TOWARDS THE IMPROVEMENT OF MAIZE IN NIGERIA

C. L. M. VAN EIJNATTEN

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(MET EEN SAMENVATTING)

PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD
VAN DOCTOR IN DE LANDBOUWKUNDE
OP GEZAG VAN DE RECTOR MAGNIFICUS IR. W. F. EIJSVOOGEL,
HOOGLERAAR IN DE HYDRAULICA, DE BEVLOEIING,
DE WEG- EN WATERBOUWKUNDE EN DE BOSBOUWARCHITECTUUR,
TE VERDEDIGEN TEGEN DE BEDENKINGEN
VAN EEN COMMISSIE UIT DE SENAAT
VAN DE LANDBOUWHOGESCHOOL TE WAGENINGEN
OP WOENSDAG 19 MEI 1965 TE 16 UUR

DOOR

C. L. M. VAN EIJNATTEN

H. VEENMAN & ZONEN N.V. – WAGENINGEN – 1965

STELLINGEN

I

De relatief hoge investeringen in speciale projecten als de ontwikkeling van geïrrigeerde tarweverbouw en 'farmsettlements' gaan ten koste van de mogelijke ontwikkeling van het overgrote deel van de landbouwbevolking. Dit verergert de situatie, ontstaan door de lage totale investering in landbouw-objecten, voorzien in de ontwikkelingsplannen van Nigeria.

Federation of Nigeria (1962); National Development Plans *1962–1968*; Lagos, Federal Ministry of Economic Development.

II

Het gebruik van het 'brachytic-2' gen ter verkorting van de maisstengel met behoud van een groot bladoppervlak per plant kan van belang zijn voor de veredeling van de mais in Nigeria.

III

Dat een uitzonderlijk hoog percentage van natuurlijke zelfbestuiving zou voorkomen in de lokale maisrassen van Dahomey, is aanvechtbaar.

J. Le Conte (1952); Centre de Recherches Agronomiques, Bingerville, Bull. No. 6: 84–86.

IV

De aantasting van opgeslagen maisgraan door verschillende kevers moet in Nigeria reeds voor de oogst van het produkt worden bestreden. Hierbij moet in de eerste plaats worden gezocht naar het tijdstip, waarop *Sitophilus zea-mais* Mots. de kolf aantast, en naar de manier, waarop dit insekt wordt aangetrokken door de maisplant.

M. A. Cornes (1964); Annual report 1963; Lagos, Nigerian Stored Products Research Institute.
Anonymus (1964); Annual report 1963/64; Ibadan, Ministry of Agriculture and Natural Resources.

V

De resistentie tegen lindaan en dieldrin in verschillende voor cacao schadelijke insektensoorten, behorend tot de familie der *Miridae (Hemiptera)*, illustreert de noodzaak om te streven naar een beheersing van deze plagen door de veredeling op resistentie van de cacaoboom.

A. F. Posnette (1943); Bull. Ent. Res. **34**: 159–162.
J. N. Telford (1964); Proceedings of the conference on mirids and other pests of cocoa, West African Cocoa Research Institute, Moor Plantation, Ibadan (p. 24–27).

Proefschrift: Van Eijnatten
Wageningen, mei 1965.

VI

Dat bewortelde stekken van kola van geen belang zouden zijn voor de toekomstige ontwikkeling van dit gewas, is onjuist.

M. BODARD (1962); Annales de la Faculté des Sciences, Université de Dakar, tome 7 (p. 76).

VII

De veronderstelling, dat de deelvruchten van de meervoudige kokervrucht van *Cola nitida* (Vent.) A. Chev. langs de rugnaad opensplijten, is onjuist.

M. BODARD (1962); Annales de la Faculté des Sciences, Université de Dakar, tome 7 (p. 72).

VIII

De veredeling van verscheidene ingevoerde vruchtboomgewassen, die geaccepteerd worden in het Nigeriaanse dieet, zou op het ogenblik veeleer moeten worden gebaseerd op de selectie in beschikbaar zaailing-materiaal dan op de invoer van bestaande cultuurvariëteiten.

IX

De oprichting van een orgaan, dat de produktie van zaaizaad voor de verschillende gewassen organiseert en controleert, is van groot belang voor de ontwikkeling van de Nigeriaanse land- en tuinbouw.

VOORWOORD

Gaarne wil ik na de voltooiing van dit proefschrift mijn dank betuigen ten aanzien van hen, die mij ertoe hebben voorbereid om een zo veelzijdig probleem te kunnen aangrijpen. Aan u, Hooggeleerde Wellensiek, Hooggeachte Promotor, heb ik vooral te danken, dat ik leerde inzien, hoe een methodische benadering van gestelde problemen de beste basis legt voor toekomstige oplossingen. Dat gehanteerde informatie en aangewende begrippen terdege op hun betekenis, geldigheid en belang dienen te worden getoetst, is een tweede facet van wetenschappelijk denken, dat u mij duidelijk maakte. Ik beschouw het als een voorrecht om onder uw leiding mijn studie aan de Landbouwhogeschool te hebben mogen voltooien.

Ik ben ook zeer erkentelijk voor het enthousiasme waarmede u, Hooggeleerde De Wilde en Hooggeleerde Oort, uw leerlingen inleidt tot de plantenziektenkunde. Ik dank u beiden voor de opleiding, die ik van u heb gekregen. Ook anderen, die aan mijn vorming hebben meegewerkt, betuig ik mijn waardering hiervoor.

Ik wil hier ook mijn erkentelijkheid laten blijken aan Ir. H. J. M. Steenbergen, die mij aanspoorde om een landbouwkundige loopbaan te kiezen.

Gedurende mijn verblijf in Nigeria hebben velen meegewerkt aan het slagen van mijn onderzoek. Op de allereerste plaats gaat mijn dank uit naar Dr. W. R. Stanton, die mij gedurende het eerste jaar inleidde in de problemen, die een maisveredelaar in Nigeria te wachten stonden. Ik heb zijn sympathieke bijstand steeds hoog gewaardeerd.

Veel gebruik heb ik gemaakt van de outillage van het Nigeriaanse Federale Departement van Landbouwkundig Onderzoek in Moor Plantation, Ibadan, dat grotendeels zijn vorm had gekregen onder de leiding van Dr. J. M. Waterston. Ik dank hem hiervoor. Ik kan niet de namen van de vele stafleden van dit departement opnoemen, behoudens van enigen, die mij bijzonder behulpzaam zijn geweest. Mijn erkentelijkheid betuig ik aan de heren J. Iferi, N. N. Okparanta, A. A. Ononokponu en T. A. Udom, die mij op het veld en in het laboratorium onverdroten op duizenderlei manieren behulpzaam zijn geweest. Ik dank ook Miss N. Shinie, die het manuscript corrigeerde.

Ook mijn administratieve medewerkers, die ik niet allen met name vermelden kan, zijn mij buitengewoon behulpzaam geweest door mij veel werk uit handen te nemen, waardoor ik meer tijd vrij kreeg om te besteden aan mijn veredelingswerk.

Tenslotte ben ik uitermate dank verschuldigd aan mijn ouders, die mij in woord en daad voor ogen hielden, dat slechts toegewijde arbeid resultaat afwerpt, en aan mijn lieve vrouw, die vol geduld haar onmisbare medewerking verleende op het buitenwetenschappelijke vlak.

LIST OF CONTENTS

1. INTRODUCTION

1.1. THE INITIATION OF RESEARCH ON MAIZE IN NIGERIA

Maize has been cultivated in Nigeria for several centuries. It had the character of a subsistance crop. Initial agricultural research work in Nigeria was directed to promote the development of various cash crops for export purposes (oil-palm, cocoa, cotton, groundnut) and the food crops were to a large extent neglected until the years after the second world war. The fast social and economic development of Nigeria caused great attention to be given to the internal food supply. In the years shortly before 1950 maize, amongst other crops, commenced to be studied. Soon afterwards, however, research work on maize has had to be extended considerably.

1.1.1. *The circumstances*

The advent of a very destructive rust disease, which entered West Africa in 1950, opened the eyes for the importance of maize as a food crop by an initial total failure and in later years severe reductions in yield of the maize crop. The ensuing panic during the first few years after the occurrence of the rust has now subsided and rash measures of introducing new maize materials for immediate release to farmers have now been replaced by an organised approach towards a systematic study of the crop in Nigeria. A salient point is that the lack of interest in former years was not substantiated on basis of a good performance of the local varieties prior to the outbreak of the rust disease. Experimentation with introduced varieties has shown, that the West African maize materials had a far lower yielding performance than many of the new materials.

1.1.2. *The environment*

Nigeria has a wide range of ecological conditions, varying from high rainfall forest areas in the south eastern part of the country, where a short relatively dry period occurs, to low rainfall savannah areas with a severe dry season, which may extend to seven months, and is characterised by the occurrence of a desiccating desert wind, the 'harmattan'.

The map of Nigeria in figure 1 will aid in locating various provinces and towns, which may be mentioned here or later in the various discussions.

The largest part of Eastern Nigeria, situated east of the river Niger (below its confluence with the Benue), is located in a relatively wet forest zone with a rainfall higher than 60 inches. This ecological zone extends westwards across the Niger to cover Benin and Warri provinces and also the southern part of Ondo province. Most of the remaining part of Western Nigeria is situated in the drier rainforest area, with a rainfall of 45 to 60 inches. Whilst in the wet forest zone the rains usually are continuous all through the rainy season, in the drier rainforest, ecologically characterised by the occurrence of deciduous forest-tree species, the rainy season is commonly broken into two parts. The first part (the early rains) lasts from the end of March to the end of July and is followed by a

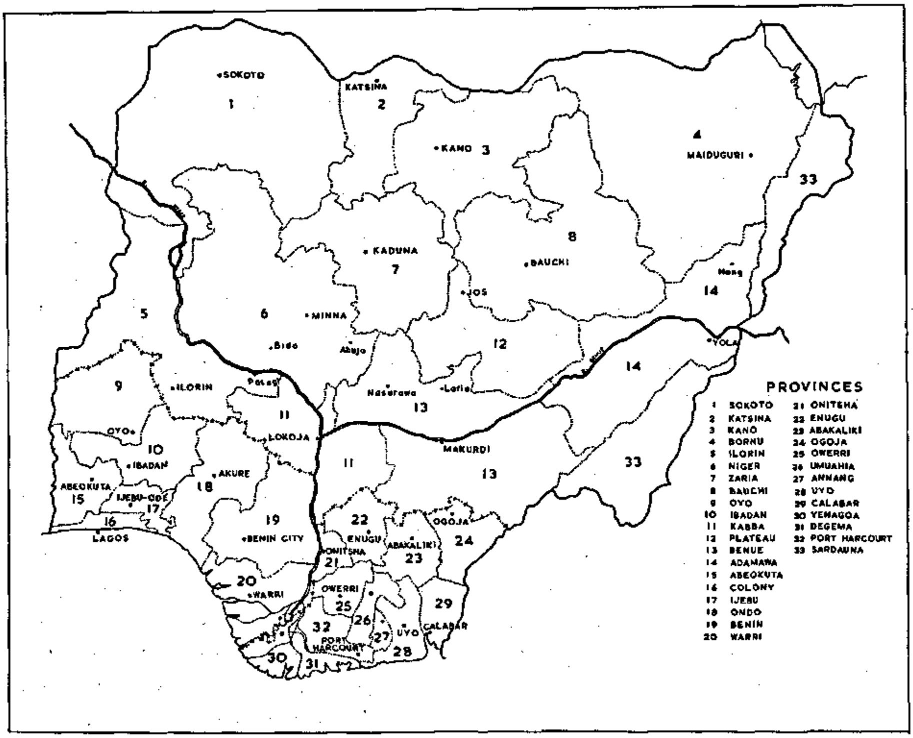


FIGURE 1. Map of Nigeria, indicating the location of the main towns and the provincial boundaries.

short dry spell of some three to four weeks. The second part (the late rains) starts at the end of August and may last untill the end of October or the middle of November. Further to the north, in the savannah areas, the two periods tend to merge into one, but short, rainy season. For more detailed information on the ecological conditions obtaining in Nigeria, reference could be made amongst others to KEAY (70) and BUCHANAN and PUGH (17).

1.2. AVAILABLE INFORMATION

The factual contents of information relevant to the purpose of this study will be given in the discussions presented under the various chapter headings. However, it seems to be opportune to account at this place for the method in which the available information has been collated to form, with own observations, the basis for a maize breeding program, which had to be initiated to cover the needs of Nigeria's people.

Statistics on the trade and the production of the crop were available in various governmental publications. These data have been compiled in chapter 2 in order to provide for an assessment of the value and the importance of the maize crop.

How the maize crop fits into Nigeria's farming systems has been discussed in chapter 3. Some information on Western Nigeria was available from a survey of the economy of the cocoa producing areas of this region. These coincide with the location of part of the main maize producing area. As very little was known on the maize in Eastern Nigeria and virtually nothing on its role in Northern Nigeria, most attention was given to these areas, and data for Western Nigeria were obtained from the above mentioned cocoa survey (54). These studies necessitated journeys through practically the whole of Nigeria and provided also an opportunity to collect information on the utilisation of the maize in various food preparations. This chapter 3 concludes then with a few thoughts on the composition of the maize grain, mainly taken from existing information elsewhere, and with a study of consumer preferences, carried out at Ibadan, Nigeria.

Considerations on characteristics of local maize varieties and on the possibilities of newly introduced varieties form the subject of the fourth chapter. This is followed by a discussion of the growth and development of the maize plant and its produce in Nigeria (chapter 5).

Much of the contents of the next two chapters on insectpests and on diseases respectively, consists of critical reviews of literature containing information on these subjects. Pests and diseases play such an important role in the success or the failure of the crop, that a thorough knowledge of these problems was considered necessary before plans for a balanced breeding project could be drawn up.

With the aid of information related in earlier chapters the goals of maize breeding projects in Nigeria are outlined in the eighth chapter. The first steps towards the realisation of these aims ensue. Some problems encountered in the production and distribution of seed of recommended maize varieties are discussed in chapter 9.

1.3. THE PURPOSE OF THIS STUDY

In the foregoing section I showed the outline of this study. From the breeder's point of view many aspects of the maize crop, its utilisation and its cultivation are to be considered with the purpose to provide a firm base for the improvement of the maize crop in Nigeria. This study intends to lay this foundation and to provide the initial outlines of the realisation of the aims, ensuing from it.

2. STATISTICS ON TRADE AND PRODUCTION OF MAIZE

The role which maize plays in the economy of Nigeria can be partially understood by placing available figures on the production or the value of this crop in the context of data on other staple foods and cash crops produced in this country and on other sources of income. The value of the output of all production factors located in Nigeria is defined as the national income and was valued at £680 million in 1955 and £812 million in 1957. Over 50 per cent of this amount was contributed by agriculture. Farm crops were valued at £305 million or 45 per cent of the national income in 1955. The Nigerian peasants produced virtually all the food consumed in the country as well as 90 per cent of the exports (6, 34).

2.1. The monetary value of the crop

The value of the main staple foods was estimated at £250 million in 1950/51, of which the rootcrops (cassava, yams and cocoyams) represented approximately £170 million. The remainder of £80 million is the collective value of the cereal staple foods, that is guinea corn, millet, rice and maize (105). The relative importance of these cereals can be judged from the estimates of their value:

Guineacorn	: £26 million
Millet	: £24 million
Maize	: £14 million
Rice	: £14 million

In 1952 to 1953 the value of the maize crop was estimated at £12.8 million, divided into £3.9 million, £3.2 million and £5.7 million respectively for Northern, Eastern and Western Nigeria. The higher figure for Western Nigeria is partly due to the fact that two crops of maize can be taken in the dry rainforest and derived savannah areas and to the higher yields per acre obtainable in this area, the 'maize belt' of Nigeria. We hope to indicate that this picture could change since the production of maize in the riverain provinces is likely to increase. North of the rivers Niger and Benue agricultural production has increased considerably since 1945 (34). With the increasing transport facilities, the farmers will no doubt intensify the production also of the maize graincrop for export to southern areas.

2.2. The area cultivated with maize

Twenty-two per cent of Nigeria's territory has been reported to be used as arable land, that is 82,000 square miles. Less than half of this (31,000 square miles) was actually under crops in 1950. This area is equivalent to almost 20 million acres. Six million acres are cultivated for the production of root crops, mainly cassava and yams, and ten million acres for grain crops. Guineacorn and millet cover most of this. Rice takes approximately 0.4 million acres and the maize crop covers 1.4 million acres. These statistics were obtained from data collected for the world census of agriculture in 1950 and are only a first approach to estimating acreages and production for food crops grown mainly for local consumption (111). They do however give an idea of the relative importance of various crops.

