
IMPROVEMENT OF HIGHLAND CROPS IN THE DRY ZONE *

Part I—Cereals and Millets

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INTRODUCTION

THE extent of the unirrigable acreage in the Dry Zone of Ceylon has been estimated at 2-2½ million acres. Broadly this land may be classified into two categories, viz., the unirrigable lowlands and the unirrigable highlands—each class comprising approximately half the total unirrigable extent. Experience gained at the Dry Zone Research Station, Maha Illuppallama, has distinctly emphasized the individuality of these two natural land classes. While the unirrigable lowlands are natural pasture lands physically unsuited for arable cropping except for rain-fed paddy, the unirrigable highlands on the other hand have been traditionally *chenaed* under a wide range of cereal, pulse, and oilseed crops.

With the development of more productive systems of agriculture, the need has arisen for improved varieties of crops with a high yield potential and capable of responding to more advanced agricultural practices. Equally important are the quality of the crops and their resistance to natural hazards of the environments such as drought, pests and diseases. The programme of work at Maha Illuppallama seeks to meet this demand for improved varieties. The impact of this programme on the agricultural productivity of the approximately one million acres of unirrigable highland in the dry zone and indirectly in the advance towards self sufficiency in food and higher standards of living can scarcely be over-emphasized.

Recent findings of soil studies at Maha Illuppallama have emphasized the importance of securing as wide a range of crops for the dry zone since it is observed that even within the unirrigable highlands, widely differing soil types occur within short distances. Since these different

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land classes are suited to different cereal, pulse, oilseed and miscellaneous crops, depending largely on their drainage tolerance and soil fertility demands, a wide range of crops is an essential pre-requisite to the development of suitable systems of rotational cropping on all the soil types comprising the unirrigable highlands. An important aspect of the crop improvement work in recent years has therefore been the extensive introduction and testing out under dry zone conditions of a very wide range of cereal, pulse and oilseed crops from similar agroclimatic zones of the world.

The crop improvement programme at Maha Illuppallama thus has two prime objectives :—

1. The search for the most promising crops for the dry zone, and
2. Breeding work directed towards improvement of yield and quality within each crop.

The present article reviews the recent progress made in these directions in respect of cereal and millet crops. The improvement in pulses, oilseed and other crops for the dry zone will be presented in a subsequent publication.

MAIZE

Maize constitutes the most important cereal crop of the dry zone chenas, next to kurrakkan (*E. coracana*). Almost all the local maizes are flint varieties. The prevalent practice of selecting seed maize for the following season within the small population of maize in each individual chena has conceivably led to steady in-breeding within the local maize varieties, particularly where a single variety is grown in a chena and the chenas are far apart. On the other hand where different varieties of maize have been grown in adjacent chenas, natural hybridisation over the years has probably obliterated all traces of the original varieties. Both conditions are known to exist locally and the indigenous maize varieties may therefore be expected to be either highly mixed or highly in-bred.

Maize is very well suited to the dry zone environment. The average rainfall and its distribution in a normal season are almost ideally suited to the growth of a three and a half month maize crop. The crop has displayed considerable adaptability to varying seasonal conditions, producing almost normal yields in both drier and wetter years. The results of recent trials at Maha Illuppallama have also confirmed the general experience in other countries, that maize responds strikingly to optimum soil management and fertilizer practices. Breeding for maximum yield and for resistance to environmental hazards has been the general objective.

The first step in such a programme is the introduction and testing of as wide and representative a range of local and foreign varieties so as to screen out the best adapted varieties on which detailed studies into their genetic relationships may be undertaken. The programme at Maha Illuppallama has so far been largely concerned with the preliminary phase.

From *maha* 1955/56 when the maize breeding programme was initiated at Maha Illuppallama until *maha* 1957/58, well over 200 varieties of maize have been introduced and tested for their suitability to the dry zone. Nearly 50 varieties collected from the villages of the North-Central Province were also included in these studies. The introductions were made mainly from the U. S. A. and Australia where large collections of maize have been established and from over 16 tropical countries in South America, Africa and South-East Asia. As would be expected the varieties exhibited wide diversity of performance under local conditions, ranging from some poorly adapted types from higher latitudes to a large group of well-adapted varieties. The preponderance within this group of varieties introduced; particularly from similar agroclimatic regions, over local varieties would appear to indicate a considerable degree of in-breeding within the local varieties, or a paucity of favourable genes in the genotype of the indigenous maizes.

