) material. This served as part of the starting material of the breeding work at the Centre of Agricultural Research in Surinam (CELOS), which will be discussed in the parts to follow.

CONSIDERATIONS WITH RESPECT TO BREEDING METHODS

In the early sixties the discussion was concentrated on the question in what way maize growing in Surinam could be stimulated most effectively. In theory, the following systems could be adopted:

- selection within local populations;
- introduction of open-pollinated exotic varieties or composites;
- importation of hybrid seed;
- development of local hybrids;
- development of synthetic varieties.

Arguments in favour of selection in local land varieties were the disappointing results with former introductions. Exotic open-pollinated varieties, provided they have superior yielding capacity, are attractive because they allow the farmer to produce his own sowing seed. Main attention in the discussions, however, was focused on the remaining alternatives. It was realized that the explosive gain in maize yield in the US corn belt since 1950 was greatly based on the use of hybrid varieties.

Hybrids unmistakably have many attractive features, the main of which are (i) high produtivity as a result of hybrid vigour, (ii) uniformity, which facilitates mechanical harvesting and cultivation measures, (iii) easy combination of dominant characters such as disease or pest resistances. On the other hand they also have obvious disadvantages: (i) their genetic homogeneity may limit their adaptability to widely divergent conditions of soil and climate, (ii) owing to their genetic uniformity hybrids are vulnerable to epidemics of diseases and pests, (iii) hybrid seed, as a result of its comparatively complicated breeding procedure, is expensive, and (iv) the use of hybrid seed forces farmers to buy new sowing material each season.

Especially the two last-mentioned points are a serious drawback for the introduction of hybrid varieties in developing countries with a majority of family small-holding. Development of locally adapted hybrids by governmental institutions might reduce seed prices as compared with import of foreign seed material, but it requires considerable developmental cost and the availability of a well-organized system of seed propagation and seed distribution. Under the prevailing situation in Surinam a local hybrid industry could not be recommended.

Let us turn now to the last alternative: development of synthetic varieties. Synthetic varieties are compositions of a number of genotypes with a high general combining ability. Through that synthetics combine in them hybrid vigour and genetic plasticity. Their heterogeneity (as compared to hybrids) makes them better suited to areas with changeable growing conditions, while their composition enables the farmer to save his own seed for the next crop. Therefore they may be of value in developing countries, especially those having marginal growing conditions and with an acreage too small to support a hybrid seed industry (Allard, 1960).

Based on the above considerations in 1969 a breeding programme was started at the Centre of Agricultural Research in Surinam (celos) aiming at (i) the improvement of local varieties by recurrent selection, and (ii) the development of synthetic varieties from local and exotic material.

BREEDING WORK AT CELOS.

Recurrent selection for phenotype

Introductional remarks

Recurrent selection is a cyclic process in which the number of acceptable genotypes in the breeding stock is gradually increased. In all systems of recurrent selection selfed progenies of selected plants are allowed to intercross freely in the next generation to provide genetic recombination and to avoid inbreeding depression. The most simple method of recurrent selection, viz recurrent selection for phenotype, is visualized in fig. 1.

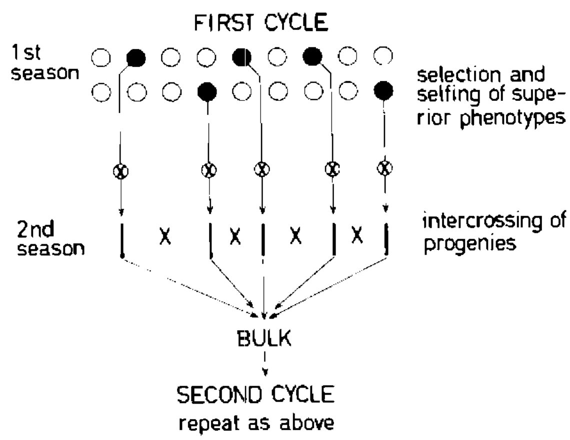

Fig. 1. Diagrammic representation of recurrent selection for phenotype

With two seasons per annum a cycle can be completed within one year. As selection occurs on the basis of the phenotype only, this method is most effective for characters with high heritability, i.e. for characters with simple inheritance and restricted genotype-environment interaction. Under some conditions, e.g. high selection intensity and an environment which maximizes the heritability, selection for quantitative characters such as yield can by this method be successful. In our breeding programme a modified phenotypic recurrent selection procedure was chosen to fulfil the above mentioned requirements.

Selection objectives and criteria.

Main objective of the breeding programme was to raise the yield of the local land race to the assumed economic minimum value of 3000 kg/ha. Since yield is affected by a large number of different components a combination of the following characters served as selection criteria:

1. *Plant characters,* including plant height, flag leaf position, firmness (stem circumference), tassel size, number of days to flowering and synchronization of male and female flowering.

2. *Ear characters,* comprising ear insertion, ear length, mid-ear circumference, ear filling and husk closing.

3. *Kernel characters,* i.a. kernel shape, kernel insertion, kernel type, kernel yield and 1000-kernel weight.

Most of the attention was devoted to the distraction of recurrent selection products from a local blend, registered as accession number 68054. In later years some other breeding stocks entered the programme.