2.3. Quantities of maize produced

Further figures relate to the production of grains expressed in tons. For Nigeria as a whole the production of maize was estimated at 585,000 tons. To relate these figures to data made available by the Food and Agriculture Organisation of the United Nations, at Rome, it may be mentioned that the world production of maize grain amounts to 137 million tons, of which 9 million tons are produced in Africa. The major part of this is produced in East and South Africa (140). The 1950 figure for the production of maize grain should also be compared with the quantity of other cereals harvested in Nigeria. The relevant figures are as follows:

Guineacorn	1,749,000 tons
Millet	945,000 tons
Rice	244,000 tons

Maize takes therefore the third place amongst Nigeria's cereals if the whole country is considered. In Eastern and Western Nigeria it is however the main grain crop cultivated, and accounts for 90 per cent or more of the cereals consumed.

In Western Nigeria, approximately one third of the 220,000 tons of maize produced, is grown as a sole crop. The remaining two thirds is interplanted with other crops. One quarter of the early crop and more than half the late crop, which comprises only approximately 20 per cent of the production, are obtained as sole crops. Eighty thousand tons of maize are produced in Ibadan province, followed by Oyo and Ondo provinces, with forty thousand tons each. Maize takes 20 to 27 per cent of the arable land under cultivation in this region (54, 111).

In Eastern Nigeria, only 8.8 per cent of the arable land is devoted to the maize crop, most of which is interplanted. In 1950/51 the equivalent of 198,000 tons of maize grain was produced. In the same year a production of 149,000 tons of maize grain was recorded for Northern Nigeria, much of which is produced as an intercrop in compounds, along riverbanks and on fadamas. The acreage was estimated at 354,000 acres or three per cent of the arable land under cultivation, most of which is situated in the riverain provinces. Later estimates of the maize acreage and production in Northern Nigeria in 1957/58 show a remarkable increase. The figures are respectively: an area of 871,000 acres and a production of 319,000 tons of grain (1). Similar estimates for Western Nigeria were more or less in agreement with the 1950/51 figures and do not show an increase.

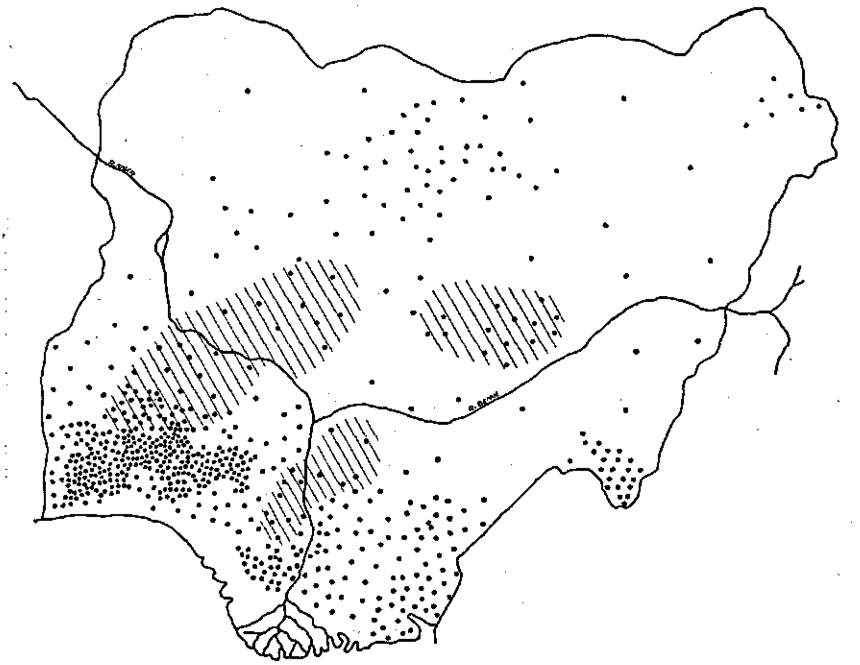


FIGURE 2. Distribution of the production of maize in Nigeria in 1950. Each dot represents 1.000 tons of grain produced.

The estimates made for the agricultural sample census 1950/51 on the basis of the provinces and of various agricultural zones, recognized for this purpose in Nigeria, have been combined into a map giving the distribution of the production of maize over the country. Some corrections were made by extrapolating the apparent distribution for the provinces of Oyo and Owerri, for which areas no data were available. See figure 2.

From this map it can be seen that much of the maize crop is produced in Eastern and Western Nigeria, with the majority in the drier parts of Western Nigeria. But it is also apparent that the maize crop is utilised throughout the whole country. Later figures, as mentioned earlier, indicate that the production in the Middle Belt area is considerably on the increase.

2.4. INTERNAL TRADE

The paucity of data makes it very difficult to obtain an accurate view of the importance of the existing internal trade in maize. Areas where surplusses are available for sale outside the production area are indicated as hatched areas in figure 2 (89, 105). It will be noticed that in the main maize belt the production is consumed locally; many large towns are situated in this area.

All surplus areas lie outside the maize-belt of Western Nigeria, mainly in the riverain provinces, from where maize is now regularly sent southwards (34). In

1950/51 it was still reckoned that the surplusses from the western part of the Middle Belt mainly went to the Jos plateau and to Kano province. From the eastern half of the Middle Belt an important trade exists into Eastern Nigeria and also to the Jos plateau (34, 105). Apart from being the yam barn of this country the Middle Belt appears to be rapidly becoming also the granary for supply of maize to densely populated areas in Eastern Nigeria and the large towns in the west, and for other grains (guineacorn, millet) to the north.

2.5. External trade

The white floury maize type common in southern Nigeria, was once highly priced on Europe's markets. In the early part of this century exports amounted to 21,000 tons. This export trade did not however survive due to the high incidence of insect pests and the lack of proper drying facilities at the source of production (40). Some export of maize from Nigeria has always existed to other parts of West Africa. Between 1949 and 1959 the value of the annual export of maize varied from £203 to £5,733, with two exceptional years of £35,000 in 1950 and 1951, when there was an enormous demand for maize along the west coast of Africa, due to maize shortages caused by the American maize rust.

Imports of maize seemed to be steadily rising from 0.2 ton in 1951 to 26 tons in 1959. This maize originated from South Africa and the United States of America. Most of it is very highly priced sweetcorn and popcorn, which is imported here for approximately £100 per ton. This quantity is of course negligible compared with the Nigerian production of other types of maize. However, the expensive sweetcorn and popcorn can also easily be produced locally, provided the correct varieties are chosen. With the increasing production of maize in Nigeria's Middle Belt, future development of an export trade might well be possible. In this connection we might refer to the considerable exports of maize grain from countries such as Congo and Angola, amounting to 20,000 tons and 25,000 tons respectively, annually. At a world market price of £20 per ton this would amount to £400,000 or £500,000 (67).

2.6. Conclusion

In this chapter the traditional production area of maize in southern Nigeria was pointed out and also the development of a secondary area of production in the riverain provinces. With the present position of an adequate food-supply in most of Northern Nigeria, apart from the periodical 'hungry gap' before the harvest of the main cereals, the fast increasing production of maize in the Middle Belt should rapidly assist in counteracting the shortage of calories reported in southern areas (34). The prospects are that Nigeria does not need to import any type of maize whatsoever, on the contrary the country may well develop into a maize-exporting country.

3. THE PLACE OF MAIZE IN NIGERIA'S FARMING SYSTEMS. FOOD PREPARATIONS AND SOME DIETETIC OBSERVATIONS

3.1. THE CULTIVATION OF THE MAIZE CROP

The cultivation of the maize crop in Nigeria is performed in various ways according to the environment and customs of the people concerned. It would be impossible to summarize in just a few words, how and to what extent maize is grown. In this chapter I intend to lead the reader through various areas, where maize is raised, and to describe the local cultivation practices. Some information will be added here and there on the acreage of the crop and any other particulars which may be of interest for an understanding of the place of this crop in farming systems. Much of the information given has been compiled during visits to the areas during the past seven years.

The journey will lead us from Western Nigeria into Eastern Nigeria, thence into the riverain provinces of Northern Nigeria, also indicated as the Middle Belt, and this will be followed by a brief review of maize cultivation in the northern provinces of this large region. A topographical map has been given earlier, in figure 1.

3.1.1. *Western Nigeria*

(GALLETTI, BALDWIN, DINA; 54).

Although Nigeria's maize belt lies west of the Niger and the crop finds a ready market in this area, maize does not rank with cassava or yams in production. Nevertheless it plays an important role in the diet and periodically becomes the main staple food. The cultivation of the crop is wide-spread. Anywhere in Western Nigeria maize is grown, although its cultivation is most intensive in the drier parts of the rain forest and the derived savannah zone bordering the forest to the north.

GALLETTI et alii (54) estimated that a fifth of the farm land dedicated to food crops, was utilised for the production of maize in Western Nigeria. Three times as much was utilised for the root crops, cassava and yam. An early maize crop is usually planted during the first weeks of the rainy season, from the end of March to half April, to be harvested from June onwards. The harvest begins with the collection of immature ears which fetch a high price initially, but this price soon drops, as the supply increases fast. The major part of the crop is however harvested as dry grain. A second crop is sown at the end of August or the beginning of September and is harvested from November onwards.

Recognisable rotations appear to be rare and many different crop sequence patterns can be found even in the same locality. During the first year after a fallow period the combination of yams interplanted with an early and a late maize crop in succession is a common one. However very often one can observe maize being cultivated as a sole crop on newly cleared land. The first year may be followed with a second year, during which yams and maize are cultivated.

During the second and third year of the rotation maize is grown often as a sole crop. The rotation is usually terminated with cassava, which in several densely populated areas, tends to take over the function of a 'fallow crop' and it may then be left in the ground for one and a half year or longer.

Also other patterns were recorded, for instance a continuous alternation of maize with cassava. An interesting cultivation pattern exists in the area west of Abeokuta where the maize and upland rice crops alternate, until the decline in yields points to the need for fallowing the farm lands.

3.1.2. *Eastern Nigeria*

In general the farmers in Eastern Nigeria cultivate only one crop of maize, in spite of the long-lasting rainy season. In much of this area a second crop seems impossible because of stemborers. Lower fertility levels of the soil during the later part of the rainy season might play an important role in this high rainfall area. The maize is generally planted in March or early April. Only in Port Harcourt province apparently two crops are raised, planted in January, February or March and July to September respectively (96).

Sole cropping is seldom practiced; the great majority of the maize crop is grown as a secondary crop between the root crops, yams, cocoyams and cassava. The yams are planted before the maize. If cocoyams or cassava are the main crops, the maize is sown long before these are planted and is harvested before the rootcrops make any real growth. In fields planted to yams the stands of up to five or six maize plants are spaced quite far apart, often at eight feet. When interplanted between cassava the stands are at a closer spacing of approximately five feet.

In the oil palm areas around Abak it is still the practice to intercrop maize in the groves of oil palms. This affects the yield procured from both the subsidiary crop and the oil palms. Already some forty years ago it was shown that extremely low yields only could be obtained from maize crops cultivated under oil palms (40).

Although sole cropping is seldom practised in Eastern Nigeria, maize is grown by almost all farmers to quite a large extent around the compounds and on the farms. The root crops are by far the main source of calories in the diets of the people, but maize takes the next place. A large percentage of the crop, estimated at more than fifty per cent, appears to be consumed as boiled or roasted ears, harvested prematurely. It is especially during the harvest of premature ears, that maize plays a very important role in the diet. This is long before the plant has been able to produce calories to its capacity.

The remainder of the crop is harvested as dry grain and is consumed in many different ways. In addition to the dry grain produced in Eastern Nigeria a considerable quantity is brought to the Onitsha and Enugu markets from the Asaba area in Western Nigeria across the Niger, and from the Middle Belt areas north of Eastern Nigeria, especially from Igala division in Kabba province.

3.1.3. *Northern Nigeria*

The riverain provinces of Northern Nigeria stretch from west to east along part of the upper reaches of the river Niger and along the Benue. They border the southern rainforest areas and show a transition towards the savannah grasslands of the northern guinea zone. The area is also designated as Nigeria's Middle Belt. It is in this area that maize is of importance, although towards the north it is gradually replaced by the savannah cereals, guineacorn and millet. As pointed out earlier, parts of the Middle Belt have much promise for the maize crop and a rather detailed account will therefore be given of the place taken at present by the maize crop.

3.1.3.1. The riverain provinces

a. South of the Niger

The north-western part of Ilorin province lies in the northern guinea savannah. Guineacorn is here the main grain crop, but in the south-western corner the cultivation of maize is quite important. The grain crops take second place in the rotation, often with the maize as an intercrop between the guineacorn. They are preceded by yams, which are occasionally in turn preceded by a sole crop of maize. The maize and guineacorn are usually planted at the sides of yam heaps, which are widely spaced (five by four feet). The south-eastern part of the province lies partly in the derived savannah area, in which remnants of forest become more and more frequent towards the south. These merge into the forest zone at places along the border with Western Nigeria. The grain crops, often mixed guineacorn and maize, take the first place in the rotation after the fields have been cleared during the dry season. They are followed by a yam crop, often interplanted with cowpeas and late maize.

The major part of the maize crop in Ilorin province is consumed as dry grain preparations, although the 'green maize' plays quite an important role during the time of its availability.

The same picture is continued in the north-western part of Kabba province but changes towards the south-west, in Igbirra division. The main part of this area lies in the derived savannah zone. Maize is often cultivated every year on or around the compounds and on upland farms, with a preference for areas of higher than normal fertility. It appears only in the first years of the rotation, which vary from three to five years of cropping, alternating with five to ten years of fallow. During the first year the farms are often planted to cowpeas or maize followed by guineacorn or this last crop on its own. In the second year yams are cultivated, interplanted with maize.

The maize cultivated on the compounds in Igbirra division is usually consumed as 'green maize', but most of the farm-crop is harvested dry. In the southern part of this division maize plays an important part in the diet: up to thirty per cent of the starch consumed. To the north it is gradually replaced by guineacorn and root crops.

b. South of the Benue

The Niger bisects the main part of Kabba Province. On the eastern bank Igala division is situated mainly in the derived savannah zone and is intersected by many forest outlayers along permanent streams. This relic forest increases towards the south. Maize is cultivated on upland farms in the second, third and fourth year of the rotation, which has a cropping period of five years, alternating with three years of bush fallow. The first year is used for the cultivation of yams. In the second year early maize and cowpeas are grown. Only the first season of the third year is used for cropping with the cultivation of a mixed crop of millet and maize, often interplanted with cowpeas. Pigeon peas, maize and cassava are grown during the fourth year.

Again in Igala division, most of the maize is harvested as dry grain, part of which is sold to Onitsha and Enugu markets in Eastern Nigeria. Fresh maize also forms a sizeable part of the diet in the early part of the rainy season.

The south-western part of Benue Province, Idoma division, resembles Igala. The place which the maize takes in the agricultural pattern of this area, is similar, but towards the east it decreases in importance, until in Tiv division, which covers most of Benue province south of the river, it becomes a minor crop. The staple foods in Tiv division are principally yams, guineacorn, and millet, towards the south also sweet potatoes and upland rice. Maize plays a minor role in the food supply of this area. The ears are generally harvested before they are matured and are then taken as fresh grain preparations. Occasionally maize is cultivated on the main (upland) farms, where it is entered in the grain course of the rotation during the second cropping year. It is then usually planted between the guineacorn or millet. As a rule however the crop is grown around compounds and on the river flood plains or fadamas. On the compounds it often covers an area of a quarter to one acre and comes back every year on the same spot. This sole crop is grown on hills spaced at three feet square with two plants per hill. The fadama-fields cultivated with maize are generally more extensive, often up to two acres per farmer. The fadama-maize crop is sown in March and is followed by rice, which is sown between the maize plants and prior to the flooding of the area. On these fadamas a three year cultivation period is practised of a first year with rice, followed for two years by maize intersown with rice. This three year period of cropping is followed by a fallow period of similar duration.

Maize takes a place in the diet of the people in Tiv division only during the months that fresh ears are harvested, that is in June and July. It helps to bridge the gap between the last year's produce of yams and guineacorn and the new harvest of those crops.

The fadamas referred to in the previous paragraphs occur in the eastern extreme of Tiv division and lead to an area with more extensive fadamas in Wukari division, the most easterly part of Benue province south of the river, where maize plays a more important role. Along the main rivers, and the many minor tributaries, large fields of maize are grown as described earlier and the crop is utilised in the form of dry grain in the diets of the people. This pattern extends over the whole of the southern part of Adamawa province.

c. Riverain provinces north of the rivers Niger and Benue

In the northern part of Adamawa, above the Benue, maize is still grown on available fadamas, interplanted with rice, but the crop is of little importance in the diet. The main staples are guineacorn and rice. In the northern corner of this province, around Hong, maize is not solely planted in fadamas but appears again on upland farms interplanted between guineacorn. This, however, is quite localised.

Again, in this part of Adamawa province, the major part of the maize crop is harvested as dry grain. Compound maize, which is almost ubiquitous, is often harvested prior to maturity. The picture seems to be that in these areas maize is merely a replacement staple food for guineacorn, in the time that this is scarce. Guineacorn is always priced slightly higher than maize, usually half a penny per 'mudu', the local measure (approximately three pounds of grain), indicating the preference of the people for this crop.