If the correct explanation for the relatively poor performance of the local maizes is the occurrence of a high degree of in-breeding and homozygosity within the local types, the breeding of adapted hybrids involving genetically distinct in-bred lines derived from both local and foreign adapted varieties offers considerable promise. Inter varietal hybrids between local varieties, or local and foreign varieties, of genetically diverse character would offer considerable promise as an interim measure until double hybrids based on in-bred lines have been evolved. On the other hand, if the local varieties owe their poor performance to inherent deficiencies in a heterozygous genotype, i.e., a deficiency of favourable genes, it is apparent that high yielding hybrids for the dry zone would have to be evolved solely from inbred lines derived from adapted foreign varieties, without any participation of local maize varieties. Possibilities for interim improvement of maize yields would be in the use of the best foreign varieties and the upgrading of the local maizes by topcrossing with the most superior and genetically distinct introduced varieties. The actual cause of the poor vigour and productivity of the local maizes thus constitutes a problem fundamental to the planning of a programme of maize improvement in the dry zone.

The progress of the work carried out at Maha Illuppallama on the testing and evaluation of maize varieties may now be briefly reviewed against the above background. During *maha* 1955/56 the first yield trial with maize was set down—comprising the most promising of the 40 varieties observed for the first time during the preceding season. Several varieties, viz., *College Yellow*, *Cuban Yellow*, *Dixie 18*, *G. O. J. 4*, *Z M—T 53* and *Z M—T 96* proved distinctly superior to the standard variety, *Yellow Maize*. The yield increases ranged from just over 15 per cent., to nearly 30 per cent. in the case of *College Yellow* (an introduction from the Philippines) and *Z M—T 53* (one of the tropcrosses evolved at Katugastota). The yield trial was continued the following season, when the varieties *College Yellow* and *Z M—T 53* excelled all the other varieties included in the trial—out-yielding *Yellow Maize* by nearly 40 per cent. During this season over two hundred other varieties of maize—largely recent introductions—were also under trial. Of this number nearly 70 varieties which had been observed the previous season were included in preliminary yield trials. Ten of these varieties, comprising four Katugastota topcrosses *Z M—T 34*, *Z M—T 48*, *Z M—T 99* and *Z M—T 105*; four introduced varieties *A. 103*, *OP1*, *Improved Yellow Dent* and *Hawaiian Yellow*; and two local varieties, *Local 9* and *Negampaha 7* proved superior in yield to the standard *Yellow Maize*. These varieties were promoted into major yield trials in *maha* 1957/58, while thirty other varieties were also retained for a further preliminary yield trial prior to a final rejection of inferior types. Thirty-five new introductions tested for the first time the previous season were also selected for inclusion in a separate preliminary yield trial for *maha* 1957/58.

The *maha* of 1957/58 was characterised by unprecedented rains, where over 70 inches were received during the three months from October to December. In the first major yield trial the varieties *Z M—T 53*, *Cuban Yellow*, *College Yellow*, *Local 1*, and *Z M—T 96* recorded the highest yields while *G. O. J. 4* and *Improved Yellow Dent* also proved distinctly superior to *Yellow Maize*. *Z M—T 53*, *Cuban Yellow*, *College Yellow*, *Local 1* and *Z M—T 96* outyielded the standard variety *Yellow Maize* by nearly 50 per cent. These results are in accordance with the results of previous seasons and confirm the earlier indications that these varieties are amongst the best of the wide range of varieties tested for their suitability to the dry zone.

In the second major yield trial—comprising mainly the more promising varieties from the preliminary yield trials of the previous season—the varieties *Creole Yellow Flint* and *Hawaiian Yellow* alone outyielded the *Yellow Maize* standard. None of the other varieties which exhibited promise in the preliminary yield trials of *maha*

1956/57 outyielded the standard variety in this yield trial. Of the 30 varieties retained for final testing in a preliminary yield trial during this season, only four, viz., the introduced varieties *Njoka Flat White G. H. 188* and *Synthetic 521*, and the local variety *Negampaha 2* gave indications of a high yield potential, while four other varieties *Oklahoma 301*, *G. H. 293*, *Mannaram 2* and *Negampaha 8* also compared very favourably with *Yellow Maize*. The rest of the varieties have been excluded from further yield trials, which will be restricted to the more promising of the newer introductions.

