Annals of the Sri Lanka Department of Agriculture. 2001. 3: 79-86.

VARIETY DEVELOPMENT AND PRODUCTIVITY ENHANCEMENT OF HYBRID MAIZE IN SRI LANKA

K. M. KARUNARATNE
Field Crops Research & Development Institute, Maha Illuppallama

ABSTRACT

Superior genetic potential of hybrids, over open pollinated varieties, has contributed to realize yield increases over four hundred to six hundred percent in different maize growing countries in the world. A program to develop maize hybrids was initiated by the Field Crops Research and Development Institute, Maha Illuppallama in 1998, aiming to supply hybrid seed at a lower price to the farmer. Hybrid research programme of the institute concentrated mainly on development of single cross hybrids that have the highest productivity potential. Initially, hybrids were compared with open pollinated varieties. Commercial hybrid, Pacific 11, was later included for better comparison. Though the yield increments initially realized were small, better yielding hybrids could be developed when heterotic pattern of the lines was understood. More promising results were obtained from hybrids developed among quality protein maize lines and drought resistant lines. From over two hundred hybrids developed, five promising hybrids, which are superior or equal to commercial hybrid, selected for testing in variety adaptability trials.

KEYWORDS: Genetic potential, Hybrid Research, hybrid seed, lower price

INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Poaceae. Maize is believed to have originated in southern Mexico or northern Guatemala. It has a large genetic diversity with races adapted to lowland environments (<1000m), mid altitudes (1000-2000m) and highlands (>2000 masl). Maize was one of the first plant species known to photosynthesize by means of C_4 pathway, associated with high photosynthetic rates, low CO_2 compensation levels, rapid photosynthate translocation, good adaptation to high temperatures and solar radiation and high water use efficiency (Hatch and Slack, 1970; Downes, 1969). Maize is a highly cross-pollinated plant. Although a maize plant may be shedding pollen when its stigmas (silks) emerge, normally more than 97% of the seeds produced by any given plant result from pollination with pollen from other plants (Pandey, 1998). Beal (1880) advocated that open pollinated varieties could be crossed because the crosses tend to be high yielding than the parents. Shull (1909) was first to report increased yields from F_1 crosses between inbred lines. The better hybrid combinations of selected lines give substantial increases in yield over the open pollinated varieties, from which the lines are generated. Other desirable characteristics, such as strength of stalks and of roots and resistance to specific diseases and insects etc. are advantages, which some hybrids possess. Hybrids have a built-in advantage often overlooked by most laymen. It permits rapid changes in the kind of corn that may be grown. East and Hayes (1912) attributed the vigor of the F_1 to its heterozygous condition. Thus the greater the number of genes in which a plant is heterozygous, the greater is its heterosis (Jugrenheimer, 1976). The cumulative interaction of many favorable dominant or partially dominant linked vigor genes is a widely accepted theory.

In the past 40 years, total maize production in China, has increased by 623%. A survey reveals that in the yield gain, hybrid varieties generated 22.4%, fertilizer application 24%, and other techniques (cropping pattern, irrigation, insect and weed control etc.) 33.7% In 1995, 93% of maize area was planted to single crosses (Hybrid Maize in China, 1995).

Uniform growth and the ability to provide few extra grains per each ear harvested, high plant vigor resulted by increased metabolic activities and uniformity are the attributes to this growing interest in hybrid maize in farmers of Sri Lanka. However, dependence on exotic hybrid seeds has to be restricted, which are imported at very high prices. In general, the price of seeds is 15-20 times that of commercial corn, which has to be lowered from 3:1 to 4:1, as the case in China, to make it affordable to low income farmers.

In 1950s, the Department of Agriculture, Sri Lanka, attempted to develop maize hybrids (Sithamparanathan, 1958) but it did not gain grounds, because the private sector had not been developed at that time to take over hybrid seed production as seen in many maize-growing countries such as United States of America. In addition, there was no demand for such high cost seeds from the subsistence farmers who preserved their own seed requirements after each crop (Hindagala, 1980). Demonstrations organized by the private sector and the Department of Agriculture in farmers' fields to introduce hybrids with improved cultivation practices paid rich dividends, creating a new interest among farmers on hybrid maize cultivation.

Attempts to improve the yield of open-pollinated corn were mostly disappointing. While it was possible to develop many different varieties, or to change the characteristic appearance of a variety by visual selection for special features, little progress was made in raising the inherent yielding ability of a well-established variety. A field of open-pollinated corn is composed of both high- and low-yielding plants. The high-yielding plants result from favorable gene combinations; but the same favorable gene combinations are not always reproduced in the progenies of the high yielding plants since the plants are fertilized by pollen produced on both good and poor plants, all of which are highly heterozygous (Poehlman, 1959). This research programme attempted to develop hybrids of intermediate maturity, with high yield and quality, to replace exotic hybrids of which seeds are very costly.