The south-eastern part of Bauchi province, Gombe division, borders on Adamawa province. A very intensive type of agriculture developed recently in this area, mainly based on the success of the cotton crop. The main food crops are guineacorn and millet, with maize very much in the minority. In the northern part of this division millet and guineacorn can scarcely be grown, because of the problem of birds depredating the crop shortly before the harvest. A good upland farm variety of maize could be of great importance in this area. Fadamas are not of frequent occurrence in Gombe division, but where they are available, maize, immediately, is one of the more important food crops, although remaining far behind rice. The reason that maize is grown in such areas is mainly because it yields its harvest earlier than other grain crops, and provides food during the hungry gap, before the guineacorn and the rice are available. Most of the maize crop is harvested as dry grain. Only about a quarter of the crop is harvested prematurely for use on the cob.

Some maize is cultivated in the southern and western parts of Bauchi division mainly in and around compounds. It 'apparently' is of some importance in the mid south of Bauchi division, where an extensive system of fadamas occurs.

South of Bauchi province lies Lowlands division of Jos province bordering the Jos plateau. These Lowlands have become of importance as a settlement area for people from the plateau. This fertile country is crosscut by many streams, with extensive fadamas along their banks. Maize is, as a rule, not cultivated on upland farms in this area, but around the compounds, often to a very considerable extent. The reason for not cultivating the crop on remote upland farms is more the likelihood that monkeys would damage the crop, than that otherwise it would be an unsuitable environment for the maize crop. Maize is also cultivated on slightly more elevated places in the fadamas. It precedes the rice, which is broadcast in May under widely spaced maize plants. If the floods happen to rise early, then the maize stalks are cut before the maize ears are fully mature and the plants are staked on dry places in order to allow them to dry. On these fadamas an annually recurring sequence of crops is practised, in which the maize is planted with the first rains, later interplanted with swamp rice which is flooded in July and August. After the floods have receded gourds are grown on the remaining water reserves. The major part of the early maize crop is harvested as dry grain and plays an important role in the people's diet from July to September. Only a small percentage is harvested green. In this area a small late season crop is usually raised on compounds for multiplication of seed, to be used during the following main season.

From Lowlands division almost towards the confluence of the rivers Niger and Benue stretches the northern half of Benue province within the southern guinea zone. The eastern part of this area is formed by Lafia division, where the main staple foods are guineacorn, yams, sweet potatoes, some cassava and millet. Practically all farmers however grow some maize either around their compounds or on the slopes of deforested kurmis, woodlands surrounding permanent streams. Around the compounds very extensive plantings of sole maize occur regularly. These are repeated annually on the same piece of land. The crop is cultivated on top of ridges, three to four feet apart, and with a population of up to fifteen thousand plants per acre.

Semi-fadamas, low situated areas of high fertility, occur regularly in this division. They are usually cropped for two years with a mixed planting of guineacorn and maize, followed by a year of mixed crops of yams and maize. After the fourth year, during which only yams are cultivated, one or two years of fallow are allowed.

In the most western part of Benue province, Nasarawa division, maize decreases in importance and is only found in some semi-fadamas, which are not very frequent, and often no more than mere depressions of the soil. Guineacorn and millet are here the main staples. Tiny pockets of maize can be found on upland farm areas where the cattle nomads of Nigeria, the Fulani, had settled during the previous dry season. Also in and around the compounds some maize is cultivated, which is harvested as dry grain. Where fadamas are available, these are cropped with maize followed by rice, the maize being harvested as 'green ears'.

Whereas in Lafia division most of the maize is allowed to mature and is harvested as dry grain, in Nasarawa division the reverse is true. In this division the maize cultivated on the fadama is usually harvested for fresh use, and the compound maize is harvested after maturation.

Via the southern part of Niger province we now return to the starting point of our journey through the riverain provinces. The picture given for Nasarawa division applies also to most of the eastern half of this area. More to the west, in Bida division, there are much larger fadamas where rice is cultivated extensively. Maize here is a very minor crop and is grown on the compounds in small areas of a quarter acre or less. Some maize is grown on upland farms amongst guineacorn and millet. It remains far behind guineacorn, millet, rice and root crops in importance, but still plays a vital role as it is, also here, the first available food in the new cropping season.

Maize increases to some extent in importance towards the south western part of Bida division, the area around Mokwa. It is cultivated on upland farms, as a rule in the second year of the rotation, interplanted between the guineacorn. The first year of the rotation is taken up by cash crops such as cotton, groundnuts or yams, and during the third and fourth year millet and guineacorn are grown. The last year is used for cassava or again for a grain crop.

In Bida division half the maize crop is harvested for fresh use and the remainder as dry grain; all maize grown around compounds is harvested prematurely.

d. On the Niger and Benue riverbanks

All along the river Niger above the confluence with the Benue and also along the Benue itself one can find broad areas of flood plains or fadamas. Maize is often cultivated, sometimes in quite large fields, on the actual river banks just beside the stream bed of the river. Typical examples of this can be found around Pategi in Ilorin province. The crop is grown both prior to the rise of the floods and also again in the dry season after the floods have receded. It is often interplanted with sweet potatoes. The early maize crop is sown with the first rains, and may be harvested before the grains are wholly mature. The dry season crop is left to ripen on the field.

Around the confluence of the two rivers the farmers have an interesting pattern of cultivation. Spinach (*Amaranthus* sp.) and onions are planted in January. This is followed by maize in March and rice in July. Every second year the spinach is left out of the cropping cycle.

e. Reviewing the riverain provinces

After this description of maize in the Middle Belt areas of Nigeria it might be well to look back and summarize what has been observed. In the area of Northern Nigeria south of the rivers Benue and Niger, maize plays an important role in the supply of food apart from the large Tiv division in Benue province. In much of the area maize is the main staple food during the 'hungry period'. North of the rivers, the character of maize as being a 'hungry gap' crop is very pronounced, apart from Lowlands division in Jos province and Lafia division of Benue province, where the maize plays its role in the diet for a longer period.

From south to north the maize seems to be retreating from the upland farms into fadamas, compounds and other areas with a higher fertility and/or a better moisture availability. An important consideration here is that maize must be planted early in the rainy season, as its main attribute lies in being the earliest supplier of food. The early planting date carries with it the great risk of drought periods in a time that no water reserves are yet available in the soil. If maize were to be planted later, it would probably not be necessary to keep this crop from the upland farms. The local maize material now available is however unsuitable for such a cultivation method, as for centuries it has been selected to favour the present cultivation methods. The selection of better yielding early maturing material from local maize and the introduction of late maturing varieties of maize for later plantings are factors which should be considered for these areas.

Another feature of importance is that the great majority of the maize plants grown by the farmers in the Middle Belt, are left to ripen on the field. The dry grain is harvested and utilised for the preparation of many different dry grain dishes. Only in Tiv division is the crop consumed almost entirely as fresh ears. The quantity of dry grain produced by the crop should be the main criterion in choosing between the cultivation of guineacorn and maize in most areas. If selected maize materials become available they should therefore be compared with good guineacorn varieties.

3.1.3.2. The northern provinces

In some areas of Zaria province maize is of local importance as it is, apparently, in the eastern part of Bornu province on the edge of Lake Chad. Furthermore, maize plants can be found anywhere in these areas on the compounds, sometimes carefully protected by grass mats placed around them. Along rivers and streams small plots of maize can be seen growing during any time of the year, together with ochra and sugar cane. A common feature in such locations is the lonely figure of a man, busying himself with the irrigation of tiny plots with selected crops along carefully laid out mud channels with the aid of a shadoof. In these areas all maize ears are harvested green, and are considered as a delicacy.

3.2. Maize in the Nigerian diets

Maize is utilised in many different ways for the preparation of various dishes. Some dishes are light and serve as a breakfast early in the morning. Others, more solid and frequently made more palatable by the admixture of palm oil, vegetables or fruits, and various sauces and meats, serve as the main meal and are eaten later in the day. Some dishes are reserved and used only for special occasions. Such a dish is the MASA-maize cake of the Yorubas which is served usually during the funeral ceremonies of a noble or a chief.

3.2.1. Various food preparations

The common preparations are well known in all areas where maize is eaten as a food and their popularity is expressed in the many local names for such dishes. The various dishes met with throughout Nigeria are described in table 1. The local names, tribes and areas where the dishes are in use have been added to these descriptions.

The list has been divided into two main headings:

1. Fresh or green maize preparations, based on grain harvested in an immature state, varying from the milky to the dough stage. Fresh maize may be eaten on the cob or the grain may be stripped off the cob prior to cooking.
2. Dry grain preparations made from mature grains. These have been further subdivided into the main or common foods (prepared from plain maize),

TABLE 1. Various Nigerian maize dishes*)

Dish	Local name	Tribe	Area
FRESH GRAIN PREPARATIONS			
Fresh or green ears harvested from three to five weeks after seed set and boiled until the seeds are soft. Salt may or may not be added.	Akpahie	Igala	Kabba
	Apapa-ojogho	Igbirra	Kabba
	Eke'agbo	Aworo	Kabba
	Gassawa	Hausa	Bauchi
	Masara ndafa	Hausa	Bauchi
	Telle	Hausa	Bauchi
	Edudu	Nupe	Ilorin; Niger
	Ikureke i jiir	Tiv	Benue
	Ipoek	Yergam	Plateau
	Oka esiriesi	Ibo	Eastern Nigeria
	Agbado sise	Yoruba	Western Nigeria
	Langbe	Yoruba	Western Nigeria
	Imiyo-sise	Itsekiri	Mid-West State
	Okanale	Edo	Mid-West State
	Okanobolo akele	Edo	Mid-West State
Green ears harvested from three to five weeks after seed set and roasted above or beside a fire or cooked in hot ashes.	Akpe 'ere	Igala	Kabba
	Apapa ojighu	Igbirra	Kabba
	Ehu 'gbado	Aworo	Kabba
	Jeddi	Hausa	Adamawa; Bauchi
	Epupo	Nupe	Ilorin; Niger
	Iwana	Yergam	Plateau
	Oka arurnaru	Ibo	Eastern Nigeria
	Agbado sisun	Yoruba	Western Nigeria
	Agbado	Yoruba	Western Nigeria
	Agbado titu	Yoruba	Western Nigeria
	Kerefe	Yoruba	Western Nigeria
	Imiyo sisun	Itsekiri	Mid-West State
	Okanatoen	Edo	Mid-West State
	Okanatoen kevbiobo	Edo	Mid-West State
Immature grains pounded or ground, sieved in water, dried and mixed with pepper and salt. The mixture is rapped in guineacorn or cocoa leaves and then boiled or steamed.	Agiriga	Ankwe	Plateau
	Ogidigbo	Igala	Kabba
	Lapata	Yoruba	Western Nigeria
	Sapala	Yoruba	Western Nigeria
	Yahi	Egba	Western Nigeria
	Utara oka	Urhobo	Mid-West State
Similar preparations to the above but mixed after steaming with pepper, salt, palm-oil and raw, cut vegetables.	Igbala akpa	Igala	Kabba
	Egbala ojiwe	Igala	Kabba
	Akpapa	Tiv	Benue
	Abari	Yoruba	Western Nigeria
	Sapala	Yoruba	Western Nigeria
	Ekuru igbado	Yoruba	Western Nigeria
	Iro	Yoruba	Western Nigeria
	Adalu	Yoruba	Western Nigeria

*) I am greatly indebted to Mr. E. F. I. BAKER, Agronomist with the Western Nigerian Ministry of Agriculture and Natural Resources, Ibadan, for information on maize preparations in Western Nigeria.

Dish	Local name	Tribe	Area
(served separately with beans)	Egbo	Yoruba	Western Nigeria
	Ososo	Yoruba	Western Nigeria
	Ewa ososo	Yoruba	Western Nigeria
	Ikpa-oka	Urhobo	Mid-West State
	Ukpo-oka	Western Ibo	Mid-West State
Similar preparations to the above but taken on their own after frying or as a stiff porridge.	Okereke	Ibo	Eastern Nigeria
	Ikpakiri	Ibo	Eastern Nigeria
	Uka 'apapa	Igbirra	Kabba
	Gusasa	Hausa	Adamawa; Bauchi
	Zinkun	Yergam	Plateau
	Lapata	Egba	Western Nigeria
	Akara agbado	Egba	Western Nigeria
	Kango	Yoruba	Western Nigeria
	Ikpakere	Yoruba	Western Nigeria
	Pemlo	Yoruba	Western Nigeria
	Ikala	Edo	Mid-West State
	Ikara	Edo	Mid-West State
	Ikpakene	Edo	Mid-West State
Fresh grain, boiled; pepper, cray-fish, fish oil and native potash added. The mixture reboiled, diluted with water and eaten as soup.	Owo-imiyo	Itsekiri	Mid-West State
Fresh grain boiled and mixed with coco-nut juice.	Imiyo ikokodie	Itsekiri	Mid-West State
MAIN DRY GRAIN PREPARATIONS			
Grain, from which the seed coats have been removed by pounding, soaked for two or three days then ground on a stone or pounded, sieved and boiled. It can be taken as a warm or cold thin gruel, as a thick porridge, or as a thick paste wrapped in leaves.	Agidi	Ibo	Eastern Nigeria
	Ekamu	Igala	Kabba
	Ekamu	Igbirra	Kabba
	Ijobu	Igala	Kabba
	Omadidi	Igala	Kabba
	Ekwa	Nupe	Kabba; Ilorin; Niger
	Kamu	Yergam; Ankwe	Plateau
	Kunu	Hausa	Bauchi
	Eko gbigbona	Yoruba	Western Nigeria
	Eko (mimu)	Yoruba	Western Nigeria
	Ogi	Yoruba	Western Nigeria
	Ruam u ikureke	Tiv	Benue
	Eko tutu	Yoruba	Western Nigeria
	Ewa	Yoruba	Western Nigeria
	Akamu	Edo	Mid-West State
	Akasan	Edo	Mid-West State
	Agbaghidi	Edo	Mid-West State
	Tuwo	Yoruba	Western Nigeria
	Ekor	Edo	Mid-West State
	Amadidi	Edo	Mid-West State
	Ori	Edo	Mid-West State

Dish	Local name	Tribe	Area
	Udekho	Edo	Mid-West State
	Madidi	Edo	Mid-West State
As the above preparation but made from a mixture of maize and cassava flour.	Oje-akpa	Igala	Kabba
	Nri-oka	Ibo	Eastern Nigeria
	Nri okwara itu	Ibo	Eastern Nigeria
	Usung akpakpa	Ibibio	Eastern Nigeria
As the first preparation but mixed with well cooked balls of maize flour.	Ukwokwo	Igala	Kabba
Grain from which the seed coat has been removed by pounding, soaked for one day and ground into coarse particles which are boiled and then mixed with fine flour and again boiled. Eaten as thick porridge.	Abakagu	Igala	Kabba
	Eje	Nupe	Ilorin; Niger
	Kpang	Yergam	Plateau
	Mumu	Mada	Benue
	Tuwo	Ankwe	Plateau
	Tuwo	Hausa	Benue; Bauchi; Ilorin; Adamawa
	Tuwo	Yoruba	Western Nigeria
As above preparation but mixed with dry flour, potash and then left for one day. The dough is then used for small pancakes, fried in oil.	Masa	Ankwe	Plateau
	Masa	Hausa	Benue; Bauchi
	Mosa	Yoruba	Western Nigeria
	Ipete	Yoruba	Western Nigeria
	Ikara	Itsekiri	Mid-West State
	Imiyo gbengberren	Itsekiri	Mid-West State
	Ekoka	Edo	Mid-West State
	Guguru	Yoruba	Western Nigeria
	Adun elepo	Yoruba	Western Nigeria
	Monsa	Yoruba	Western Nigeria
	Ukpakpa	Itsekiri	Mid-West State
	Akara	Itsekiri	Mid-West State
	Imasa	Itsekiri	Mid-West State
	Ikpekele	Itsekiri	Mid-West State
Grain from which the seed coats have been removed is ground. The flour is sieved and mixed with dried stem of Dargaza (*Grewia mollis*), water and sugar. The mixture should have a thick consistency and is used for pancakes, fried in groundnut oil.	Mase	Hausa	Adamawa
	Tsafa	Hausa	Adamawa
The first dry grain preparation mentioned in this list left overnight after mixing with ochra, salt and potash. The dough is then fried in oil to provide pancakes	Kass	Nupe	Ilorin; Niger
	Pandaso	(Lafia)	Benue
Grain from which the seed coats have been removed, ground into	Fura	Hausa	Bauchi; Adamawa