Materials, methods and results.

The selection was initiated in 1968 with two generations of negative mass selection against strikingly off-type plants in a heterogeneous mixture of local origin. From this pre-selected breeding stock 40 superior plants were chosen in 1969. Their off-spring were selected in three successive steps on the basis of (i) synchronization of female and male flowering, (ii) plant habit and ear characteristics, and (iii) kernel characteristics respectively (troika selection). To minimize environmental variance stratified selection was applied. This means that the field was divided in a number of grids and that the best performing plants were chosen within each grid. This procedure enhances the probability of selecting the superior genotypes (Gardner, 1961).

Synchronization between silking and tasseling proved an important selection criterion. With an increase in gap between male and female flowering the percentage of seed set after selfing decreased rapidly (table 1).

Table 1. Relation between the number of days from tasseling to silking and seed set percentage after selfing in a local maize variety.

No. of days	sample	91-100%	76-90%	51-75%	26-50%	< 25%	0-5 seeds
≤ 7	58	41	23	36	–	–	–
8-9	87	25	7	36	3	17	12
10-11	132	8	6	36	9	25	16
12-13	111	2	2	17	11	24	44
≥14	102		-	2	·	13	35

Out of a total of 4000 plants some 111 passed the troika selection. Their selfed progeny was sown in bulk for propagation by random mating giving rise to the first cycle composite. Part of seed was tested for yielding capacity. As the yield equalled 4900 kg/ha (Anon., 1972a) the remainder was released as selection 68054CS1. This first all-suriname selection was tested at several locations by governmental services and private farmers with varying success. It was also adopted as the standard variety of maize in experiments executed at CELOS.

Two further selection cycles were realized in 1972 and 1973 in which closing of the husks and the angle between main stalk and ear were added to the selection criteria of the first cycle. Husk closing is correlated with resistance of the ears against borer attack, whereas outstanding ears facilitate harvesting. The second and third cycle selections were released under the names 68054CS2 and 68054CS3 respectively.

Caribbean blend. Ears of superior open-pollinated plants of a selection field comprising some hundred Caribbean composites obtained from CIMMYT, Mexico, grown in 1971, were put together and named "Caribbean blend". The bulked seed was sown on a 1500 m^2 block on heavy clay soil to test performance and yielding capacity. Despite extremely unfavourable growing conditions in the early stages, caused by water logging and soil capping, which resulted in incomplete and irregular emergence and growth retardation, the ultimate general performance was good and kernel yield amounted to about 3900 kg/ha. It was concluded that the "Caribbean blend" is a valuable source for recurrent selection, reduction of plant height and improving the uniformity of seed characteristics being the primary selection goals. However no further breeding work has been undertaken as yet.

Njoenjacobkondre population. Since all the selection work on the aforementioned material was executed under the conditions of the coastal plain, the resulting selections will be particularly adapted to the locally prevailing soil and weather conditions. This was demonstrated clearly by the comparatively poor performence and yields of the 68054CS-selections on the sandy loams of the Zanderij formation. Therefore an additional selection programme should be started in this region. Some preliminary work was done in 1972 with a grain mixture collected in Surinam's interior near the bush negro settlement Njoenjacobkondre. This was sown on a 1200 m^2 area. Selection was severely impeded by differences in crop stand which reflected the irregularities in soil conditions. To avoid the effects of environmental variability the five best performing plants of each row were selfed and harvested. Their bulked grain together with some 40 kg from open-pollinated plants of good appearance was reserved for further selection. The material, however, was lost as a result of unadequate storing.

Development of synthetic varieties.

Introductional remarks

As stated in section 2 synthetic varieties can be considered as a compromise between the favourable and disadvantageous features of hybrid varieties. On the one hand they have a certain amount of hybrid vigour, resulting in a fair yielding capacity. On the other hand they are less homogeneous which implies loss of uniformity, but increased flexibility. Synthetic varieties can be made in various ways, but I will avoid to engage in speculations about the most effective method. All synthetics have in common that they are selected on the basis of high general combining ability, in other words on the assumption that all components of the variety combine well for yield or other desirable characters. Starting from the relation developed by Sewall Wrigth:

$$\hat{F}_2 = \bar{F}_1 - \frac{\bar{F}_1 - \bar{P}}{n}$$, in which

$\hat{F}_2$ = the estimated value (e.g. yield) of the synthetic variety,
$\bar{F}_1$ = the average yield of all possible single crosses between parents,
$\bar{P}$ = the average yield of the parents, and
n = the number of parents,

it is obvious that the yield level of the synthetic can be enhanced in three different ways, viz.

– high number of parental lines,
– choice of productive parents, and
– choice of parents giving hybrid vigour in all single cross combinations.

At CELOS determination of the general combining ability was done by polycross and top-cross tests. In a polycross test each component is tested against all the other potential components of the synthetic; a top-cross is effectuated by crossing all the components under investigation with a common tester variety. Components are definitely chosen as parents in a synthetic variety, on the basis of the performance of their polycross or top-cross progenies respectively. The breeding objectives and selection criteria were similar to those formulated in foregoing sections.