MATERIALS AND METHODS

In 1998, a program was initiated to meet the requirement of developing hybrids locally by introducing inbred lines released by the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, and Thailand, to develop hybrid maize varieties locally. Initial program was solely dependent upon exotic inbred lines in which over 160 different hybrids were developed between them, which were evaluated for yield and other desirable grain characters. Among the parent lines, there are six lines selected for Quality Protein Maize (QPM), which contain high percentage of lysine and tryptophan and four lines selected for drought resistance. In addition, there are two lines for multiple disease resistance, four lines for developing hybrids for using as local checks and twenty-three lines for general yield. Hybrids were developed to combine these characters into their progenies. Simultaneously a program was launched to develop inbred lines locally after deliberate selection of source materials, to give rise to high heterotic progenies. High heterosis, uniformity, tolerance to stress and grain yield and quality were given attention in hybrid development. Of the 56 lines generated, first hybrids that were developed as early generation hybrids, were evaluated during *maha* 2000/2001.

During *yala* 1999, 47 single crosses that were developed for general yield and 4 other single crosses developed with drought resistant lines were tested in 7X7 simple lattice experiment and RCBD experiment respectively. The promising hybrids from these evaluations and new hybrids developed during *yala* 1999 were evaluated in 8X8 lattice trial during *maha* 1999/2000. A RCBD trial was conducted separately to evaluate hybrids that were developed with Quality Protein Maize lines. Promising hybrids selected from *maha* 99/2000 evaluations and the new hybrids developed during *maha* 99/2000 were tested in two separate 6X6 lattice experiments during *yala* 2000. A third experiment was conducted during the same season to evaluate hybrids that were developed with drought resistant lines. During *maha* 2000/2001, the twelve most consistent hybrids selected from these evaluations were tested in 5 locations covering maize growing areas and another 14 hybrids were tested in an Advanced Yield Trial at FCRDI, Maha Illuppallama.

For the initial evaluations, Bhadra and Ruwan, two open pollinated varieties were included as local checks. With the availability of hybrid varieties, Pacific 11, which is popular among maize growers in Sri Lanka, was included for better comparison. Hybrids, which were equal or better than the check variety, Pacific 11, were selected for further testing. A common fertilizer mixture of 225 kg urea, 100kg Conc. Super Phosphate and 50kg Muriate of Potash per hectare was applied in all locations and seasons tested. Nitrogen was applied as basal and with 1-2 top dressings. Seeds were planted on 60cm wide ridges 30cm apart. Fertilizer and compost were applied to the soil before seeding. Irrigation and pest and weed management were done as necessary. Grain yield, color and texture were given consideration in selecting desirable hybrids. CIMMYT guidelines were followed in recording growth parameters and evaluating the performances.

RESULTS AND DISCUSSION

From the 7X7 lattice, 14 hybrids were selected for further testing (table 1), which had almost similar maturity with the check variety Bhadra, but equal or better yielding than the open pollinated check

Table 1. Mean grain yields of most promising single crosses of maize during *yala* 1999 at FCRDI, Maha Illuppallama.

Entry	*Grain Yield ($t\ ha^{-1}$)*	*50% Flowering (days)*	*Entry*	*Grain Yield ($t\ ha^{-1}$)*	*50% Flowering (days)*
KH 31	5.44	51	KH 9	4.84	47
KH 11	5.42	52	KH 29	4.48	51
KH 7	5.29	47	KH 20	4.41	49
KH 13	5.26	51	Bhadra	4.40	50
KH 35	5.26	51	KH 8	4.33	50
KH 5	5.15	52	KH 15	4.29	51
KH 28	5.00	53	KH 6	4.22	51
KH 30	5.00	54			

Table 2 shows performance of two drought resistant hybrids that they are far superior to the local check, Bhadra. Six of them were tested during *yala* 2000, with the promising hybrids selected from *maha* 1999/2000 evaluations, in which 13 QPM hybrids were compared with 7 other hybrids and general hybrids were tested in 8X8 lattice. Out of 20 entries tested in *maha* 1999/2000 QPM Trial, 10 out-yielded two check varieties from which 8 are QPM hybrids (table 3). Grain yields of two lattice trials are given in Tables 4a and 4b. Out of 16 hybrids developed for drought resistance, tested in *yala* 2000, 9 yielded greater than check variety, Pacific 11. Consumers prefer flint types and flint-dent types too are acceptable. Dent hybrid KH 43 was selected for its high yield, as maize is mainly utilized in provender industry. All hybrids have acceptable plant heights but the ones that have ear height more that 50% of plant height considered not suitable (table 5). From the three *yala* 2000 experiments 26 promising hybrids were selected and 12 most promising were tested in 5 different locations while the rest were tested in an Advanced Yield Trial at FCRDI, Maha Illuppallama (table 6).