Dish	Local name	Tribe	Area
a fine flour to which pepper is added. The flour is squeezed into balls and dropped into boiling water for ten minutes. The material is pounded with sour milk.			
Grain pounded or ground. The flour is mixed with oil, salt, pepper and fish. The mixture is boiled after wrapping in leaves. It may be served hot or cold.	Ekereke-ukwore	Ibo	Eastern Nigeria
	Igbagwu	Ibo	Eastern Nigeria
	Ukuoka	Edo	Mid-West State
As above but with beans or onions and tomatoes instead of fish.	Ilozo	Urhobo	Mid-West State
	Otseko	Urhobo	Mid-West State
Dried grain roasted and ground, salt, pepper and palm-oil added.	Adun	Egba	Western Nigeria
As above but sugar added.	Elekute	Yoruba	Western Nigeria
MIXED PREPARATIONS			
Grain from which the seed coat has been removed, cooked as whole kernels or coarse particles, sometimes mixed with beans, until done. The cooked grains are then mixed with oil. Sometimes pepper, onions and tomatoes are added to the dish.	Ayicha	Igala	Kabba
	Dafuwa	Hausa	Bauchi
	Kanin tuwo	Hausa	Bauchi
	Kuti	(Tula)	Bauchi
	Egbo	Yoruba	Western Nigeria
	Ewa	Yoruba	Western Nigeria
	Ewa ososo	Yoruba	Western Nigeria
	Efienayin	Urhobo	Mid-West State
Grain after removal of seed coat pounded to a flour and mixed with groundnuts and sugar, then fried in oil.	Emu	Itsekiri	Mid-West State
	Unoka	Itsekiri	Mid-West State
As above but taken with coconut instead of groundnuts and sugar.	Okanaranmwen	Edo	Mid-West State
	Okakhuokhuori	Edo	Mid-West State
	Ikpekele	Urhobo	Mid-West State
	Ekaka	Urhobo	Mid-West State
	Okanalami	Itsekiri	Mid-West State
As above but mixed with yam and beans and fried in oil as pancakes.	Guruguru	Itsekiri	Mid-West State
	Tayitayi		
Grain after removal of the seed coat pounded to a flour and mixed with groundnut or guineacorn flour. Cold water, pepper and salt added; occasionally ochra, garden egg and palmoil. The mixture is wrapped in leaves and cooked.	Madidi	Hausa	Kabba: Bauchi; Adamawa; Benue
	Kafa	(Lafia)	Benue
	Tubani	(Gombe)	Bauchi
	Gulguli		Adamawa
	Abari		Ilorin
Grain from which the seed coat	Hayi	Yoruba	Western Nigeria

Dish	Local name	Tribe	Area
has been removed, pounded or ground and the flour cooked into a porridge.			
As above but mixed with ground, germinated guineacorn seeds.	Kunu	Hausa	Bauchi; Adamawa
	Mang	Yergam	Plateau
	Mbususi		Adamawa
Coarse grain particles obtained from pounded grain from which the seed coat has been removed, are boiled. Mixed with salt, oil and pepper before serving.	Buboche	Nupe	Niger
As above but without additions.	Madi	Nupe	Niger
A mixture of cooked whole maize and cowpeas. Occasionally prepared with ground materials.	Ewa	Yoruba	Ilorin
	Ochoto	Ibo	Western Nigeria
MINOR DRY GRAIN PREPARATIONS			
Dry grain popped by placing it in sand above a fire or in hot dishes.	Apapa oyiwara	Igbirra	Kabba
	Apura	Aworo	Kabba
	Guguru	Hausa	Adamawa; Benue
		Yoruba	Western Nigeria
		Ankwo	Plateau
	Edifran ibokpot	Efik	Calabar
	Ikang akpakpa	Ibibio	Eastern Nigeria
	Kaba kanchi	Nupe	Ilorin; Niger
	Udo akpuenyi	Ibo	Eastern Nigeria
	Eyan igbado	Yoruba	Western Nigeria
	Yere	Yoruba	Western Nigeria
	Okanalamen	Itsekiri	Mid-West State
Popped grains are ground, the flour is taken dry, after mixing with a little salt.	Mok	Yergam	Plateau
	Potaka	Nupe	Ilorin; Niger
Dry grains roasted or popped and ground. After sieving the flour is mixed in equal parts with roasted groundnut flour. The mixture is pounded and made into balls about one inch in diameter after addition of pepper and salt.	Dokuwa	Igbirra	Kabba
	Omumu	Aworo	Kabba
	Dankuwe	Nupe	Kabba: Ilorin; Niger
	Dakuwa	Ankwe	Plateau
	Dakuwa	Hausa	Lafia; Adamawa
	Adun	Yoruba	Western Nigeria
As above but fried (no groundnut).	Adun	Yoruba	Western Nigeria
Soup prepared from coarse maize flour which is placed into boiling water and mixed with palm-oil and some meat.	Pate	(Lafia)	Benue

Dish	Local name	Tribe	Area
MAIZE DRINKS			
Dry grains roasted and ground. After sieving the flour is mixed with water and served cool.	Gari Kafansafi Kunu	Ankwe (Kaiama) Mada	Plateau Ilorin Benue
Grains soaked in water for one or two days, allowed to germinate for three days, ground and sieved. The ground particles are boiled in water and left to ferment for twelve hours. The liquid is boiled again and left to ferment for a period varying from one to several days. This might be called 'maize beer' and is an alcoholic drink, often drunk in areas where palmwine is not readily available.	Burukutu Burukutu Eche Kwacha Ma Men Nwon Ntebe Pito Pito Oti Oti agbado Oti-seketa Sekete Baba Afofogbo	Hausa Igala Igbirra Efik Mada (Gombe) (Tula) Yergam Ibo Yoruba Yoruba Yoruba Yoruba Yoruba Yoruba Yoruba	Adamawa; Bauchi Kabba Kabba Calabar Benue Bauchi Bauchi Plateau Eastern Nigeria Western Nigeria Western Nigeria Western Nigeria Western Nigeria Western Nigeria Western Nigeria Western Nigeria
Grains soaked for a short time and the seed coats removed by pounding. The flour is mixed with sweet potato flour and boiled to a thin watery drink.	Obiolo Odugba	Igala Igala	Kabba Kabba
Grains pounded into coarse particles, after removal of the seed coat. These particles are boiled and the liquid allowed to cool before serving.	Changada	Nupe	Kabba

mixed preparations, the minor or less common dishes and various kinds of drinks.

In southern Nigeria maize preparations are often sold on the markets by women specialising in the preparation of a particular type of food. The 'agidi'- or 'eko'-makers themselves depend on others for the purchase of other items for their meals (90). The picture of young girls and women hawking 'eko' wrapped in leaves or selling boiled or roasted maize ears from a large enamel basin are common features of any town in southern Nigeria. This practice of marketing prepared maize dishes decreases as one travels further north until, in the northern parts of the Middle Belt, the people prepare the various dishes within each compound.

The variety of dishes prepared with maize is great, especially in areas where it plays an important part in the people's diets. It is typical for example that in Tiv division (mid south of Benue province) the variety of dishes is restricted to three fresh grain preparations and one dry grain dish. In areas where the maize is only grown as a filler for the hungry gap, it is to be expected that the greatest variety of preparations is found in the fresh grain dishes. In most areas in the Middle Belt the three grain crops, maize, guineacorn and millet, are interchangeable in the preparations listed, especially of the dishes given under the major dry grain preparations. The minor dry grain preparations tend to be more specific for maize, although here and there the women do replace maize with guineacorn in these cases also. The minor dry grain preparations are called minor as they are prepared less often than the others. However, it should not be inferred, that they are only rarely used. They have much more the nature of delicacies, prepared when celebrations are held or on market days.

It will be clear from the descriptions of the dry grain preparations, that very often the seedcoat, often inclusive of the aleuron layer, and the maize germ are removed by a light pounding with a pestle and morter. What little good quality protein this contains, is thus already removed from the resulting flour prior to pounding or grinding. In the normally utilised wet grinding process, care is taken that only the flour settling in water is taken for the preparation of the various dishes. This means that more or less pure starch is obtained for this purpose. Fortunately the use of power driven mills is spreading rapidly. Even in many small towns and villages all over Nigeria one can meet the women carrying the soaked or dry whole, unpounded maize grains to these mills. This means that the germ is milled also, and if the meal is used without further separation in water, then much of the available protein remains in the flour. However, several of the maize dishes, especially 'ogi' and 'eko' or 'agidi' require removal of the seedcoat and are therefore still based on pure starch.

These considerations led us to consider the role of the maize crop in the context of the entire food intake. Apart from the 'hungry period' in the last part of the dry season, and the early weeks after the onset of the rains, an adequate supply of staple foods appears to be available north of the two rivers Niger and Benue. South of the rivers, however, the position is reported to be less satisfactory, the consumption of calories being rather low (twenty to twenty five per cent below a satisfactory level) and the diet lacking in protein (6, 34, 68). In 1955 BUCHANAN and PUGH (17) reviewed available information and stated that most subjects were shown to be underweight to the extent of one to one and a half stones, compared with well nourished Nigerian people. Still, the lack of proteins and various other specific nutritive substances seems to be of much more importance than the actual shortage of calories; most diets do not contain sufficient proteins, although many of the dishes taken are often prepared with an admixture of some proteinous foods, such as groundnuts or other legumes. Much attention should therefore be given to a reorientation of the diet towards existing, or new, protein-rich, palatable preparations.

3.2.2. *Composition of the maize grain*

The value of maize as a source of other nutrients than the caloritic starch is not high. Some information was collected on the composition of maize grain

TABLE 2. Chemical composition of maize grain grown in Nigeria.

	Floury flint varieties (White)			Floury Variety (White)	Flint Variety (Yellow)
	Sicaragua	EAFRO 231	Mexico 5	Lagos White	Tsolo
Oil and fats	4.3%	5.5%	4.0%	4.8%	4.1%
Ash (minerals)	1.9%	1.4%	2.1%	2.1%	3.7%
Crude fibre	2.1%	2.6%	2.4%	1.8%	1.3%
Crude protein	9.6%	11.1%	10.9%	11.3%	10.7%
N-free extract	68.5%	66.5%	67.4%	66.4%	70.7%
Carbohydrates	70.6%	68.9%	69.8%	68.2%	72.0%

harvested from several varieties of maize cultivated in Nigeria. These data are presented in table 2. The nitrogen free extract was obtained by deducting the percentages for moisture, ash, protein, fibre and fat contents from one hundred, the figure for the carbohydrates by adding to the percentage of nitrogen free extracts the percentage of crude fibre. The figures prove comparable to data reported elsewhere.

More than two-thirds of the protein available in the maize kernel is present in the endosperm, considerably more so in the flinty parts than in the floury parts. This protein is designated as zein, which is a badly balanced protein in that it lacks some of the essential amino-acids. Its biological value is extremely poor (99). Two of the essential amino-acids, lysine and tryptophane, are more or less absent and isoleucine and threomine are very low, whilst there is superfluous leucine (60, 99).

Most of the remaining protein, over twenty two per cent, is located mainly in the scutellum and some in the embryo and the nutritional quality of this protein apparently approaches that of animal protein (62). An increase in the size of the germ (inclusive of the scutellum) would therefore automatically give an important improvement in the quality of the maize flour, if this part of the grain is included in the milling process. It is unfortunate that with the practice of removing the seedcoat prior to milling, so prevalent in Nigeria, the germs are mostly removed also, thus leaving only the virtually useless zein in the flour.

The protein content of maize grains varies with a number of environmental conditions. A decrease of available nitrogen per plant (increasing populations per acre) is reported to effect a decrease of the protein content of the grain and also, conversely, increasing rates of nitrogen applications to increase the protein content of the grain, of course within limits. The increase is, however, more or less restricted to the zein and the nutritive value of the resulting product is therefore lowered considerably (33, 76, 87, 88). The maize cultivated under a higher nitrogen regime tends to show also a considerable increase in flinty endosperm, which, especially in the south, will cause a decrease in acceptability of the crop (60).

White and yellow maize grains seem to be similar in their composition. See table 2. One of the main differences is that the yellow maize contains a good quantity of carotene, a precursor of vitamin A, equivalent to three to four hundred milligrams per hundred grams of product. A part of this is lost again if the seedcoat is removed. Both yellow and white maize varieties are reported to have very small quantities of the vitamins B_1 and B_2 and of niacin, respectively 0.3, 0.1 and 1.3 milligrams per 100 grams of product. The lack of niacin in the maize kernel is a serious disadvantage as this induces the incidence of pellagra, which is commonly found in areas which depend heavily on maize as a staple food. Niacin is a pellagra-preventive. As stated earlier maize is also low in the aminoacid tryptophane, which could be converted into niacin in the body (67).

It should be realised, that much of the wet processed maize flours used for the preparation of many of the important maize dishes, consist of a high percentage of pure starch. Darker particles originating from the seedcoat and the germ are normally carefully removed during the preparation of the flour and this practice therefore results in a very low protein content in the resulting foodstuffs in spite of any protein which might be available in the grains prior to milling.

3.2.3. *Consumer preferences*

The acceptability to consumers of any agricultural product used for the preparation of their food is vital for its success. We shall now proceed to show how certain preferences occur in this country for particular types of maize grains and for various colours of the seeds.

3.2.3.1. Grain colours and the nature of the endosperm

Various factors influencing foodcrop preferences and their significance to plant breeding programs were separated into irrational and rational ones by STANTON (126). Some of the irrational factors such as religious dictates and taboes, prestige and customary values have played a role, especially in colour preferences for maize in Nigeria. These however are disappearing rapidly. Other such factors as suitability of grain types and variously coloured grains for traditional methods of preparation and use, are still of major importance.

But also such factors will gradually decrease in importance, in as much as preparation of various kinds of foodstuffs will no doubt be rationalised and industrialised. Other ways of consumption will even find acceptance. However, the suitability of maize types for the present ways of preparing foodstuffs is of major importance for the time being. It is this aspect which is considered in the following paragraphs.

Two main grain colours can be recognised for maize in Nigeria. In the first instance, white prevails in most of Western Nigeria, apart from the 'yellow flint' area in the eastern part of this region. The white colour of the grain is often coupled with flouriness of the grain. The white floury maize type of the Yorubas reaches into the southern part of Ilorin province. In Eastern Nigeria pure floury, white maize types are cultivated in an area which stretches from Ogoja province in the north-east down to Calabar, and from there to the west. In Enugu and Onitsha provinces the picture is confused by the intensive trade in maize, bringing in various grain types from northern and western directions. Both white and yellow, floury and flinty grains are found in these areas.

In Northern Nigeria most of the maize cultivated is of a pale yellow colour and is flinty, although white flinty varieties do occur quite regularly. Around larger towns white floury varieties are regularly cultivated, but these only on a small scale and invariably only for sale to 'southern' inhabitants of these towns. In the northern and eastern parts of this region the occurrence of dark brown, red or blue coloured grains is quite common.

In the whole of southern Nigeria the people have a strong aversion towards brown, red or blue grains. A definite preference for white colour does exist in Oyo, Abeokuta and Ijebu provinces of Western Nigeria, and in the eastern part of Eastern Nigeria, both of which areas produce mainly white maize varieties. It is in these areas that type and colour preferences are very pronounced, especially in the Yoruba communities of Western Nigeria (127). In most other areas colour preference is of little importance. Either of the two colours, white or yellow, will be acceptable, provided the grain type is suitable for the preparation of various foodstuffs. The preference for flinty or floury grains is less pronounced than the colour preference even in the 'white floury' areas of Western and Eastern Nigeria. When preferences for these two types of grain were plotted on a map of Nigeria, a mosaic was obtained, of intermingled preferences, varying from one town to the other. Outside these areas flinty grains were normally judged more acceptable than soft, floury types, apart from Niger province. In Ilorin province, just north of the distribution area of white floury maize varieties, the white, floury 'Yoruba maize', as it was called, was definitely not acceptable.

It seems from this discussion that colour preference is of major importance in a part of the maizebelt of Western Nigeria, where a white maize is preferred, as is also the case in much of the eastern and southern parts of Eastern Nigeria. These areas coincide more or less with areas where a majority preference for floury grain types was expressed.

Wherever white grained varieties of maize are commonly in use for dry grain food preparations, apparently yellow grained varieties are preferred for use as maize on the cob. This is found throughout the 'white preference' areas.

3.2.3.2. Floury and flinty grain types

Little investigational work has as yet been done on the actual reasons responsible for the differences in acceptability of various grain types. Comparisons of flinty with dent maize grains were made in East Africa (51) and some information on differences between floury and dent or floury flint grain types has become available in Nigeria.