Materials

Breeding stock for the synthetic variety programme consisted of the following materials:

– 16 inbreds (I_8) of local origin, and
– 82 inbreds (I_6) extracted from two Central American composites, handed over by the Surinam Agricultural Experiment Station (MA-lines),
– 104 Caribbean composites, obtained from CIMMYT (CC-lines).

Methods and results

Local inbreds

The local inbreds were pre-selected in early 1970 as to reduce the number of potential components for a synthetic variety. Considerable variation between lines was observed for mean plant height (164-214 cm), mean ear number (1.26 – 2.74) and mean kernel yield (47-76 g), the other relevant characters showing a smaller range. Synchronization between silking and tasseling was existent in nearly all lines. Finally ten inbreds were selected for participation in on polycross and two top-cross trials.

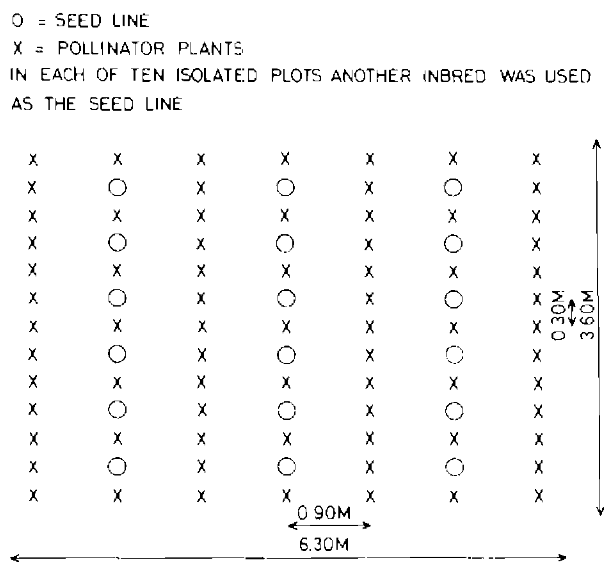

Fig. 2. Composition of a polycross trial plot

The polycross test was performed by planting each of the 10 selected lines on an isolated plot, surrounded by pollinator plants originating from a mixture of equal numbers of kernels of the nine other lines (fig. 2). The top-cross test was laid out on each of two separated locations, and consisted of alternating rows of the 10 selected inbreds and the tester variety (fig. 3). As such served the heterogeneous local land variety, 68054. At the one location the inbreds were emasculated prior to pollen shedding, at the other the line pollen was allowed to compete freely with the pollen of the tester plants. Seed lines of polycross plots and top-cross blocks were harvested separately and seed was put together per line. The bulked seed was used in a comparative yield trial, laid out in randomized blocks at two locations. Two replicates were planted on heavy clay soil at the CELOS grounds and four on a sandy loam soil at the Experimental Citrus Plantation Baboenhol, 80 km south of Paramaribo. Each block comprised 30 plots, viz. 10 progenies of each the polycross, the non-emasculated top-cross and the emasculated top-cross. Plots consisted of 7 rows of 13 plants spaced 90 x 30 cm. The two outer rows and two plants on both ends of the remaining rows served as guards, leaving 45 record plants.

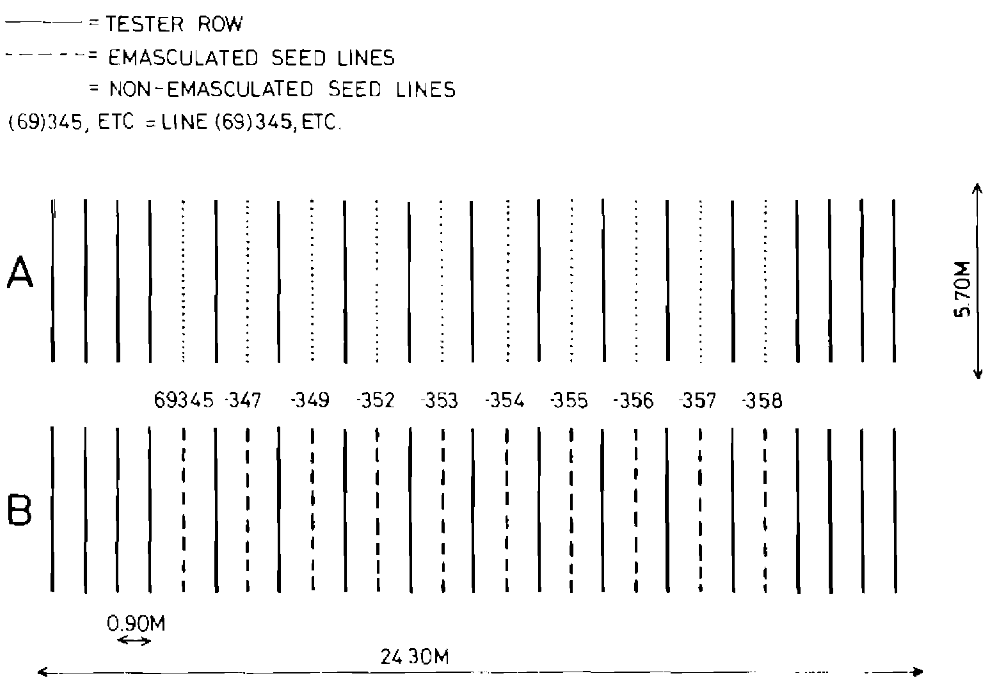

Fig. 3. Lay-out of trop-cross trial blocks. A and B distantly separated.