Table 2. Yield and yield increase of two drought resistant hybrids during *yala* 1999.

Entry	*Grain Yield* *($t\ ha^{-1}$)*	*50% Flowering* *(days)*	*Yield Gain* *(%)*
KH 42	6.65	54	150
KH 43	4.71	59	112
Bhadra	4.20	59	100
Ac # 98117 (OPV)	3.57	58	83(-)
AC # 9897	2.85	53	69(-)

LSD(0.05) = 1.85; CV(%) = 27.28

Table 3. Grain yields of Quality Protein hybrids in comparison to several general hybrids during *maha* 1999/2000.

Entry	*Grain Yield* *($t\ ha^{-1}$)*	*Entry*	*Grain Yield* *($t\ ha^{-1}$)*
KH 81	4.62	Pacific 11	3.86
KH 33	4.58	KH 115	3.82
KH 78	4.48	KH 80	3.67
KH 79	4.37	KH 78	3.61
KH 36	4.23	KH 75	3.49
KH 111	4.15	Pacific 626	3.23
KH 85	4.14	KH 76	3.15
KH 115	4.10	KH 41	3.12
KH 41	3.981	KH 90	2.69
KH 116	3.86	KH 117	1.97

GM = 3.76; LSD(0.05) =0.716; CV(%) =22.52

Table 4a. Grain yields of new single crosses of maize during *yala* 2000.

Hybrid	*Grain yield* *($t\ ha^{-1}$)* *	*Hybrid*	*Grain yield* *($t\ ha^{-1}$)* *	*Hybrid*	*Grain yield* *($t\ ha^{-1}$)* *
KH 129	2.74	KH 159	3.81	KH 128	4.09
KH 130	3.63	KH 141	3.92	KH 153	4.52
KH 131	4.23	KH 142	4.30	KH 154	3.91
KH 132	3.80	KH 143	3.94	KH 155	3.20
KH 133	3.26	KH 144	5.39	KH 156	4.96
KH 134	3.86	KH 145	4.68	KH 157	4.58
KH 135	4.64	KH 146	5.34	KH 158	4.47
KH 136	4.27	KH 147	5.01	KH 166	4.97
KH 137	4.07	Pacific 11	4.75	KH 167	4.87
KH 138	3.80	KH 149	5.54	KH 168	3.24
KH 139	3.75	KH 150	3.45	KH 169	3.67
KH 9	4.06	KH 151	4.56	KH 170	3.91

- Mean yields

Table 4b. Grain yields of promising single crosses of maize during *yala* 2000.

Hybrid	*Grain yield (t ha⁻¹)* *	*Hybrid*	*Grain yield (t ha⁻¹)* *	*Hybrid*	*Grain yield (t ha⁻¹)* *
KH 2	4.75	KH 42	3.28	KH 111	4.27
KH 97	5.17	KH 6	4.65	KH 36	5.54
KH 7	4.67	KH 116	4.07	KH 77	4.72
KH 98	4.22	KH 112	4.28	KH 79	4.93
KH 51	2.33	KH 11	4.30	KH 83	5.13
KH 100	2.80	KH 15	4.35	KH 84	4.53
KH 113	5.00	KH 109	3.54	KH 85	5.21
KH 20	3.63	KH 58	4.32	KH 87	4.74
KH 25	3.10	KH 59	4.22	KH 88	4,41
KH 56	5.60	KH 64	4.30	KH 96	5.19
KH 106	5.01	KH 23	3.08	KH 8	3.90
KH 115	4.30	KH 33	4.44	Pacific 11	3.96

Table 5. Grain yields and other growth parameters of single crosses developed with drought resistant lines during *yala* 2000.

Entry	*Grain yield, (t ha⁻¹)*	*50% flowering (days)*	*Grain type*	*Plant ht.*	*Ear. Ht.*
*KH 122**	*5.59 a*	*55*	*Flint*	*177*	*89*
*KH 120**	*5.44 ab*	*54*	*Flint*	*164*	*83*
*KH 124**	*5.42 ab*	*54*	*Flint-dent*	*164*	*82*
*KH 119**	*5.42 ab*	*58*	*Flint-dent*	*168*	*81*
*KH 125**	*5.35 abc*	*58*	*Flint*	*174*	*86*
*KH 85**	*5.17 abcd*	*53*	*Flint-dent*	*154*	*79*
*KH 117**	*5.07 abcd*	*57*	*Flint*	*165*	*79*
*KH 43**	*4.96 abcd*	*58*	*Dent*	*178*	*94*
*KH 118**	*4.80 abcd*	*56*	*Flint*	*175*	*98*
Pacific 11	*4.69 abcde*	*54*	*Dent-flint*	*167*	*89*
*KH 126**	*4.61 bcde*	*56*	*Flint*	*161*	*75*
*KH 121**	*4.61 bcde*	*54*	*Flint*	*168*	*85*
KH 123*	4.48 cde	59	Dent	169	87
KH 46	4.30 def	56	Dent	185	93
KH 45	4.01 efg	55	Dent	178	91
KH 44	3.45 fg	55	Dent-flint	175	99
KH 127*	3.21 g	54	Dent	172	73
LSD(0.05)	0.94	2.43		12.9	9.03
CV(%)	13.97	3.45		5.33	7.35
GM	3.77	55.8		170.3	86.4