Prior to discussing these investigations, it seems opportune to describe what exactly is meant by the terms floury, flint and floury flint. The essential differences between these grain types lie in the distribution of areas of different density of starch granules in the endosperm tissue of the grain. Where the granules are tightly packed, the tissue is hard and corneous and shrinks little on drying. Much shrinkage occurs in the less tightly packed part of the tissue, known as the

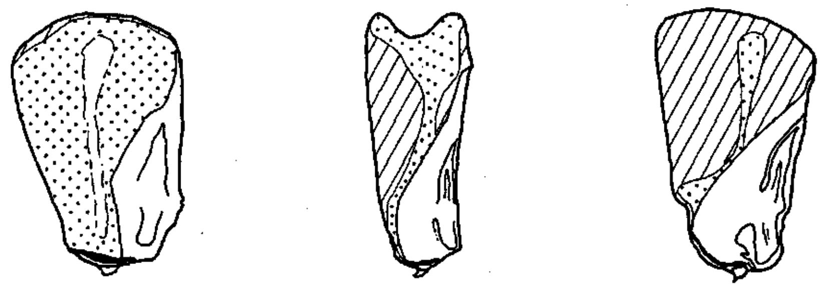


FIGURE 3. Longitudinal sections through floury, floury flint and flint maize grains. The amylaceous part of the endosperm is dotted, the corneous part is hatched.

amylaceous part of the endosperm (51). In the flint maize types the corneous endosperm comprises most of the grain and it forms a cap over the embryo, which gives the grain its glassy appearance. In the dent or floury flint maize types the corneous endosperm is present as an open cylinder, which partly surrounds the germ at the base of the seed. The differential shrinking of the central amylaceous part of these grains produces the typical dent in the tip of the seed. Floury grains have an endosperm, which is mainly amylaceous, sometimes surrounded by a very thin layer of corneous endosperm. The white floury grains have a very typical dull chalk-white appearance. These features are illustrated in figure 3. The picture of preferences for types of maize grains appears a very confused one; many conflicting statements have been made in this respect. That newly introduced varieties of a common, popular crop can be wholly unacceptable to the farmers in spite of a good performance on the field, is an often observed phenomenon. The aversion from the new product can be due to the low degree of palatability under the prevailing preparation methods, which might not be adapted to new varieties of crop plants. This phenomenon of a low acceptability of newly introduced, well performing varieties has been experienced in the 'floury' areas of southern Nigeria, when white dent varieties of maize from Mexico were introduced some ten years ago. The problem did not arise in the flinty areas, where the people were used to the harder flinty grain types.

Preliminary tests by CHINWUBA and OKPARANTA (28) to verify the preference for floury varieties, commonly found in southern Nigeria, were arranged by issuing three floury flint varieties of maize and one floury one, to some twenty Yoruba-girls at Ibadan. They were requested to prepare 'ogi', a maize gruel, and 'eko', a much more solid food, according to their local methods. The maize grains were soaked for three days and then ground by hand. The grinding tools consisted of one flat slab of stone and a round smaller piece of stone, which is used to crush the grain. This process proved to be very wasteful, as only twenty five to twenty nine per cent of the original material was recovered as flour and thirteen to seventeen per cent as chaff. From the tasting tests with these materials, it followed that the local, floury variety Lagos White was ranked first, followed by the floury flints, Sicaragua and EAFRO 231. The floury flint variety Mexico 5 ranked lowest. In other words, in these trials the general statement that the floury varieties are preferred, was corroborated. However, no control was achieved over the method of preparation, as the participants were allowed to follow their own methods and use their own tools. Another comment is, that the use of mortar and pestle and of manual grinding stones is declining fast in favour of power driven grain mills. This is true not only for many parts of Eastern and Western Nigeria, but also for the Middle Belt. This process has gone so far, that presently in these areas the use of power driven mills, run on a commercial basis by an individual, is the main way of preparing flours from maize. In the smaller villages, more in the Middle Belt than in southern Nigeria, the mortars and pestles and the grinding stones are still the only means of processing the various cereals. It is of interest that in such localities, even in the northern flinty areas, the women always appeared eager to obtain softer grained varieties, because of the ease of processing. In the northern flinty areas, however, the men normally asserted that the harder grain types were preferable (46).

It was not clear whether the problem was one of acceptability, or one of real taste differences, that is: palatability. Two varieties of maize were therefore taken to study the differences between a floury variety and a floury flint. The floury variety Lagos White, and the floury flint ES2, a derivative of Mexico 5, had been ranked respectively as the best and least palatable varieties in former experiments. An often repeated judgement passed by farmers and consumers is a complaint about the chaffiness of the floury flint or dent maize types. This could mean that with the flour extraction methods presently in use, the coarse fraction, separated from the flour by sieving, was larger for the newly introduced varieties than for the acceptable, floury maize varieties. Therefore, the efficiency of flour yield was determined for similarly milled maize grains of the two varieties and also of the flint variety ES1. Sieves of varying mesh were used for this purpose. The resulting figures for the yield of flour were expressed as percentages by dry weight of the total milled product. See table 3.

The fractions thus obtained, were utilised to prepare 'ogi'. It was noticed that

TABLE 3. Yield of flour in percentages by dry weight of the total milled product.

Flour fraction indicated with sieve meshes	Maize varieties		
	Floury (Lagos White)	Floury flint (ES2)	Flint (ES1)
Dry milled flour			
25 mesh < fraction	92	87	93
36 mesh < fraction	77	66	74
60 mesh < fraction	65	43	44
Wet milled flour			
25 mesh < fraction	70	69	65
36 mesh < fraction	69	63	56
60 mesh < fraction	67	58	54

this dish, prepared from dry milled flour separated from the chaff with a sieve of twenty five mesh, was never acceptable, because of its rough appearance and the occurrence of many conspicuous dark particles. With the use of finer sieves the product improved very much in appearance. The finer the sieve, the more acceptable the dish. The floury variety excelled however in appearance above the two others. The wet milled flours gave a similar picture, although sieving with the coarsest mesh (twenty five mesh) already resulted in acceptable 'ogi' preparations. The use of finer meshes improved the dishes considerably. Again the floury variety proved to be slightly better in appearance than the dent one.

The wet milled flour fractions were also used to prepare 'eko', which is usually prepared from wet milled flour. Here again, the appearance of the preparations improved with the use of finer flour fractions. In this case it was unanimously agreed that the ES2-preparations were far more attractive than those prepared with the floury variety.

When studying the flour yields as given in table 3 it is apparent that both the efficiency of flour yield and the appearance of the 'ogi' dishes, are in favour of the local floury variety. It was shown that with the use of a sieve of sixty mesh only half the initial weight of product is returned as flour. This return percentage is higher for the floury variety than for the two others, for all sieve meshes tested. It is probably this characteristic which induces the consumers to describe the introduced varieties as chaffy.

Formal palatability tests were restricted to flours obtained from the varieties Lagos White (= LW) and ES2 only. The actual tasting tests did not fully comply with the eye judgements, discussed in foregoing paragraphs. The results of a tasting test on 'ogi' dishes prepared from the two coarsest flours, obtained with the aid of twenty-five and thirty-six mesh sieves, are given in table 4.

TABLE 4. Ranking of 'ogi' dishes prepared from various types of maize flours.

Rank	Flour	Mean coded ranking
Dry milled flour preparations:		
1 (best)	ES2 < 25 mesh	0.687
2	ES2 < 36 mesh	0.000
3	LW < 36 mesh	0.000
4 (worst)	LW < 25 mesh	–0.687
	Standard error of the means	0.140
Wet milled flour preparations:		
1 (best)	ES2 < 25 mesh	0.441
1	ES2 < 36 mesh	0.423
2	LW < 25 mesh	0.061
3 (worst)	LW < 36 mesh	–0.926
	Standard error of the means	0.250

If dry milled maize flours were used for the preparation of the 'ogi', then the coarsest flour, prepared from ES2 (fraction <25 mesh) proved to be the most palatable one followed by both the ES2 and Lagos White fractions obtained by the use of a thirty six mesh sieve. The coarsest Lagos White flour proved inferior. The use of a sieve of sixty mesh proved not to alter the palatability of the 'ogi' dishes for either of the two varieties, compared with that of the 'ogi' prepared with the flour fraction obtained with the sieve of thirty six mesh. Because of the differences in return percentages of flour with the use of various sieves, the coarsest sieve possible should be advocated. It now follows that for the floury variety a finer sieve should be used than for the floury flint maize. The actual sieve mesh used in the separation of dry milled maize flours proves to be very important in determining the palatability of food preparations. In the wet flour preparations, the two coarse ES2 flours were ranked similarly, both higher than the 'ogi' prepared from the coarsest Lagos White fraction. All three preparations were preferred above that made with the Lagos White flour obtained through a thirty six mesh sieve. The use of finer flours did not alter the palatability of the 'ogi' dishes, prepared with the ES2 fractions, but lowered this in the case of Lagos White, although the outward appearance did improve.

Apparently quite different requirements are given to wet milled maize flours, used in the preparation of 'eko'. The results of tasting tests on this food dish are presented in table 5.

TABLE 5. Rankings of 'eko' dishes prepared from various flour fractions (wet milled).

Rank	Flour fractions	Mean coded ranking
1 (best)	ES2 $<$ 60 mesh	0.726
2	LW $<$ 60 mesh	0.318
2	ES2 $<$ 36 mesh	0.301
3	ES2 $<$ 25 mesh	−0.424
3	LW $<$ 25 mesh	−0.451
3 (worst)	LW $<$ 36 mesh	−0.469
	Standard error of the means	0.220

The two coarsest fractions of the floury variety, and only the coarsest fraction of ES2, were considered to give the least palatable 'eko' preparations. They were by far superseded by those prepared from the finest Lagos White flour and the medium fine flour of ES2. The finest ES2 flour, obtained with a sieve of sixty mesh, proved to give the most palatable 'eko' preparation.

From these investigations it could be inferred that the acceptability of the floury flint maize varieties in the floury areas has been based mainly on the appearance of the food preparations and the return of flour from the milled product. In all cases it was found that the floury flint variety gave more palatable food preparations than the floury variety, if similar sieves were utilised for the separation of the flours. It is important to note here that it was shown that attractive appearance and palatibility are not synonymous, but are very different factors, which must be assessed separately.

It is now apparent that the introduction of floury germplasm into the floury flints, is important in order to improve their yield of flour per pound of grain bought on the market by the consumer. These investigations have provided us with a simple tool to evaluate newly selected materials for this quality: a simple sieving test will now suffice.

In the Middle Belt of Nigeria, where flint varieties of maize are generally accepted, high yielding floury flint material has been found acceptable in many locations. Here also the same problem of the efficiency to yield flour might occur. Some investigational work in East Africa revealed that twelve per cent more flour could be obtained from flint maize varieties than from floury flint (or dent) types (51).

3.3. Conclusions

Reconsidering the contents of this chapter, it is apparent that a great variety of maize preparations exists. This is only partly linked up with the importance of the crop. In much of the Middle Belt, maize is of high importance only during a short period of the year, when it acts as a filler crop for the hungry period, early in the rainy season. However, the greatest variety of dishes was found in that area. In Eastern Nigeria the crop is grown as a secondary staple, root crops generally taking the first place. In Western Nigeria, a real maize belt exists, which depends to a large extent on this crop as a staple.

From south to north the maize crop seems to withdraw from the upland farms towards the fadamas, other low-lying moist areas and to compounds. Above the Middle Belt maize is only found in the compounds or on river banks, often irrigated. The retreat of maize to such areas seems mostly conditioned by the fact that it is sown very early in the season. If the crop were to be grown later in the season, when the rains are more reliable, upland farms in most parts of the Middle Belt could also sustain a good maize crop. This however demands selection of suitable maize material.

The general assumption that maize is consumed mainly on the cob in the Middle Belt, appears quite wrong. It is only in Tiv division that this is true; in the remainder of this area the major part of the crop is taken as dry grain. Another area where the use of green maize is of great importance is Eastern Nigeria, where half the crop is consumed in this form. An assumption has been made that until eighteen pounds of maize is consumed per subject, maize is taken fresh (90). This, again, might be true for the northern provinces of Northern Nigeria and for Tiv division in the Middle Belt, probably not in southern Nigeria, and certainly not so in most of the riverain provinces. Generally, if new maize varieties are to be produced, attention should be given to the yield of dry grain. It might be of importance to produce separate varieties for fresh use, with a shorter time to tasseling, as it is especially the fresh maize, which acts in the first instance to fill the hungry period, early in the rainy season.

It has also been shown that for areas where a preference for floury grained varieties is expressed, any new maize cultivars should be selected for a high flour-yield per pound of grain. The available floury local varieties can serve as a source of germplasm with this characteristic.

4. MAIZE MATERIALS IN NIGERIA AND THEIR PRODUCTIVITY

4.1. INTRODUCTION OF THE CROP INTO WEST AFRICA

Maize was an ancient, widely cultivated crop of very high importance in Central and South America, when Columbus discovered the Americas. Several theories have been advanced as to the evolution of this crop plant from wild ancestors. Definite proof of any of these theories has not yet been found. Whatever the evolutionary history, the exceptional variation of maize types, which developed in the widely varying environments of the lowlands, highlands, valleys and mountainous areas of Central and South America, is of prime importance to maize breeders.

How the crop came to Europe and Africa is also an open question. Much has been written on the pre- or post-Columbian introduction of maize into the 'Old world' areas (127). It has been suggested that maize originated in south east Asia, or that a secondary centre of diversity was established in this area, but this is now considered rather doubtful. ZUKOVSKII (141) states categorically that maize came to China only in the sixteenth century. The presence of pre-Columbian maize in Africa has been defended on the basis of ceramic markings of maize ears, reported from Nigeria (63, 64). This question has not yet been solved, but the most plausible assumption seems to be that maize was introduced into West Africa soon after the discovery of the West Indies by Columbus in 1492 A.D. The crop was reported for the first time in 1498. Certainty on the presence of maize was not established until P. DE MAREES mentions the crop, as having been introduced into San Thomé from the West Indies by Portuguese traders. In this case the word 'West Indies' should be taken to indicate Central and South America; it is probable that the maize came from Portuguese possessions in what is now Brazil. In 1686 DAPPER wrote that the Portuguese brought maize from San Thomé to Ghana. Later authors all report that the crop occurred throughout West Africa (86). In 1852 DANIELL stated that maize was grown widely in West Africa and that in several parts of Ghana and the Bight of Benin the crop was considered as one of the main staple foods. In other parts it was grown more 'to vary the constant uniformity of the African diet, than as a commodity for sale'.

A detailed study was made by PORTÈRES on the mode of introduction of various cereal crops into Africa (103, 104). Very convincing linguistic evidence was compiled supporting the entry of maize into West Africa along the Nile valley-Lake Chad route. For West Africa he also recognises the searoute Brazil-San Thomé, along which floury maize varieties entered the coastal areas of West Africa. Portères's survey points out, that names of maize among the northern tribes of West Africa are often related to the Arabic word MASAR which means: Egypt. For example the Hausa name for maize is MASARA.

These two main routes of introduction brought into the country from the north the flinty maize types with generally a light yellow or sometimes white colour, and from the south flinty and floury grained varieties. As will be discussed elsewhere, there is still a quite marked differentiation between various southern types of maize and the northern ones. However in areas of high population density, especially in Eastern Nigeria, imports of maize grains from elsewhere caused an introgression of northern maize types into the southern types. How far south the northern types penetrated originally is illustrated by the name for maize in Idoma division (south west of Benue province). The Idoma-word for maize is analysable into roots, meaning: Hausa Guineacorn, which suggests the role which the Hausas played in spreading the crop (8). The northern maize types are supposed to be related to those of the Antilles or Caribbean Isles and the coastal maizes to those of Guiana and Brazil. STANTON (127) advanced the theory that a particular sample of maize collected in the northern part of Ghana (Tamale) is related to the 'Early Caribbean' race as recognised and described by BROWN (15). This was based on similarities in ear and tassel morphology and grain characters, and supports the suggestion of a Caribbean origin of the northern maize types. Own observations have shown that one particular southern floury maize variety has an internode pattern very similar to that of a variety belonging to the Mexican Tuxpeño race of maize, as described by WELLHAUSEN and others (135). The internode patterns of this variety and of

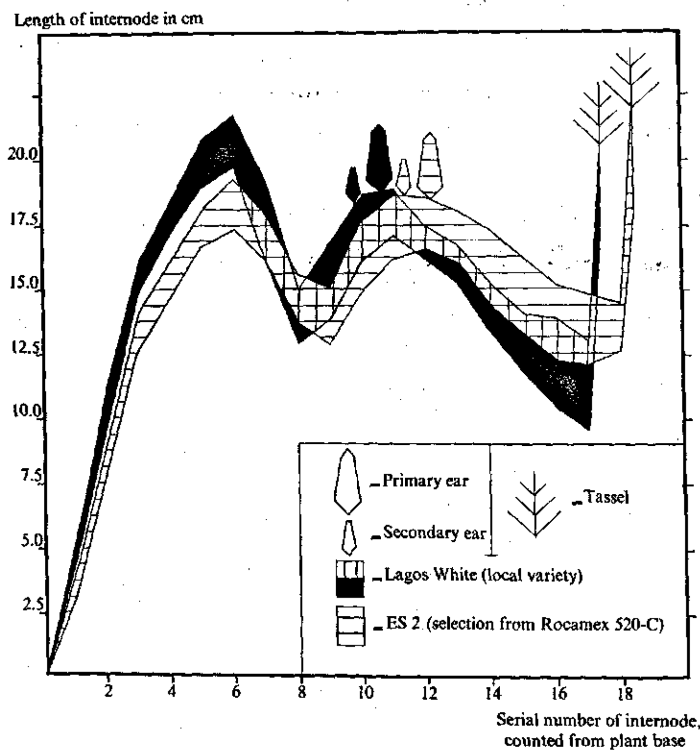


FIGURE 4. Internode patterns of the Nigerian maize variety Lagos White and a variety belonging to the Mexican Tuxpeño Race.

the Nigerian white, floury maize variety, Lagos White, are presented in figure 4. These internode patterns were obtained by setting off the average length of the internodes against their serial numbers, when counted from the base of the plant. The width of the resulting ideogram was obtained by adding or subtracting twice the standard error to, or from, the mean internode length. The ideograms represent therefore the internode patterns and their variability.