As a result of the above work on the testing and evaluation of maize varieties, over 150 varieties of local and foreign maize have already been rigorously screened for their adaptability to the environmental conditions of the dry zone. The number of adapted varieties to be used in the further improvement of the crop by in-breeding and the development of high yielding hybrids has been reduced to a small and manageable number. Exploratory intervarietal hybridisations to assess hybrid vigour in crosses amongst these varieties, and morphological studies directed at classifying these varieties into races and thus estimating the genetic diversity amongst them, are already in progress. These studies will provide the necessary basic information for the planning of a sound programme for the maximum and most efficient utilisation of hybrid vigour and the development of high yielding hybrids for the Dry Zone of Ceylon.

SORGHUM

Sorghum appears to have been introduced into Ceylon only around 1930 but the encouraging performance of the crop in the dry zone and its unrivalled potential as a substitute cereal for rice merited for the crop a priority in importance equal to that accorded to maize. Sorghum is distinctly more drought resistant than maize and is particularly suited to the lower rainfall areas of the dry zone which are too dry for maize. The crop is also adapted to a wider range of rainfall and soil conditions than maize. Thus, although the best yields of sorghum are produced in relatively drier years, there is very little depression in yields in wetter years particularly on well drained soils. Yields have, on the average, been almost as high as those of open-pollinated maize varieties.

Apart from its desirable characteristics of high yield and resistance against environmental fluctuations, nutritional and food technological investigations have stressed the potential of sorghum as the best available substitute for rice among the highland cereals of the dry zone. The analyses conducted by Joachim and Pandittesekera (1938) on the

nutritional value of cereals and millets in Ceylon revealed that although the protein and carbohydrate contents of sorghum, maize and unpolished rice are very similar, the mineral content of sorghum grain is nearly thrice as high whilst its calorific value is the highest amongst the common cereals. The grain is far more digestible than that of maize while the flour is eminently suited for use in food preparations in the manner of rice flour. The small grain size of several lax paniced varieties has also offered attractive possibilities for the use of sorghum grain in the same fashion as cooked rice, provided certain technological problems are overcome.

While the high degree of drought resistance, considerable range of adaptability and its nutritional attributes have endowed sorghum with its high potential and possibilities as an ideal rice substitute, experience has revealed the importance of several other characteristics as essential pre-requisites in an ideal grain sorghum for the dry zone of Ceylon. Dwarfness of habit, an open lax panicle, white or pearly seeded grain, and corneous endosperm constitute the most important of these essential characteristics. The importance and desirability of the dwarf habit and laxity of the panicle are closely related to the heavy incidence of bird damage in this crop—a factor which has proved to be the most formidable obstacle impeding the popularisation and expansion of sorghum. The degree of devastation of dwarf varieties is much lower than in the taller varieties owing to the easier and more effective control of bird attack. Open lax panicles also exhibit a lesser degree of bird damage since the activities of the birds are considerably hampered in such panicles. A further advantage of laxity in the panicle is associated with the frequent occurrence of unseasonal rains during maturation of the grain since the occurrence of moulds and of germination within the panicles is retarded.

The desirability of the grain characteristics—white or pearly seededness and corneous endosperm—is associated with the role of grain sorghums as a substitute cereal for rice. Palatability of sorghum grain is closely governed by the absence of an astringent principle in the grain, and white or pearly seeded varieties exhibit almost complete freedom from this undesirable characteristic. Varieties with pigmented grain—particularly the darker pigments—are characterised by the presence of astringency. The character, corneous endosperm, is correlated with good milling quality, slower development of rancidity in storage and a distinctly lower degree of susceptibility to insect pests. Varieties possessing floury endosperm are undesirable in all these respects.