Table 6. Grain yields in tons per hectare of promising hybrids tested in different locations as National Coordinated Variety Trials during *maha* 2000/2001.

Entry	*Location 1*	*Location 2*	*Location 3*	*Location 4*	*Location Mean*
KH 2	7.22	2.99	4.06	3.68	4.89
KH 97	8.65	4.33	4.16	4.13	5.02
KH 113	6.68	3.78	4.35	3.76	4.64
KH 115	6.79	5.32	4.39	3.56	5.01
KH 84	6.35	5.08	4.01	3.77	4.80
KH 86	6.89	5.98	4.57	3.69	5.28
KH 120	7.05	5.02	4.60	3.45	5.04
KH 122	6.98	5.75	4.15	4.04	5.23
KH 124	7.32	4.93	4.69	3.96	5.22
KH 87	7.82	4.93	3.99	3.30	5.01
KH 96	6.89	3.94	3.52	2.41	4.19
KH 83	7.62	3.89	4.67	3.72	4.97
Pacific 11	6.86	5.21	4.70	3.72	5.12
Ruwan	5.61	4.36	4.88	3.17	4.51
GM	4.67	4.68	4.34	3.60	4.92
LSD(0.05)	0.74	0.92	NS	NS	NS
CV(%)	20.32	29.2	11.6	20.54	12.13

Better hybrid combinations could be developed subsequently when combining ability and heterotic pattern of parent lines were understood through the evaluations of earlier hybrids. As a result, promising hybrids selected earlier were replaced with more productive combinations subsequently. Improvement in adaptation of parent lines to local environment also may have contributed to generation of better hybrids later. KH 2 is the only hybrid, which was included in early evaluations, which continued to perform consistently.

Majority of promising hybrids, which reached final stages of evaluations, are combinations of drought stress and quality protein maize lines. Both experiments conducted at FCRDI, Maha Illuppallama during *maha* 2000/2001 had to be abandoned due to damage by wild animals. They are being retested during *yala* 2001. Data of 4 other locations were considered for performances of the hybrids. They are being further tested during *yala* 2001 at 4 locations. QPM hybrids were found to be more productive than other general hybrids (*maha* 1999/2000 QPM Trial), but grain quality was poor in many due to formation of white caps. According to results (table 6), under favorable conditions, hybrids give higher yields than open pollinated varieties (Location 1), and when planted in poor soils the reverse was observed (Location 3). When performances of hybrids across environments were taken, 3 local hybrids were found to have performed better than the check variety, Pacific 11.

REFERENCES

Beal, W. J. 1880. Indian Corn. Mich. State Bd. Agr. Ann. Report. 19: 279-289.

Downes, R.W. 1969. Differences in transpiration rates between tropical and temperate grasses under controlled conditions. Planta. 88: 261-273.

East, E.M. and H. K. Hays. 1912. Heterozygosis in evolution and plant breeding. U.S. Dept. Agr. Bul. 243.

Hatch, H.D. and C.R. Slack. 1970. Photosynthetic Co_2- fixation pathways. Annual Review of Plant Physiology. 21: 141-162.

Hindagala, C. B. A. Varietal Improvement and Agronomic Studies of maize in the Dry Zone, Tropical Agriculturist. 138: 119-135

Hybrid Maize in China, a success story, 1995. FAO publication, Bangkok, Thailand

Inglettt, G. E. 1970. CORN: Culture, Processing, Products. The Avi Publishing Company. Pp 7-20

Jugendheimer, R. W. 1976. Corn Improvement, Seed Production and Uses. New York. John Wiley.

Pandey, S. and M. M. Michael, 1998. Maize Seed Industries CIMMYT Publication Pp. 32-76

Poehlman, J. M. 1959. Breeding Field Crops. Pp. 464-465

Research Reports. 1999. Field Crops Research & Development Institute, Maha Illuppallama

Shull, G.H. 1908. The composition of a field of maize. Amazon Breeders' Association Report. 5: 51-59.

Sithamparanathan, J. 1958. Improvement of highland crops in the Dry Zone, Part I – Cereals and Millets, Tropical Agriculturist. CXIV: 19-26.