The resemblance of the two internode patterns does suggest a close relation between the two types of maize. It was noted that both ideograms compare closely with internode patterns of the 'Southern Dent' type of maize from the south western region of the United States of America (59). A further study of the internode patterns occurring in other Nigerian varieties of maize may well give us a more thorough understanding of the means of introduction of the crop into this country and its origin. The only indisputable fact at present is that the distinction between northern and southern maize is great enough to warrant the hypothesis that maize entered West Africa by two entirely separate routes.

The original introduction should be considered as an influx of maize material, which lasted perhaps for a century, perhaps even for a longer period. It is likely that the original introductions were followed by later ones, which apparently had a far more restricted influence on the distribution of various maize types, as, by then, the crop had spread all over the area and was well established. This is illustrated by the fact that the main division between the 'northern flints' and southern maize types still stands. Evidence for a multiple rather than a single way of introduction may be found in the fact that in the area along the coast several, quite different, types of maize have been found.

4.2. Local maize varieties

4.2.1. *Collection of local varieties*

Many samples of local maize varieties have been collected since 1953. The majority of these were acquired during the first two years, that is prior to the large scale distribution of such new varieties as Mexico 1, Mexico 5 and ES1. The main purpose was to obtain samples of all types of maize in existence in Nigeria in order to study the type distribution and the differentiation which must have occurred in the maize crop by selection under the influence of the environment and of man. In southern Nigeria it is apparent that the varieties cultivated at present, often show characteristics of the new varieties, distributed by the various Ministries of Agriculture. A reconnaisance of the availability of useful characteristics in locally adapted maize materials is of high importance for any program for the improvement of the maize crop. These local varieties have been grown at Moor Plantation, Ibadan and preliminary observations were taken on a few plant and grain characteristics. Stanton, who initiated this work, suggested a maize type distribution on the basis of grain characters only (120, 127). This was a first step towards the recognition of various maize types present in Nigeria. However, much more observational work needs to be done before a clear understanding can be gained in this respect. For instance a study of the internode patterns, so characteristic of various types of maize (59), might lead to very interesting conclusions.

4.2.2. *Geographic distribution of plant characters*

Early interest in the local maize varieties centred on a few characters of importance for the improvement of the crop, and for an understanding of preferences exhibited for various maize types. With the aid of data collected by STANTON (3, 120, 127) and our own observations, an illustration can now be given of the distribution of a few plant characters amongst the local maize varieties collected from various localities in Nigeria. In figure 5 observations made on the locally collected maize varieties are represented by compound symbols which are mapped against the place of origin of the variety concerned. All observations were made on the first or second generation of the collected seed, when cultivated during an early season at Ibadan.

4.2.2.1. Grain characters

Only very few dent maize materials have been collected in Nigeria and these are believed to be recent introductions. The great majority of the Nigerian varieties of maize have a flinty or a floury endosperm. The main distribution area of the floury maize varieties appears to be in the eastern part of Eastern Nigeria and in south western Nigeria, where however also many flinty varieties were recorded. Between these two 'floury' areas a wide belt of mainly flinty grain types intermingled here and there with floury varieties, seems to extend as far south as the delta of the river Niger.

Floury varieties are often white in colour, although several red and some yellow ones, were recorded in Eastern Nigeria. The 'yellow flours' were recorded in the area where flint types occur and they might have resulted from crosses between the white flour and yellow flint types of maize. Both yellow and white grains are found amongst the flinty varieties of the Midwest Region and of Eastern Nigeria. Most of the northern maize types are flint in nature; they can be either white or yellow, although the last colour predominates.

Susceptibility to the fungus *Cochliobolus heterostrophus* in local varieties of maize collected in the western part of Eastern Nigeria, suggests that the yellow and white flinty materials in this area might be recent introductions from Northern Nigeria, which intermingled with southern flinty and floury types (42). The yellow flint found in Warri, Benin and Ondo provinces, west of the Niger, showed however a high degree of resistance to this leaf-blight, which is prevalent in southern Nigeria. These maize types might represent therefore a separate introduction from abroad or an early influx of northern flints to the south, which could have been subjected to a natural selection for higher resistance to this leaf-blight; the northern flint maize types are characteristically highly susceptible to *C. heterostrophus*. (More details on resistance to this disease are given in section 7.2.2.3.).

In Western Nigeria all floury varieties proved to have a white grain colour, but in Eastern Nigeria floury maizes sometimes have red coloured

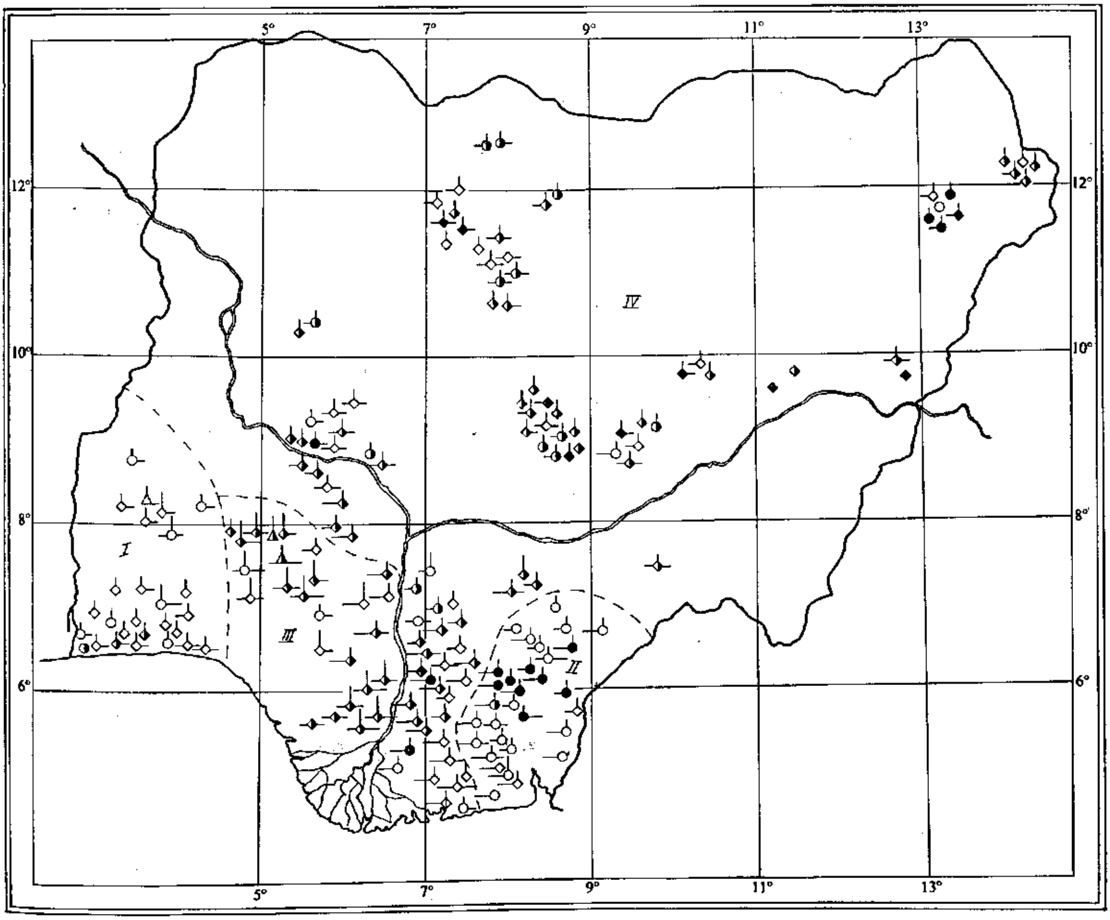


FIGURE 5. Distribution of various plant characteristics of local maize varieties in Nigeria.

LEGEND:

Endosperm types:	round symbol:	floury grains
	triangular symbol:	floury flint or dent grains
	diamond symbol:	flint grains
Colour of grain:	solid symbol:	red, brown or blue grains
	half solid symbol:	yellow grains
	hollow symbol:	white grains
Tasseling time:	no pointer to the left of the symbol:	< 45 days
	short pointer to the left of the symbol:	45–63 days
	long pointer to the left of the symbol:	> 63 days
Seed row number:	no pointer to the right of the symbol:	< 14 seed rows
	short pointer to the right of the symbol:	14 or 16 seed rows
	long pointer to the right of the symbol:	> 16 seed rows
Plant height:	no pointer above the symbol:	< 1.2 meters
	short pointer above the symbol:	1.2–2.2 meters
	long pointer above the symbol:	> 2.2 meters

grains. The red or blue grain colours were not found amongst the flinty maize types in southern Nigeria. In Northern Nigeria however quite a few flint and floury varieties proved to be of a red or blue grain colour.

4.2.2.2. Tasseling time

The time taken by a maize plant to reach male anthesis is influenced by many factors. Detailed information is given in section 5.5. Here we are concerned with the tasseling behaviour of Nigerian maize varieties when grown during an early season at Ibadan. It should be noted that the time to maturity is considerably prolonged when these varieties are planted in more northerly locations.

South western Nigeria is the home of early varieties of maize, reaching tasseling stage within forty five days and maturity within approximately eighty to ninety days. More early maturing varieties can be found scattered throughout Northern Nigeria, although the majority of the northern maizes is of a medium maturity, reaching anthesis in fifty to sixty days. Medium to late varieties are characteristic for the Midwest Region and Eastern Nigeria, with a tendency for the varieties originating from more southerly locations to take longer in reaching tasseling stage.

As yet unexplained deviations from the general distribution of these plant characters do occur. For example, a few early varieties were recorded in the Akure-Owo area and in Eastern Nigeria around Bende and Afikpo. It is however of importance to note the general picture, showing vast differences in tasseling responses between varieties collected from the south west corner of Nigeria and the south eastern part, in both of which white floury varieties are the dominant maize types.

4.2.2.3. Plant height

Varieties with very small plants were recorded, strangely enough, for six of the Eastern Nigerian varieties of maize, of which the time taken to reach tasseling varied from early to late. Tall varieties (larger than 2.2 meters) were recorded in Ondo, Benin and Warri provinces; few small varieties were found in this area. The great majority of the varieties from elsewhere in Nigeria developed plants of 1.2 to 2.2 meters in height, whether belonging to early, medium or late tasseling maize types.

Height is one of the decisive factors determining the plant's resistance to storms, usually accompanying the rains. Inclusion of tall growing local materials might be an unwise step to take in a breeding program.

A subsidiary observation revealed that invariably the tall maizes in the three provinces listed earlier, had a high ear placement, that is, on the sixteenth node or higher. This might be one of several reasons why even these tall maize varieties have proven to give only relatively low yields. See sections 4.3. and 4.4.

4.2.2.4. Number of rows of seeds per ear

Both in Northern and Eastern Nigeria there is a mixture of maize varieties bearing a low (twelve or less) or a medium (fourteen or sixteen) number of seed rows on the ears. The low number of seed rows per ear predominates in Northern Nigeria, apart from a few distinct areas around Zaria and in Ilorin and Niger provinces. In Eastern Nigeria, a medium number of seed rows occurs in a fifth of the varieties which are distributed throughout the area. The remaining varieties have a low number of seed rows. Most of the Midwest Region and Western Nigeria, however, have predominantly a medium number of seed rows, with a few deviating centres. In northern Ondo province, and in the eastern part of Warri province, several local varieties of maize are cultivated with more than sixteen seed rows. In the southern parts of Abeokuta and Ijebu provinces, a low number of seed rows predominates.

4.2.3. *Grouping of the local maize varieties*

Only a few, important, characters have been studied and as pointed out earlier, much investigational work has still to be undertaken before a recognition of distinct maize types will be possible. However, with the data available at present we might suggest, that for breeding purposes (choice of breeding materials from amongst the local maize materials) four groups of varieties could be distinguished provisionally:

1. Western Flours: White floury grains, often showing some flintiness in the endosperm. The plants are early maturing and of medium height. The ears have up to sixteen seed rows.
2. Eastern Flours: White floury grains, larger in size than the Western Flours. Red and blue grains are not uncommon. These maizes are characterised by a medium to late maturity time, although developing only to a medium height. The ears have a low to medium number of seed rows (less than sixteen).
3. Southern Flints: Predominantly yellow flinty varieties with a medium to late time to maturity. The plants characteristically are tall (over 2.2 meters) and have a medium to high number of seed rows per ear (more than twelve seed rows).
4. Northern Flints: Predominantly yellow flint varieties, although a white grain colour is not uncommon. The majority of the varieties are of medium maturity time, although early varieties do occur regularly. The plants are of medium height and have a low to medium number of seed rows (up to sixteen seed rows).

Between the Northern Flints and the southern grain types a broad transitional zone is present, which reaches very far south in Eastern Nigeria, because of the intensive trade in maize grains from more northern localities into this area. The purest types occur apparently in Western Nigeria and the Midwest Region, both forming at present Nigeria's main maize belt, which has not been a maize importing but a maize exporting area. This might explain the lesser degree of mixing in these areas. However, changes are occurring in this pattern, as the fast growing large towns in Yorubaland now demand their maize supplies even from the Middle Belt areas. Also in the area of the Eastern Flours only a low degree of contamination has apparently occurred.

The four groups given are still quite heterogeneous and are only based on plant characters, which might be of direct importance for the maize improvement programs. STANTON (120) recognised for instance within the Western Flours two groups indicated with the name Ijebu and Egbado and within the Eastern Flours the Ogoja and Ibibio types. These more detailed classifications will have to be verified with the aid of careful observations on the morphology of the Nigerian maize varieties.

4.3. NEWLY INTRODUCED VARIETIES OF MAIZE

Occasional introductions of maize into West Africa have been made probably ever since the crop was brought into the country for the first time. Since late in the last century the number of test plantings with new varieties of maize increased, but large scale introduction has only occurred since 1950. Presently a large collection of maize germplasm is held at Ibadan. Most material originated from Central and South America, the Caribbean Isles and from West Africa.

Many trials were carried out to screen well performing introductions for their yielding ability. As a rule these trials were restricted to three or four localities, situated in various environments. Outstanding materials have been tested subsequently at many sites and over several years. A number of salient points which emerged from these trials, will be discussed.

Most yield tests carried out in the first few years after the onset of a rust disease in 1949, were characterised by tremendous percentage differences in yields between the local varieties and some of the introduced ones. For instance in 1954 the floury flint varieties Mexico 1, Mexico 7 and Sicaragua yielded on the average eighty per cent more than the local varieties, which gave yields of 1,100 to 1,200 lb. per acre over six localities in Eastern Nigeria (132). Similar observations were made in Western Nigeria, where some introduced varieties (Tsolo, White Tuxpan) yielded some fifty to sixty per cent more than the local varieties (131). High percentage increase in yield by cultivation of some introduced varieties compared with local maize varieties has remained valid ever since, although at a somewhat lower level, since the at one time very virulent rust disease now levies a lower toll from the local maize varieties.

During 1955, for instance, the varieties Mexico 1 and Sicaragua scored in many trials throughout the main maize belt of Western Nigeria, average yield increases respectively of forty six and fifty six per cent over the yield level of the local varieties (122). CHINWUBA reported in 1962 yield increases varying from twenty to fifty five per cent for the varieties EAFRO 231, EAFRO 237, Mexico 5 and ES1. These figures were obtained from yield trials carried out throughout Nigeria (27).

The important point emerging from these observations is the large increase in yield obtainable by mere introduction of other maize material. In this respect it is not relevant that most of the varieties were not adapted to the Nigerian environments nor suited to the requirements of its peoples. Cross testing of local varieties from one locality in other environments has not yet led to a discovery of local varieties of maize, promising from the point of view of yielding ability. These facts led to the conclusion that new varieties had to be bred from high yielding introductions, which however, have to be modified to suit local requirements by inclusion of local maize materials.

Outstanding maize materials proved to be available in the collections acquired from Mexico, mainly maize varieties belonging to the Tuxpeño race, and from Trinidad and San Domingo in the Caribbean Archipelago.

4.4. Productivity of maize varieties in yield trials

A good number of experiments has now been carried out throughout Nigeria with several maize varieties. It seems of interest to study the overall productivity of the crop in these trials and to compare this with data available from agricultural surveys. The average yields of sole crops of maize grown during the main growing season were reported to vary from 500 to 1,500 pounds per acre in Western Nigeria on the basis of data collected in 1950 (106). In Eastern and Northern Nigeria they varied from 700 to 1,100 pounds per acre. The overall average yield per acre amounted to 1,012 pounds. This is below the world average which was given as 1,440 pounds per acre during the period from 1948 to 1954 (140).

From some hundred and sixty yield trials in which the two introduced varieties, Mexico 5 and Trinidad, were compared with local varieties of maize in the period from 1952 to 1962, average performances were estimated. The trials were divided into four groups according to the main environments (70):

1. Wet rainforest, comprising the area south of the 60 inch isohyet and covering most of Eastern Nigeria and the south eastern part of Western Nigeria.
2. Dry rainforest, covering the remaining part of the rainforest area.
3. Derived savannah, fringing the forests and forming the transition to the southern guinea savannah.
4. Southern guinea savannah.