None of the earliest introductions made around 1930 possessed all the desirable characteristics of the ideal grain sorghum. In view of

the importance of sorghum as a dry zone cereal, an elaborate programme of introduction of foreign varieties was initiated in 1952. Nearly 150 varieties have since been introduced, mainly from India, S. Rhodesia, the Sudan, the Belgian Congo, Australia and the U. S. A. Although most of the introduced varieties were grain sorghums, none of the varieties within the wide range combined all the characteristics associated with the ideal grain sorghum. Two distinct groups were, however, clearly distinguishable, viz., the medium tall and tall open lax-panicled varieties characterized by small white or pearly corneous grain, and the dwarf or medium-height varieties possessing a stiff, compact or semi-compact panicle with large and generally floury grain. The lax panicle varieties possess almost all the desirable attributes of the ideal grain sorghum except the vital dwarf habit characteristic of some of the stiff panicle varieties. Substitution of the dwarf character, in the character complex of the lax panicle varieties, would be expected to produce the ideal variety and the breeding programme with sorghum is accordingly directed towards the achievement of this recombinant type.

Observational studies and subsequent yield trials carried out on the entire range of grain sorghums over the past five years have already defined the highest yielding varieties in the crop under dry zone conditions. The results have been consistent despite considerable fluctuations in the rainfall from season to season. The highest yielding varieties comprise both lax panicled and stiff panicled types, viz., C.O. 2, C.O. 3, *Sanpyaung A. S. 475*, I.P.I.—*Jowar 3*, *Fulgar White*, *Tambagala* and *Combine Black Kaffir*. The varieties C.O. 2, C.O. 3 and *Sanpyaung* are tall open lax panicled types whilst *A.S. 475* and I.P.I.—*Jowar 3* are also lax panicled varieties, but characterised by medium heights. Among the stiff semi-compact panicle types *Fulgar White*, *Tambagala* and *Combine Black Kaffir*, the latter alone is characterised by dwarf height. The breeding programme seeks to transfer by the back-cross method the genes for dwarfness present in *Combine Black Kaffir* into the genetic background of the otherwise desirable high yielding lax panicled varieties.

The important sub characters governing the differences in gross morphological structure of the panicle in sorghum are the length, degree of stiffness and the disposition of the grains on the panicle branches. Semi compact stiff panicle types like *Tambagala* and *Combine Black Kaffir* are characterised by very short, highly condensed, stiff panicle branches, bearing grain along almost their entire length. The open lax panicles varieties like C.O. 2, C.O. 3, *Sanpyaung* and *A.S. 475* are on the other hand characterised by their very long, uncondensed, slender, flexible branches. The grains are borne only on the

distal halves of the primary and secondary branches, causing top-heaviness and consequent dropping of the laterals. The latter group of varieties also possesses the desirable grain characteristics of small size and corneous endosperm in contrast to the large grain and more floury endosperm of the stiff paniced type. In the backcross programme for developing the ideal grain sorghum, therefore, five genetic correlations are of importance, viz., between plant height on one hand and length and texture of the panicle branches, and grain disposition, size and endosperm character on the other. Studies to determine these values have been initiated along with the programme of backcrosses involving *Combine Black Kaffir* as the non-recurrent parent and several lax paniced varieties *C.O. 2*, *C.O. 3*, *Sanpyaung*, *A.S. 475* and *I.P.I. Jowar 3* as recurrent parents.

Besides its importance as a grain crop, sorghum is also a potential forage crop for the dry zone. Forage varieties of sorghum constitute a distinctive group distinguishable from the true grain sorghums. They are characterised by tall, sweet, succulent stems carrying a greater density of foliage. The grain is generally pigmented, astringent and almost completely enclosed by persistent well developed glumes in contrast to the unpigmented palatable and exposed grain of the grain sorghums.

Of the large number of introduced varieties of forage sorghum tested at Maha Illuppallama, the variety *Sweet Honey* has consistently proved to be forage sorghum 'par excellence' for the dry zone. Yields of green forage have averaged as high as 15 tons per acre without fertilizers. These figures compare very favourably with the annual yields of 15—17 tons of green forage produced by *Brachiaria* pastures under fertilized conditions. The total yield from forage sorghums on fertilized soils may be expected to be considerably higher since it is general experience that the crop responds markedly, particularly to nitrogenous fertilizer.