At the CELOS grounds emergence and growth was excellent and no conspicuous decay of the photosynthetizing organs was found until the ripening stage. Plot yields ranged from 4870 to 8420 g corresponding with 4000 to 6930 kg/ha.

As a result of low and ill-distributed precipitation and heavy borer attack, emergence and growth were poor for the blocks on sandy loam. Percentages unoccupied plant hills per plot two weeks after sowing ranged from 0 to 70. Despite filling up and large fertilizer applications emergence remained irregular and the growth was retarded. Differences in chemical composition and physical structure of the soil were held responsible for the irregularities observed. In some plots hardly any plant reached the stage of kernel-filling. Plot yields varied from 202 to 3065 g, corresponding with 170 – 2520 kg/ha. Even by elimination of the effect of the low number of harvested plants by converting the yields on the basis of 40 plants/plot, i.e. the mean value found in the clay replicates, the results remained far below those on clay soil, viz. 504-3565 g per plot or 410-2930 kg/ha.

The large differences between the results of the two trial locations made it impossible to consider them as replicates of the same experiment. At Bahoenhol both within and between block variation was so big and undirectional that there was no point in analyzing the results. Consequently the choice of lines to be used in a synthetic variety was based only on the results at the CELOS grounds. These are presented in table 2. The final selection of six lines occurred on the basis of average performances in the polycross and top-cross tests. This was done by adding up for each entry the ranking numbers in each of the three tests.

Equal proportions of the six superior lines were mixed and bulk-seeded on a 1200 m^2 block early in 1972. The open-pollinated ears were harvested in bulk and released as synthetic variety SR1.

Table 2. Average dry kernel yields (12% moisture) of polycross (P), emasculated top-cross ($\overline{T}_o$) and non-emasculated top-cross ($\overline{T}_n$) progenies and the sum of their ranking numbers (ΣR) on clay soils at CELOS (December 1971).
x = selected line.

Entry	Descent	P kg/plot	$\overline{T}_o$ kg/plot	$\overline{T}_n$ kg/plot	Average kg/plot	Average kg/ha+	ΣR
1	69345^x	8.0	7.1	7.2	7.4	6080	6.5
2	69347	6.2	6.2	6.8	6.4	5270	24
3	69349^x	7.4	7.2	7.1	7.2	5930	7
4	69352^x	6.7	6.7	6.9	6.7	5550	16
5	69353	6.4	7.0	6.8	6.7	5550	17.5
6	69354	5.9	6.6	6.6	6.4	5240	26
7	69355^x	5.8	6.9	7.4	6.7	5520	16
8	69356	6.2	6.2	6.9	6.4	5280	21.5
9	69357^x	5.3	7.1	7.2	6.5	5350	15.5
10	69358^x	6.2	7.1	6.9	6.7	5520	15

+ based on factual plot yields.

Central American lines.

The 82 I_6 lines derived from two Central American composites were planted for observation and final selection within and between lines in 1970 and 1971. Lines differed largely for plant height and number of ears per plant (table 3), but proved more uniform with respect to most ear and kernel characteristics. Ear length means varied from 9.3 to 16.3 cm, and mid-ear circumference from 9.0 to 13.4 cm (table 7). Common features were (i) orange to yellow kernel colour, (ii) regular seed insertion and ear-filling, (iii) small kernels of the flint type. After selfing and selection 41 lines (I_7) remained, which were sown in a top-cross block in alternate rows with 68054CS1 as the tester parent. Final selection between these led to the choice of 16 of them. Table 4 shows the values for some characters of the selected lines.

Table 3. Average flag leaf height and average ear number/plant for 82 Central American inbreds in two subsequent large dry periods (1970 and 1971).

Flag leaf height (cm)	No. of lines 1970	No. of lines 1971	Ears/plant	No. of lines 1970	No. of lines 1971
50 – 99	5	–	0.5 – 0.9	7	–
100 – 149	59	28	1.0 – 1.4	51	10
150 – 199	17	53	1.5 – 1.9	23	33
200 – 249	1	1	2.0 – 2.4	1	21
			2.5 – 2.9	–	13
			3.0 – 3.4	–	5

Table 4. Plant height, ear number, ear length distribution, kernel yield and general performance for 16 selected Central American inbreds (I_7). Average values based on random samples of 20 plants.
S = < 10 cm; M = 10-15 cm; L = > 15 cm
++ = very good; + = good; (+) = fair; ± = average.