The average yields obtained are given in table 6. The majority of the trials has been carried out at plant populations of approximately 12,000 plants per acre and without fertilizer application. The higher productivity of the maize cultivat-

Table 6. Average yields of maize varieties, grown in 158 yield trials throughout Nigeria during the years from 1952 to 1962. Yields are expressed in pounds per acre.

Variety	Location and numbers of trials				
	Rainforest		Derived	Southern	
	Wet	Dry	Savannah	Guinea Savannah	Average
	44	91	9	14	
Local varieties	914	1,347	1,080	860	1,168
Mexico 5	1,259	2,078	1,648	1,173	1,693
Trinidad	1,445	2,078	1,780	1,145	1,698

ed in the dry rainforest areas illustrates why the main maize belt developed there. The future uses of fertilizers and of improved plant materials will go far to double the output of the maize crop per unit area of land.

The average productivity of the local varieties in yield trials surpassed the overall average yield per acre of local maize on farmland, estimated at 1,012 pounds, by approximately fifteen per cent. It might be inferred from this table that such newly introduced varieties as Mexico 5 and Trinidad would give a yield of approximately 1,450 pounds per acre, that is fifteen per cent less than the figure obtained in yield trials, if cultivated by the farmers. This represents an increase of 45 per cent above the yield of the local varieties.

In fertilizer trials it has become apparent that increases in yield obtainable with the application of fertilizers to the maize crop, will be considerably larger with some of the newly introduced varieties than with many of the local varieties. These varieties apparently respond far better to higher fertility conditions than the local varieties. The reverse also seems to be true. Under adverse conditions the higher yielding introduced varieties decline in productivity very sharply, whilst the local varieties seem to withstand such conditions, especially drought periods, far better. However, the yield levels of the local varieties are so far below those of some introduced varieties, that as a rule only at uneconomically low yield levels will the local varieties surpass the others in productivity.

4.5. Conclusions

The maize crop was brought to West Africa probably towards the end of the fifteenth century, via Egypt and through direct introductions along the coast. Within Nigeria the distribution of various plant characters shows a clear differentiation between a large northern group of maize varieties and various southern groups. The variation amongst the latter is indicative of the varying origin of the southern maize varieties.

Several newly introduced varieties of maize proved to outyield the local maize varieties to a great extent. These materials are therefore considered to be of high importance for the breeding programs.

5. BOTANICAL INVESTIGATIONS

5.1. The growth and development of the maize plant

The maize plant shows a very fast development in the tropical environment. In southern Nigeria the maize plant shoots up from an approximately one foot high plant to its full size, often ten to twelve feet high, within the short period from three to four weeks after planting to six or eight weeks after planting depending on the maturity index of the plant. The late maturing ones show this tremendous development in the course of only four weeks. Of course earlier maturing ones take an even shorter period. It was noted that far higher yielding varieties, introduced from elsewhere (Mexico 5, EAFRO 231), showed a similar pattern of growth as the long maturing local varieties. A study was therefore made of the development of a local variety (Lagos White) and a variety bred from introduced materials (ES2) in order to investigate what differences existed between these, and to explain the variation in yielding ability (48).

Growth observations were made on plants grown under the routine agronomic practices applied at Moor Plantation, Ibadan, during the early season of 1960. Both varieties were planted in replicated plots at the end of March, immediately after the onset of the rains. They received a routine application of

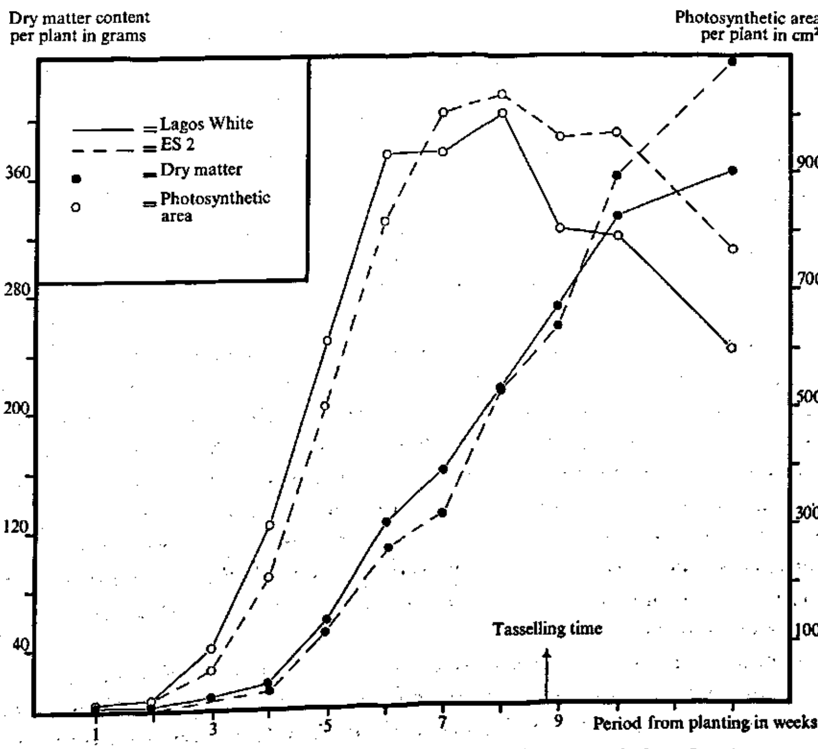


FIGURE 6. Increase in photosynthetic area and dry matter in two varieties of maize.

fertilizers at an age of three weeks. They were grown at a spacing of one foot, on ridges three feet apart, with one plant per stand. The crop gave a yield of 3,000 lb. per acre for ES2 and 2,000 lb. per acre for Lagos White.

Basic information was collected by determining the dry matter content of all parts of sampled plants and the area of leaves, leafsheaths and husks. The observations are presented in figure 6.

The two varieties developed in a more or less parallel manner during the first six weeks, although both in dry matter content and in photosynthetic area the local variety was more vigorous. The variety ES2 surpassed Lagos White in photosynthetic area during the seventh week and reached its slightly higher maximum in the eighth week, a few days prior to tasseling. Both the laminae and the leaf sheaths played an important role in the increase of photosynthetic area. The data proved that the net assimilation rate (N.A.R.), the production of dry matter per unit area of photosynthetically active plant parts (laminae, leafsheaths, husks of ear) per unit of time, was quite variable. The values averaged 70 and 72 $g/dm^2/week$ respectively for the two varieties. The salient point is that the N.A.R. was similar for both the low yielding local variety and the high yielding selection, ES2. Under influence of the environment the N.A.R. also varied similarly in both cases. The differences between the yielding capacities of these varieties cannot be explained therefore by differences in efficiency of the photosynthetic apparatus.

The leaf area index (L.A.I.), a proportion indicating the photosynthetic area of the plant available per unit area of land, was calculated. The values are listed in table 7.

TABLE 7. Leaf area indices for two varieties of maize.

Week	1	2	3	4	5	6	7	8	9	10	12
Lagos White	.01	.08	.07	1.15	2.39	3.50	3.49	3.85	3.04	2.98	2.33
ES2	.01	.06	.28	.83	1.92	3.09	3.75	3.90	3.62	3.64	2.87

This proportional figure shows clearly the rapid increase in leaf area of the maize crop from the fourth till the seventh week from sowing. It is of importance to realize that in the fourth week L.A.I. already reached unity, with the spacing used in this experiment. Within another two weeks, L.A.I. reached a value of 3.5 slowly rising to four in the eigth week. Senescence of the leaves then caused a decrease. In this crop, important shading effects on leaves are already to be expected from the fourth week onwards. The photosynthetic activity of the lower leaves especially might be impaired. The main fact emerging from a study of the L.A.I., is that the local variety apparently lost its available photosynthetic area faster than the variety ES2.

The relative growth rates (R.G.R.), the rate of increase in dry matter per unit weight and per unit time, of various plant parts were also studied. Most organs of the plant showed a high initial value of the R.G.R., which decreased rapidly. In both varieties the stems deviated from this pattern in that they had a slow initial R.G.R., rising to its maximum value in the fourth and fifth week, characterised by a rapid elongation of the plants. The laminae of the variety Lagos White also showed a similar growth pattern. The roots had relatively high values of R.G.R. during the first six weeks of growth, and again in the eighth week, concurring with the elongation of another set of braceroots, providing the plant with its final anchorage.

Negative values of R.G.R. were observed for the tassel and the silks in the time that the tassel lost its pollen (during anthesis) and for the silks one to two weeks later, at which time accidental loss of dried silks often occurs. Negative values of R.G.R. occur for most plant parts, apart from the developing ear, in the tenth week and from then onwards. It was estimated that in the tenth to the twelfth week, that is, from the tenth to the twenty-fifth day after silk emergence, ninety-five per cent of the newly assimilated and the translocated dry matter were accumulated in the ear. This is likely to become even higher during the last few days of the effective life of the maize plant lasting up to approximately thirty-five days from silk emergence in these varieties.

From only a few days after pollination, approximately in the ninth week of growth, the ear starts a fast development, aided by the mechanism built by the plant in the preceding weeks of its existence. The top leaves seem to be especially important as pointed out in defoliation trials in Rhodesia (112). Removal of the tassel and three top leaves at anthesis reduced yields considerably. From whatever angle the growth processes of these two varieties were considered, the retention by the introduced variety ES2 of a larger potential photosynthetic area from the eighth week onwards, seems to be a major factor controlling the higher production of dry matter during the last part of the growth period of the ES2 plants, when compared with that of Lagos White plants.

Earlier we mentioned that N.A.R. was similar for both varieties and had the same deviations from the average at various stages of development, probably caused by differences in environmental factors. Also the leaf area ratio (leaf area per unit of dry matter) was more or less the same for the two varieties. Both facts point to the similarity in size and efficiency of the photosynthetic mechanisms.

The leaf area index (L.A.I.) shows in clear terms the differences between these two varieties, grown at equal spacing. The variety ES2 increased its leaf area further with additional laminae, when Lagos White had come to a standstill. The ES2 had on an average one and a half more leaves than Lagos White. Further, the latter variety had a more rapid loss of leaf area by senescence. The more pronounced longevity of the photosynthetic area in ES2 appears therefore the major determinant of the higher production of dry matter by this variety. The importance of this fact is, that apart from selecting for a large leaf area, selection of the local material should be directed towards an 'active leaf area-retention' or 'longevity' characteristic of plants having otherwise desirable features.

5.2. Floral biological observations

Many detailed studies have been made on the floral biology of maize. Much of the knowledge has been summarized by Kiesselbach and Bonnet (11, 71) and many of the facts are as valid for West Africa as they are elsewhere. We refrain therefore from summarizing these data once more and will point out only a number of observations, of relevance to particular problems met with in the West African environment. The facts are considered from the breeder's point of view in relation to controlled pollinations; the available data are not complete, but might invite other workers to a further study.

In two varieties, Lagos White and ES2, observations were made on the duration of the pollen-shedding period. This was approached in two ways. Ten plants of each of the two varieties, growing on alternating ridges on a field, were observed for the dates on which stamens emerged from the spikelets in the maize tassels. The duration of the period of emergence of new stamens was taken as that of the period of pollen shedding, as a stamen sheds its pollen almost immediately after it has appeared from amongst the various glumes of the spikelets. Both varieties tasselled in the same week (last week of May 1960). The variety Lagos White took an average of 3.8 days and ES2 of 4.1 days for the emergence of all stamens. In these observations only such newly emerged stamens were recorded as were apparent to the observer at ground level; the tassel of these varieties is often placed at ten feet or more above the ground. In addition, more detailed counts of emerging stamens were made on an average tassel of each of the two varieties for comparison with the crude field observations. When counting, the newly emerged stamens were removed from the tassel. The observations were made at daily intervals. The data obtained are listed in table 8.

Table 8. Number of stamens emerging on various days during the pollen-shedding period of two maize plants.

Day from first appearance of stamens	Variety	
	Lagos White	ES2
1	122	342
2	1717	2351
3	3449	2251
4	1459	1463
5	69	1379
6	24	453
7	9	135
8	–	90
9	–	15
10		
Total	6849	8479

These figures illustrate that in the earlier field-observations only those days were recorded, during which relatively great numbers of stamens emerged. The pattern of stamen-emergence confirms observations elsewhere (71), that the first stamens appear on the tip branch of the tassel, at two thirds of its length from the base. The emergence of stamens then proceeds over the entire tip branch and simultaneously halfway along the other tassel branches. From then onwards, it spreads over the entire length of the various tassel branches.

In the local variety the production of pollen (emergence of new stamens) apparently lasts approximately until the fourth day. This largely prevents the occurrence of self-pollination, as the relation between tasseling and silking time at Ibadan can be expressed in the formula: tasseling time $= 1.01 \times$ silking time $- 4.8$ days (35). In the second variety (ES2), however, the emergence of stamens is spread over two more days and tails off less suddenly than in the case of Lagos White. It is our opinion, that this longer period of stamen emergence is an advantage, in spite of a probable slight increase in natural self pollination, as most of the maize crop in Nigeria flowers at the height of the rainy season. If continuous rain occurs, as happens in several areas, fertilisation of the stigma's is largely prevented and a low percentage seedset results. A longer spread of the stamen-emergence would increase the availability of pollen over a longer period. The longer pollen shedding period also allows for more certainty on the availability of pollen for controlled pollinations to be carried out on selected materials. In special cases the pollen, which is normally viable for one or two days, could be kept viable for up to five days by keeping it under refrigeration (139).

The influence of pollination and the use of paper bags (pollination bags) on the development of silks was studied at Ibadan. The observations reported here were made on the variety Tsolo in 1958. The lengths of silks were measured daily on variously treated earshoots:

1. Ear shoots, bagged prior to silk emergence. No pollination was allowed to occur.
2. Ear shoots, bagged prior to the emergence of the silks, pollinated four days from silk emergence and rebagged after the pollination.
3. Ear shoots, not bagged and exposed to open (natural) pollination.

The silks were also observed for drying symptoms and for the moment when no more fresh silks were available. The various measurements and other data collected have been presented graphically in figure 7.

The observations on the non-pollinated, bagged ears are represented with circles in figure 7. These ears produced long silks, which also required a long time before the first symptoms of drying up were observed and before all silks had died back (represented by a small black arrow at the end of the relevant curve). In the case of the pollinated, not bagged (represented by triangles) or bagged (represented by squares) ears, the silks remained shorter and took less time to die back. All silks had dried up twelve to fourteen days from silk emergence, if pollination was allowed. A similar figure (twelve days) was recorded in the Congo, where pollination studies indicated that pollination is most successful from the third till the seventh day after silk emergence (139).

After fourteen days have elapsed, the pollination bag can safely be removed to allow for a free development of the ear, without danger of contamination with undesirable pollen. On the non-pollinated ears, the silks took nineteen days

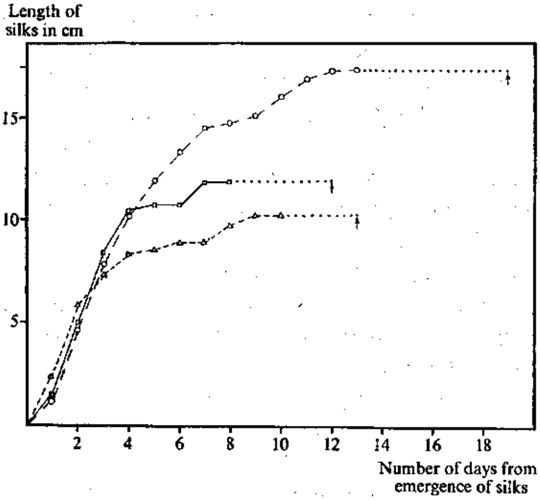


FIGURE 7.
Graphical representation of observations on the growth of stigmas on maize ears.
The circles represent: non-pollinated, bagged ears; the triangles: naturally pollinated, non bagged ears; the squares: controlled pollinated, bagged ears. The arrows at the end of the curves indicate the moment that all silks had dried up.

to dry up completely. This is indicative of the fact that some receptive silks remain available for more than two weeks and a half from the moment that the first silks emerge.

It seems opportune to mention here the problem of high relative humidities prevailing at the time of pollination. Certainly the early season pollination period in southern Nigeria usually coincides with frequent rainfall and high relative humidities. This poses severe problems for the carrying out of controlled pollinations, as very often tassels turn mouldy in the pollination bags, placed on them for the collection of the pollen. This can occur in the course of one or two days, depending on the 'sanitary' state of the tassel concerned. Some experiments have been done with various types of tassel bags and of ear bags to determine the more suitable ones. The main aim was to find tassel bags which allowed for a good evaporation of moisture from the tassel without undue increase in the relative humidity within the bags, so conducive to the development of moulds and also of aphids, which sometimes colonise bagged maize tassels to such an extent, that no pollen can be gathered. Suitable bags are now made locally from a light grade, pure ribbed Kraft paper. This paper is quite thin but sufficiently strong to allow for its use in the field. Tassels in the locally made pollination bags are less often covered with moulds than when commercial pollination bags are used.