MINOR MILLETS

Apart from maize and sorghum, several minor millets are of considerable importance as cereal grain crops in the dry zone. Finger Millet, Kurakkan or Ragi (*Eleusine coracana*) is the most widely grown cereal crop in the Maha chenas. It is particularly suited to the poorer-drained lower slopes which are too moist for maize or sorghum. Another minor millet, Meneri (*Panicum miliaceum*), constitutes the commonest cereal component of the Yala chenas of the dry zone. The extremely short duration of this crop endows it with the capacity to

mature and produce reliable yields of grain during this season. Bulrush millet or Kambu (*Pennisetum typhoideum*) is a more recent introduction offering considerable promise as a yala cereal for the dry zone.

The minor millets are in general better balanced foods than rice, sorghum or maize, by virtue of their higher protein, fat and mineral contents. The protein contents of tanahal (*Setaria italica*), Meneri and Kambu are over 50 per cent greater than that of rice, sorghum or maize. Seed storage also presents a less acute problem in the minor millets since damage from insect pests is not as severe as in sorghum or maize. Meneri is almost immune from attack, while Kurakkan, tanahal and Kambu are damaged only to a very limited extent.

Finger Millet, Kurakkan (*Eleusine coracana*) is the only minor millet of importance in the dry zone during the *maha* season. The crop is moisture loving and well adapted to the relatively high rainfall conditions that commonly prevail during this season. Tanahal and Kambu are highly drought resistant crops suited to regions of low rainfall and their relatively poor performance in the dry zone during *maha* is presumably due to excessive moisture conditions. During *maha* 1956-57 a yield trial of 12 kurakkan and tanahal varieties was set down. The results clearly demonstrated the superiority of kurakkan varieties over tanahal varieties—the increase in yield of the former being as high as nearly 40 per cent. The kurakkan varieties *Ragi* 958 and *Ragi* M-1 introduced from Madras significantly outyielded the current Departmental selection E. 43 by over 18 per cent. The trial is being continued to confirm the superiority of these varieties.

In view of the importance of kurakkan as a highland cereal in the dry zone, work on the improvement of the crop has been intensified. Besides the primary objective of increased yields, the breeding programme with kurakkan aims at improving qualitative characteristics of the crop—particularly resistance to lodging, even maturity and a loose panicle. Most of the local varieties and introduced varieties exhibit heavy lodging and uneven maturity, characteristics leading to considerable loss of seed and increased harvesting costs. A non-lodging, uniform maturing variety possessing a loose panicle structure is the objective of the kurakkan breeding programme in progress at Maha Illuppallama. The possession of a loose panicle constitutes an important characteristic owing to the frequent recurrence of unseasonable showers during maturation. The introduced higher yielding varieties *Ragi* 958 and *Ragi* M-1 possess this panicle characteristic, which is lacking in most of the indigenous varieties.

Local varieties appear to be relatively poor yielders compared to the improved Indian varieties, while genes for lodging resistance and uniform maturity are also apparently lacking in the indigenous material. A programme of introduction of varieties, particularly from India and Africa where the crop occupies a position of importance, is now in progress. Already over 10 new varieties are under observation. The identification of high yield potential, lodging resistance and uniform maturity within the wide range of local and introduced varieties now being collected, and the determination of heritability values of these and other important qualitative characteristics constitute the immediate objectives of the programme of work with this crop.

Meneri (*Panicum miliaceum*) is the most important, if not the only cereal crop grown in the dry zone *chenas* during the *yala* season. Like gingelly and perhaps green gram, it is one of the very few short-duration crops which can be sown with the first *yala* rains and mature before the soil dries out by the middle of June. Yields are very low but, nevertheless, reliable unlike in sorghum or maize which more often than not, fails completely during this season. Work on the improvement of the crop has been initiated with the collection of a representative range of varieties both locally and from abroad. An earlier-maturing higher-yielding variety is the objective of the breeding programme with this very nutritious *yala* cereal.

The possibility of growing crops of Bulrush or Pearl Millet (*Pennisetum typhoideum*) and photoperiod-insensitive, short-duration varieties of sorghum and maize during the *yala* season is presently under investigation. Considerably higher yields of grain may be expected if a suitable variety in these crops can replace Meneri during the short *yala* season.

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