Line	Av. plant height (cm) + extreme values	Ears/plant filled	Ears/plant unfilled	Ear length L	Ear length M	Ear length S	Kernel yield (g) total	Kernel yield (g) per ear	Estimation
70174-5	242 (200-290)	1.00	1.15	22	11	2	3928	112	++
70161-4	17[illegible] (110-215)	0.95	1.10	6	21	3	2179	73	+
70161-11	188 (155-215)	1.00	0.90	5	21	4	1746	58	+
70170-9	199 (170-240)	0.90	0.40	6	21	2	1485	51	+
70181-15	224 (185-245)	1.00	1.05	10	18	2	1883	63	+
70194-3,4	216 (170-255)	1.05	0.80	10	22	1	1977	60	+
70208-6,17	208 (160-270)	0.85	1.05	18	7	5	1928	64	+
70161-12	198 (165-220)	1.00	0.95	10	18	1	1997	69	(+)
70172-11	199 (175-235)	0.95	0.55	7	22	3	1874	59	(+)
70182-3, 15,17	189 (145-260)	1.10	1.10	4	22	5	1751	56	(+)
70195-5, 6,13	199 (140-250)	0.85	0.75	8	13	9	1478	49	(+)
70161-7	173 (155-205)	1.00	0.85	0	23	5	1229	44	±
70177-1, 7,15	182 (125-230)	0.90	1.05	0	13	13	949	37	+
70189-19	185 (150-220)	0.95	0.90	6	17	1	1281	53	±
70193-1, 6,10	219 (130-270)	0.85	1.45	0	27	1	1540	55	±
70210-17, 19	201 (150-250)	0.65	1.05	5	13	8	799	31	±

Eleven MA top-cross progenies were tested at the end of 1976, selection 68054CS2 serving as the control. The progenies were tested both on heavy clay (CELOS grounds) and on sandy loam (Coebiti). Each of the trials was laid out in a randomized block design with four replicates. Nett plots consisted of 6 rows of 17 plants spaced 90 x 30 cm. As the seeds had been stored already for over four years, precautions were taken to obtain a complete plant hill occupation. Depending on the germination percentage as determined on seed in petri dishes, two to five seeds per plant hill were sown and seeds of the less viable entries were pre-soaked in tap water during one day before planting. Unoccupied hills were filled up immediately after emergence.

Table 5. Average numbers of harvested plants and average dry kernel yields (12% moisture) of 11 MA top-cross progenies at different locations (March, 1977).
x = selected line. + = control.

Entry	CELOS				COEBITI		
	Descent	Plants harvested/plot	Kernel yield/ plot (kg)	kg/ha	Plants harvested/plot	Kernel yield/ plot (kg)	kg/ha
25	70174-5x	98	12.0	4300	97	10.7	3880
26	70161-4	99	10.0	3630	90	9.6	3480
27	70161-11	98	9.6	3480	81	8.9	3230
28	70170-9	80	9.4	3410	81	8.2	2980
17	70181-15x	96	10.2	3700	97	9.9	3590
18	70194-3,4x	94	11.3	4100	86	8.7	3160
19	70208-6,17x	97	10.4	3780	91	9.3	3380
20	70161-12	95	10.1	3670	96	9.6	3480
21	70172-11	93	9.9	3590	88	9.4	3410
22	68054CS2+	93	9.0	3560	-	6.3	2290
23	70195-5,6,13x	97	10.4	3780	94	10.7	3880
24	70193-1,6,10x	97	11.8	4280	87	9.2	3340

Though kernel yield was the main criterion in the top-cross progeny test, some other plant and ear characteristics which bear importance for maize growing on a practical scale were also evaluated, including early vigour, growth rate, plant height, flowering synchronization, ear number, ear size, and ear attachment. These evaluations were made on random samples of 10-20 plants per plot.

At both locations plants grew undisturbed resulting in a regular stand and comparatively high numbers of maturing plants (table 5). On clay soils dry kernel yields ranged from 9.4 to 12.0 kg/plot (3410-4360 kg/ha), of the top-cross progenies yielding more than the control (table 5). The MA-progenies were surprisingly productive at Coebiti with plot yields between 8.2 and 10.7 kg (2980-3880 kg/ha). All top-cross populations outyielded the control by far, but seed set of CS2 may have been negatively affected by mistakenly detasseling of the plants.

Though statistical analyses did not reveal significant differences between the entries, five lines were chosen as components of synthetic variety SR2 on the basis of the average performance on the two soil types. Along with dry kernel yield, plant height and seed production per ear were used as the decisive criteria.

Caribbean composites

As a result of their heterogeneous make-up, the CIMMYT composites were highly variable for all measured characters. Differences between accessions, however, were much bigger than within-composite variation. All 104 accessions were tested in two successive years, 1970 and 1971. Compared to the foregoing year, the 1971-planting performed considerably better. This became manifest mainly in plant height but also in a character as ear number, which is thought less sensitive to environmental conditions (table 6). Most stems were firm with circumference

Table 6. Average flag leaf height and average number of ears per plant for 103 Caribbean composites planted in subsequent large dry seasons (1970 and 1971).

Flag leaf height height (cm)	No. of composites		Ears/plant	No. of composites	
	1970	1971		1970	1971
100 – 149	50	10	0.0 – 0.4	3	–
150 – 199	53	20	0.5 – 0.9	33	1
200 – 249	–	62	1.0 – 1.4	59	15
250 – 299	–	11	1.5 – 1.9	8	46
			2.0 – 2.4	–	34
			2.5 – 2.9	–	7

values of 7 cm or more. Though there was also a considerable variation in ear and grain characteristics some general features can be summarized:

- ears large, thick, and well-filled,
- grain insertion often irregular,
- grains large, alabaster white or ivory, more or less dented, sometimes shrinking and/or sensitive to bolting.

As to ear length and mid-ear circumference variation appeared to be huge. Average ear length varied from 10.9 to 21.8 cm, average mid-ear circumference from 10.6 to 17.2 cm. The distribution of values for these characters is shown in table 7. For a comparison also the values

Table 7. Frequency distribution of average ear length and average mid-ear circumference for 104 Caribbean composites and 82 Central American inbreds grown in 1971.

Ear length (cm)	Caribbean composites		Central American inbreds	
	size	circumference	size	circumference
≤ 9.9	–	–	2	7
10.0-11.9	5	11	17	40
12.0-13.9	14	56	40	24
14.0-15.9	26	31	20	–
16.0-17.9	32	6	3	–
18.0-19.9	22	–	–	–
20.0-21.9	5	–	–	–

for the Central American inbreds are given.

Some hundreds of well-performing pre-selected plants were self-pollinated. After hand-harvesting the ears were scrutinized for ear and kernel characteristics. Minimum criteria for final selection were (i) ear size > 20 cm, (ii) mid-ear circumference > 14.5 cm, and (iii) see yield over 160 g. This led to the ultimate choice of 44 plants.

I_1-lines of the selected plants were sown in a top-cross block in alternate rows with tester variety 68054CS1. Very variable lines were discarded beforehand and the remaining ones were evaluated according to the selection criteria. Ultimate selection yielded 16 lines. Table 8 summarizes the values for important characters in the selections.

Table 8. Plant height, ear number, ear length distribution, kernel yield and general performance for 16 I_1 lines selected from the Caribbean composites. Average values based on random samples of 20 plants. S = < 10 cm; M = 10-15 cm; L = > 15 cm. ++ = very good; + = good = (+) = fair; ± = average.

Line	Av. plant height (cm) + extreme values	Ears/plant		Ear size			Kernel yield (g)		Estimation
		filled	unfilled	L	M	S	total	per ear	
70049-18	226 (200-250)	1.00	1.00	18	7	0	3016	121	+
70104-2	262 (220-310)	1.00	1.00	21	10	0	3053	98	+
70117-10	281 (245-335)	1.00	0.70	25	4	0	2989	103	+
70015-12	243 (210-285)	0.95	0.70	16	11	2	2951	102	(+)
70032-16	268 (180-310)	1.00	1.00	15	12	0	2186	81	(+)
70082-4	219 (165-250)	0.95	0.60	6	22	1	2573	89	(+)
70084-22	242 (205-285)	1.00	1.15	22	5	0	2761	102	(+)
70054-6	230 (200-290)	1.00	1.00	17	10	0	2741	102	±
70084-21	208 (140-235)	1.00	0.95	18	9	2	2041	70	±
70084-23	214 (155-245)	0.95	0.90	19	10	0	2521	87	±
70065-23	210 (155-250)	0.95	0.95	6	16	3	1594	64	±
70079-23	199 (140-245)	0.75	0.90	14	11	2	2173	80	±
70085-5	299 (195-270)	0.90	1.00	9	16	1	2519	97	±
70085-8	243 (205-285)	1.00	0.85	12	12	2	2526	97	±
70092-21	259 (220-290)	0.95	0.55	11	10	1	1866	85	±
70095-4	236 (215-280)	1.00	1.15	11	16	0	2343	87	±

Twelve CC top-cross progenies were tried out in completely the same way as the MA-entries except that no control variety was included. At Coebiti patches showing poor growth were observed. In these many plants died shortly after emergence or did not reach maturity. Of course, this adversely affected the mean yield per plot of the respective entries. Therefore a corrected yield was computed from which plots with less than 70 occupied hills were excluded. In spite of this correction all yields except one (entry 1) were below 2500 kg/ha (table 9).

Table 9. Average numbers of harvested plants and average dry kernel yields (12% moisture) of 12 CC top-cross progenies at different locations (March, 1977).
At Coebiti plots with less than 70 harvested plants left out of consideration (see text).
+ = corrected; x = selected line.

		CELOS			COEBITI		
Entry	Descent	Plants harvested/plot	Kernel yield/ plot (kg)	kg/ha	Plants harvested/plot	Kernel yield/ plot (kg)	kg/ha
1	70049-18^{x}	86	12.4	4500	91 +	8.3	3010
2	70104-2	81	10.3	3740	78	5.4	1960
3	70117-10^{x}	88	10.9	3960	92	6.7	2430
4	70015-12	88	9.7	3520	93	5.4	1960
5	70032-16	75	9.5	3450	82 +	5.4	1960
6	70082-4	86	10.7	3880	95 +	6.2	2250
7	70084-22^{x}	87	11.9	4320	80 +	5.2	1890
8	70054-6	68	7.7	2800	80 +	4.7	1710
9	70084-21^{x}	89	11.7	4250	91 +	5.5	2000
10	70084-23^{x}	88	11.3	4100	92 +	5.5	2000
14	70085-8	87	10.4	3780	91	5.8	2110
16	70095-4^{x}	88	11.4	4140	92 +	5.8	2110

On clay-soil plants grew well and plot yields amounted from 7.7 to 12.4 kg corresponding with 2800-4500 kg/ha. At composing a synthetic variety of CC-lines (SR3) only the results on clay soils were taken into consideration. Comparing the results of the MA and CC progeny trials it is obvious that the respective performances on clay soil are not very divergent. At Coebiti, however, CC-progenies are outclassed by far by the MA-progenies. Though this partially might be explained by differences in soil condition — the MA and CC progenies were tested at different sites of the experimental garden — it looks as if the CC-material is only suited for heavy soils, whereas a synthetic variety which is based on MA-lines can be cultivated both on clay and sandy loam soils. The different habit of MA- and CC-progenies is visualized in table 10.

Trials with the CELOS-selections.

Since their release the CELOS selections have been tried at several locations and by various potential users, including private farmers, extension officers and the Agricultural Experiment Station. Reported results, however, are scarce. The author compared performance and yield of 68054CS2 with eight tropical Pioneer hybrids in two similar experiments, one on heavy clay soil (CELOS-grounds), the other on sandy loam at Coebiti (Anon., 1973).

On clay soils the local selection flowered 10-15 days later than the hybrids and about the same delay was found with respect to ripening time.

Though CS2 had the highest number of ears, it was less productive than the hybrids because of its smaller ears and low kernel weight (table 11). However, according to Duncan's multiple range test, only the yields of X304B, X105A and X101A were significantly better than that of CS2.

Table 10. Comparison of dry kernel yields of CC and MA top-cross progenies at two locations

Entry	CC-progenies Kernel yield (t/ha) CELOS (A)	Coebiti (B)	B/A	Entry	MA-progenies Kernel yield (t/ha) CELOS (A)	Coebiti (B)	B/A
1	4.5	3.0	0.67	25	4.4	3.9	0.88
2	3.7	2.0	0.54	26	3.6	3.5	0.97
3	4.0	2.4	0.60	27	3.5	3.2	0.91
4	3.5	2.0	0.57	28	3.4	3.0	0.88
5	3.5	2.0	0.57	17	3.7	3.6	0.97
6	3.9	2.3	0.59	18	4.1	3.2	0.78
7	4.3	1.9	0.44	19	3.8	3.4	0.89
8	2.8	1.7	0.61	20	3.7	3.5	0.95
9	4.3	2.0	0.47	21	3.6	3.4	0.94
10	4.1	2.0	0.48	22	3.6	2.3	0.64
14	3.8	2.1	0.55	23	3.8	3.9	1.02
16	4.1	2.1	0.51	24	4.3	3.3	0.77
Mean	3.9	2.1	0.55		3.8	3.4	0.91

Table 11. Average values of ear number, kernel weight and kernel yield for eight hybrids and local selection 68054CS2 grown on two soil types.

Entry	Clay soil ears/plant	Clay soil 1000-grain weight (g)	Clay soil yield (kg/ha)	Sandy loam ears/plant	Sandy loam 1000-grain weight (g)	Sandy loam yield (kg/ha)	Yield ratio clay/sandy loam
X101A	1.00	277	4800	1.05	248	3175	1.52
X105A	0.97	282	4900	0.99	267	3450	1.42
X304A	0.92	299	4475	0.94	280	3300	1.35
X304B	0.99	295	5050	0.99	267	3300	1.53
X306A	0.93	290	4375	0.97	279	3175	1.38
X306B	0.91	325	4200	0.97	287	2650	1.59
X352	0.96	308	4200	1.07	303	3525	1.20
X354	0.93	285	4425	0.89	246	3275	1.35
68054CS2	1.07	274	4000	1.05	248	3050	1.31
Average	0.96	293	4500	0.99	269	3200	1.41

More detailed measurements were done at Coebiti. Again CS2 lagged behind the hybrids for flowering and maturation. In average plant height and place of ear attachment it exceeded by far the hybrid varieties (table 12). With respect to the average number of ears per plant no large differences were found. Kernel yield and grain weight were lower on sandy loam than on clay (table 11), X306B being the lowest producer followed by CS2. Yield differences, however, were less obvious than on clay; none of the hybrids appeared to be significantly superior to the local selection. This might be explained by a larger adaptive value of the synthetic. The relative flexibility of the synthetic can further be illustrated by the relative yields on clay and sandy loam (table 11). Only one hybrid (X352) was more stable than CS2 in this respect. Crude protein percentage ranged from 9.9 to 11.8, CS2 having the highest content.

Table 12. Plant height, flag leaf position and ear insertion for eight hybrids and local selection 68054CS2 grown on sandy loam.

Entry	Plant height (cm)		Ear insertion		
	total (t)	flag leaf (f)	(e) (cm)	t-f	t/e
68054CS2	233	192	118	41	2.0
X101A	202	160	71	42	2.8
X105A	212	167	72	45	2.9
X304A	199	163	74	36	2.7
X304B	204	159	73	45	2.8
X306A	203	161	72	42	2.8
X306B	199	153	66	46	3.0
X352	204	161	75	43	2.7
X354	205	157	68	48	3.0

In an experiment comparing different tillage systems at Coebiti, CS1 yielded between 2410 and 2980 kg/ha dry kernel weight (12% moisture) depending on the tillage procedure (Van der Sar, 1976).

Much lower yields were obtained for CS3 on sandy and sandy loam areas of the same experimental garden (Consen-Kaboord et al., 1975). Here dry kernel yields (15% moisture) ranged from 1420 kg/ha on sand to 2320 kg/ha on sandy loam.

Synthetic variety SR1 was tested in 1972 both at CELOS and Coebiti (Anon., 1972b). Dry kernel production amounted to 4070 kg/ha at CELOS, but on the sandy loams, despite high doses of fertilizer, only 1940 kg/ha was realized.

Local selections CS1 and CS2, the Caribbean blend (CB) and the synthetic variety SR1, propagated both at Coebiti (SR-Co) and at CELOS (SR-Ce) were tried at the experimental garden Tijgerkreek West in 1975 (Anon., 1976). The relative data are presented in table 13.

Table 13. Yield data of some maize selections and composites at Tijgerkreek West (adapted from Anon., 1976).

Selection	Ears/ plant	Ear weight (g)	Kernel yield (kg/ha)	1000-kernel weight (g)	Crude protein (%)
CS1	1.3	103	4630	299	10.7
CS2	1.2	113	4630	303	11.2
SR-Co	1.3	86	4010	275	11.5
SR-Ce	1.3	87	4100	285	11.5
CB	1.0	173	5690	383	10.1
LSD (Scheffe, 10%)			1030		0.8

The Caribbean blend yielded significantly higher than all of the Surinam selections, its protein content being lowest of all except CS1.

REFLECTIONS

Agricultural production in Surinam is rather unbalanced with paddy rice in a dominating position. For many food- and fodder crops and their derived products Surinam depends on import. Therefore diversification and increase of agricultural production are put forward as major goals of Surinam agricultural policy (Werkgroep Raamwerk Ontwikkelingsplan, 1975). In this scheme maize seems to play an important role. Maize is imported in increasing quantities to meet the local demand for poultry-feed and concentrated fodder for cattle. The value of imported maize displayed a rapid growth between 1971 and 1974 as can be seen from table 14. Large quantities of meat, mainly beaf, are imported in Surinam to a value surpassing Sf 10,- million per year. Expansion of the local beef cattle industry would require further imports of maize.

Table 14. Local production and imports of maize in 1971 and 1974 in Surinam (from: Sjauw Koen Fa, 1976a).

Year	Production		Imports		
	ha	tons	tons	price (Sf/ton)	value (Mill.Sf)
1971	126	150	10,200	147	1.5
1974	250	300	15,000	267	4.0

Sjauw Koen Fa (1976b) estimates the present amount of maize to replace today's import and to increase the local beef production at almost 20.000 tons per year.

Promotion of the cultivation of maize can only be successful if it becomes a profit-earning undertaking and an attractive alternative for other cultures, such as rice. Sjauw Koen Fa (1976b) computed that at the present level of prices and costs and a minimum living of Sf 4500,- per year, the farmer should achieve a yield of 3000 kg/ha on coastal clay soils. Though there are no exact computations on hand for the Zanderij soils, a similar minimum yield seems required for a profitable culture, partly on the basis of high demands of manure with such poor soil types.

When the maize breeding programme of CELOS was set up, an increase of the yielding capacity to an economically acceptable level was deliberately chosen for a main criterion. The selections obtained so far and the synthetic variety SR1 meet the basic requirement of a production of 3000 kg/ha, at least on maritime clay soils.

A further increase of the yield seems attainable once the synthetic varieties SR2 and SR3 have been introduced and via selection in the Caribbean blend population. Especially SR3 may offer adequate possibilities for cultivation on sandy soils. Thus the first breeding goal has been materialized.

In the second phase of the investigations one is to pay attention to the reduction of plant height (to reduce lodging) and to site and mode of ear insertion (to enable mechanical harvesting). Tolerance to abiotic factors as water logging (especially on heavy clays) or drought (mainly on sandy soils) is another major objective, just like resistance to animal parasites as *Spodoptera frugiperda* and the corn-earworm, *Heliothis zea.* Fungal diseases do not seem to play such an important part as yet, but this may come to change when the maize area is strongly increased. It is possible that under the influence of natural selection pressure the local populations have obtained a certain degree of resistance. Thus, in an experiment to compare yields on Coebiti in 1972, all hybrids were rather heavily attacked by southern corn leaf blight *(Helminthosporium maydis),* whereas the local selection 68054CS2 remained practically free from infestation.

A last breeding objective is protein content and improved protein composition. As far as the former is concerned, selection CS2 appeared to be superior when compared with a number of hybrids. Imported opaque and flury-2 varieties generally performed badly at CELOS (Consen-Kaboord, 1973). The CIMMYT composite KC2 (o_2,fl_2) and the Venezuelan variety Simeto (o_2) were the only ones to attain a yield of 3 tons/ha. They could be valuable progenitors in crossing programmes.

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