A comparison was made by placing fresh tassels in locally made tassel bags and others in commercial ones. The percentages loss in weight recorded for these samples were as follows:

	in locally made tassel bags	in commercial tassel bags
after one day	20 per cent	12 per cent
after five days	43 per cent	28 per cent

The commercial tassel bags proved therefore far less suited than the locally made ones. Waxed paper bags, which are also available for pollination work, appear to be even more unsuitable under the wet conditions prevailing during the pollination season in Nigeria. The cost of the preparation of locally made tassel and ear bags has been worked out and proved approximately one penny for one pair, consisting of a tassel bag and an ear bag. This includes costs of paper, glue and labour.

5.3. Development of the grain

It has been shown in section 5.1. how the developing ear demands all newly assimilated dry matter produced by the maize plant. Even some of the dry matter of various plant parts is apparently transferred to the growing ear. All these processes start as soon as the silks are exposed to pollination, because the atmosphere usually abounds with maize pollen at that time. Bonnett (11) describes how within five minutes after the pollen grain lights upon the silk, it germinates and begins to enter. Fertilisation of the nucleus and endosperm nucleus happens within approximately twenty seven hours. Division of the nuclei starts within a short time from that moment.

The pollination process and the subsequent development of the ear usually coincide with a high rainfall, as the maize is sown with the onset of the rains. The late season crop, grown in Western Nigeria, however often ripens in a relatively dry environment at the end of the 'small' rains. The deleterious effect of rains during the tasseling-silking period was noted also in Brazil where a high positive correlation was found between the number of dry days in this period and the ultimate yield of the crop (93).

Observations on the development of the seeds were made in the variety Trinidad, a composite of several 'Trinidad' lines from Brown's collection (15). From the day that the first tassels started anthesis, twenty plants were chosen each day and tagged, for ten consecutive days, that is during the major part of the tasseling period of this variety. The twenty plants of each of the ten groups were harvested one at a time on twenty days starting from the eleventh day until the thirtieth day after the emergence of the silks of the relevant plant. Observations were made on the moisture content, fifty grain weight and the viability of the developing seeds. The results were plotted against the time of harvesting, that is the number of days from silk emergence, and are shown in figure 8.

As will be seen from the graphs the grains had not reached full maturity at thirty days from silk emergence, if maturity is taken to be the moment that the grains reach hundred per cent viability. The rainy weather conditions and the high relative humidity prevalent at the time of observation probably retarded the maturing processes somewhat. The duration of sunshine especially was much restricted because of overcast weather.

The moisture content of the grains was very high when the observations started. Between 15 and 18 days from silk emergence the moisture content dropped in the course of two to three days from 85 to 65 per cent. From then

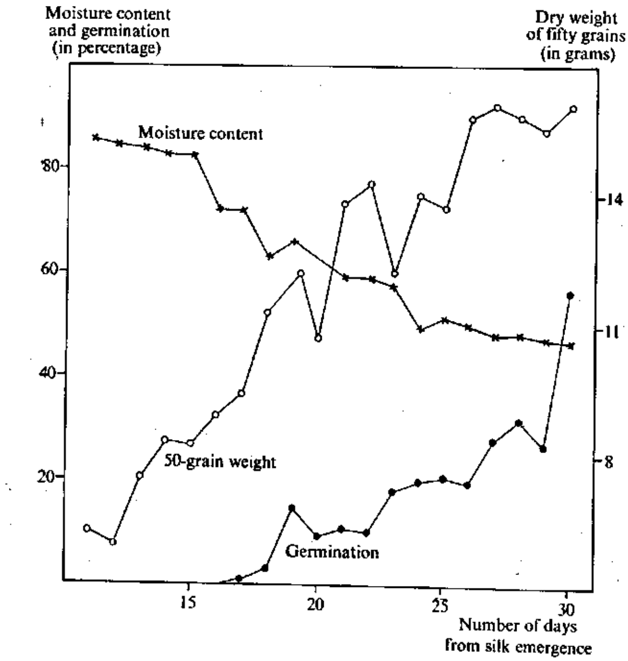


FIGURE 8.
The moisture content of the seed, germination percentage and fifty grain-weight (dry) at various numbers of days from silk emergence.

onwards it declined regularly. It is presumed that a faster decrease would have occurred if the weather had been more conducive to transpiration.

The decrease in moisture content concurred with a rapid increase in dry weight of the seeds from approximately 6 grams per fifty seeds at 11 days from silk emergence, to 16 grams after 30 days. This is a regular increase of half a gram of dry matter per day and per fifty grains.

The first germination symptoms, growth of the radicles, were observed on samples taken at 17 days from silking. Plumules started to develop from grains harvested after 19 days. It may be worthy of note that the first signs of viability were observed in the period, during which the seed increased rapidly in relative dry matter content (that is: decreased in moisture content). The germination percentage showed a steady increase with the time after silk emergence. The samples taken at thirty days had a suddenly increased viability, thus indicating that the grains were approaching full maturity rapidly.

For the field worker it is always difficult to point out exactly the time when full maturity of the crop has been reached. In maize this is often done by examining the appearance of the foliage and the husks. The colour changes of the husks were therefore studied in correlation with the development of the ears. The first yellowing symptoms of the outer husks were observed 20 days after appearance of the silks. Seven days later all harvested ears had only dried up husks. At this time most of the top leaves (above the ear) started to die back very fast. It is estimated that approximately a week after the moment that all husks had dried up, this variety of maize (Trinidad) was fully mature.

From this moment the post-maturity drying period starts, which is so important in obtaining seeds with a reasonably low moisture content. Only maize material which allows for a quick moisture-loss after maturation, will give a product largely free of pests, diseases and pregerminated grains.

5.4. Moisture content of the grain at harvest

We have now followed the development of the maize plant from germination to anthesis, and further until it approached maturity. At harvesting time again, the moist conditions in almost all the maize growing areas of Nigeria (apart from the crop cultivated during the late season in Western Nigeria or under irrigation in the dry season) constitute a serious problem, more so in southern Nigeria than in the Middle Belt. Low vapour pressure deficits do not permit the grain to lose sufficient moisture rapidly. This often results in the occurrence of pregerminating grains, fungal and bacterial rots, and favours infestation of the ears by insects. Important diseases are the black grain disease, caused by *Botryodiplodia theobromae*, and banded sheathrot, caused by *Rhizoctonia solani*, often accompanied by bacterial rots.

From many trials in which local varieties were compared with introduced materials, it is apparent that a spontaneous selection must have occurred in the local materials for quicker drying types. Local maize varieties nearly always have a considerably lower retention of moisture at harvest than other materials, even when these tassel at the same time (37). This may be one of the reasons why local varieties often show a shorter longevity of their leaves, which in its turn is responsible for lower yields.

The difference in death rate of the leaves between two varieties of maize, a local one and an introduced one, is illustrated in table 9. The two varieties had been planted on the same day and tasseled with a day's difference. The number of leaves still functioning was counted at weekly intervals from a week after tasseling. The total number of leaves produced just before tasseling time, that is at eight weeks from planting, has been given also.

TABLE 9. Death rate of leaves in two varieties of maize.

Period from planting in weeks	Number of leaves still functioning	
	Lagos White	ES2
8	16.20±.24	17.68±.23
10	8.50±.36	10.20±.32
11	7.72±.34	9.04±.32
12	6.66±.34	8.18±.32
13	3.16±.42	5.88±.47
14	.10±.04	2.22±.36
15	.00	.00

Seed set occurred during the ninth week. Lagos White had therefore virtually no more functionable leaf area after thirty five days, whilst ES2 took forty two days for its leaves to dry up completely. See also section 5.1.

At Ibadan, local varieties grown as an early crop are often harvested with a moisture content of twenty to twenty two per cent. Mexican materials grown under similar conditions show a moisture content of twenty six to thirty per cent. This characteristic prohibits the use of this material in the wetter parts of the rainforest in southern Nigeria (108).

The observation mentioned earlier that local, quicker drying maize varieties lose their leaves sooner after seedset, was followed up by a study of the influence of various spacings on the moisture retention at harvest for an early season crop at Ibadan. Care was taken to maintain the same number of plants per unit of area, that is a population of 14,560 plants per acre. The variety ES2, which has a high moisture retention at harvest, was planted at two differently spaced populations: the first at one foot apart on three feet ridges (the usual practice) and the second on six feet ridges with two rows of maize at one foot apart on top of the ridge and one foot between the plants within rows. The moisture regime of the air, the moisture deficit, was studied with the use of 'Piche' evaporimeters placed at ear height within the crop and protected against radiation. From silking time onwards the quantity of water evaporated from the standard paper disks of this equipment was measured daily until the time of harvest.

In the population planted on three feet ridges the evaporimeters placed in the furrows and on the ridge, showed a similar loss of water, approximately 103 cc, indicating that this crop had a more or less closed canopy of leaves. As expected, in the six feet plantings the air between the double rows of plants in the wide furrows was considerably drier, 108 cc of water being evaporated in the same period. Between the plants a lower evaporation of 99 cc was observed, thus indicating a lower moisture vapour deficit between the closely spaced plants on top of the six feet ridges and a marked increase in this deficiency towards the furrow, where turbulence of the air was not prevented by the maize leaves.

The influence on the moisture content was rather limited. The grain harvested from the six feet wide ridges contained on the average 29.5 per cent moisture and that from the three feet ridges 31.1 per cent. A significant reduction in moisture content of 1.6 per cent only was obtained. These facts point once more to the intrinsic nature of the drying process of the grain, a problem which is unlikely to be solved by cultural practices.

In other parts of the world some work has been done on preharvest sprays, applied in order to kill the remaining leaves and to induce a quicker loss of moisture from the ears. Spraying and defoliation trials showed mostly small effects, if any (4, 84, 92). It was noted however that severing the ear from the plant did allow a faster drying, even after death of all leaves, indicating a continued flow of water to the ear (31). Defoliation or postharvest sprays before maturation of the grains can however hardly be accepted as this, apparently, invariably leads to a loss in yield (92). This again goes to show that a solution to this problem is to be obtained by utilising the quick drying characteristics of the local varieties.

One of the probable reasons for the quicker drying rate of local varieties, the shorter period of retention of green leaf area, has already been mentioned.

Other factors have been considered also. One of these is the question of the role, which husks play in the loss of moisture from the seed. When dry, they supposedly restrict the loss of moisture from the ear, unless a flow of water from the ear to the husks continues even after the husks have died back. Ears do lose some of their moisture by transpiration through or via husks. This was proven by covering a number of ears with polythene hoods at twenty, twentyfive or thirty days from the moment of silk emergence. The moisture content of the grain and of the cob was determined at 45 days both on the bagged ears and on ears which had not been covered with a polythene bag. The data obtained are listed in table 10.

TABLE 10. Moisture content of ears, covered with polythene hoods at various times from silk emergence, and of controls.

	percentage moisture	
	in grain	in cob
Ears, not covered	19	16
Ears, covered after 20 days	22	17
Ears, covered after 25 days	20	17
Ears, covered after 30 days	27	22

The ears which had not been covered were drier than any of the others. This shows that evaporation direct from the ear plays a significant role. However, the differences between the covered ears were not as expected. The last covered ears, showed by far the highest moisture contents. The ears, in this case, had been covered after the husks had died back. When covered before the dying back occurred, the moisture content was much lower, although evaporation must have been considerably reduced. The prevention of moisture loss from the ear by the presence of dried husks seems in any case acceptable. Covering the ear at thirty days from seed set with polythene amounts more or less to increasing almost infinitely the efficiency of the husks in preventing transpiration from the ear. This supports the observation that a greater number of husks is correlated positively with higher moisture contents of the seeds at harvesting time. Increasing diameter of the ear, which characteristic correlates positively with the number of husks available, also increased the moisture retention, probably as a larger quantity of moisture has to be released. The above observations were made on flinty floury (Mexico 5), floury (Lagos White) and flinty maize material (Trinidad).

5.5. MATURITY RATINGS

5.5.1. *The problem*

It is well known that the environment determines to a large extent the period taken by a maize plant to reach anthesis and the subsequent stage of maturity. For example, varieties classified as medium maturing ones at Ibadan often take much longer to mature, when transferred to more northerly locations in Nigeria, whilst maize from northern locations, where they may take ninety to one hundred days to mature, often completed this process at Ibadan in an extremely short period. The knowledge of a satisfactory maturity rating for maize varieties is of importance to the maize worker and farmer. The maize breeder can hardly be expected to carry out any planned recombinations of selected materials in his crop unless there is a precise knowledge of their behaviour, especially in terms of flowering responses to environmental factors. A lack of this knowledge will, of course, place considerable restrictions on such a program. Also, the farmer needs information on time to flowering and on the duration of the maturation process in order to enable him to plan the cropping program.

The problem of maturity ratings in maize has received much attention from research workers in other parts of the world. Difficulties arise at once with the term 'maturity', which can be defined in many different ways. It seems essential that the definition accepted should be practical, that is, easy to apply and reasonably accurate.

The term maturity implies that the plant has been brought to completeness of growth and development. In grain producing crops this moment will be reached as soon as the seeds are ready to serve their reproductive purpose, or when germination approaches hundred per cent. This botanical criterion can be narrowly defined and fairly accurately determined, but is not easy to observe. If maturity is understood as readiness for harvesting the difficulties are greatly increased. The percentage of moisture retained in the seed is not a practical means for a general system of maturity ratings either. Various types of maize grains (flour, flint, floury flint) differ in dry matter content at the moment, that the seeds attain hundred per cent viability. They are influenced differently by environmental factors during the pre-harvesting period. Observations on the dry matter content of the grain are again not sufficiently practical to be used as an indication of maturity. Each of the definitions of maturity implies a series of tests to be made to verify whether a particular group of maize plants is approaching maturity. Dry matter determinations, direct moisture content readings and viability tests are usually impractical for application as a routine, when large numbers of cultivars are to be observed in the course of a breeding program.

In any particular environment, there proves to be a close relation between the flowering time of the maize and the period it takes to produce mature grains. The more easily identifiable stages in the development of the maize plant are the time to tasseling (male anthesis) and the time of appearance of the silks. The variability between varieties in the time taken to produce mature grains seems mainly due to differences in the period from seed emergence to tasseling, although important differences exist in the rate of water loss after attaining the stage of one hundred per cent viable seeds.

The actual moment of maturity, however defined, is extremely difficult to assess by easily applicable field methods. Therefore, the time needed by the plant to develop to maturity is difficult to measure, more so as many methods of assessment are necessarily based on non-essential plant characteristics, that is, hardness of the grain, bleaching of the husks, browning of leaves and so on.

The best alternative seems to be to take the tasseling time, which can be measured easily and correlates well with the variation which occurs in the maturity time of any one maize variety. The major advantage of the method of relating maturity times of maize varieties with tasseling times is that the moment of tasseling can be defined exactly and observed accurately. The moment of tasseling for any one maize plant is the day that shedding of pollen starts from the central spike of the tassel. If a group of plants is considered, the average of these observations is taken for an adequate sample of the population. This proved to coincide with the moment that fifty per cent of the plants have started to shed pollen. The field observations thus become extremely simple and involve little or no skilled labour.

This choice of the tasseling time to serve as a maturity rating calls for a careful investigation of the relation between this characteristic and the theoretical and practical maturity points. There sponse of the tasseling time to various environmental factors (climate, cultural practices) is another point of interest.

Once the behaviour in respect of tasseling and maturity time of a number of maize varieties is known, a series of type varieties, hybrids or inbred lines, can be chosen to cover the practical range of maturity and to serve as standards. Any new material can then be classified in terms of this series. Finally it may be stressed that, although the question of scaling tasseling responses could be solved satisfactorily after much investigational work, the problem remains how and with what speed various types of maize plants develop from anthesis to maturity. Other methods of measuring maturity can provide useful information in this respect, although they cannot serve the purpose of general maturity ratings.

5.5.2. *Type varieties*

Only when material with a relatively narrow gene basis has been grown for several years in various environments in Nigeria, will it be possible to identify a number of type varieties representing various classes of maturity ratings. At present only limited information is available and a tentative series of open pollinated varieties is given in table 11.

TABLE 11. Some tasseling data of frequently grown varieties of maize.

Variety	Tasseling time at Ibadan (average of five years of observations)		
	early season	late season	designation
Mexico 1	61.0 days	65.6 days	late
ES1, ES2	59.2 days	61.6 days	late
Sicaragua	56.8 days	59.7 days	medium to late
Tsolo	54.3 days	56.3 days	medium

For maize varieties grown at Ibadan some regressions were worked out between the tasseling time, the silking time and the time that the crop was ready for harvesting (35). It is proposed to classify any maize materials at Ibadan according to the following five classes:

	tasseling time	*silking time*	*maturity*
1. very early	30 days	35 days	60 days
2. early	40 days	45 days	72 days
3. medium	50 days	55 days	84 days
4. late	60 days	64 days	95 days
5. very late	70 days	74 days	107 days

Once varieties typical of various maturity groups have been found, similar information can be added as to the probable behaviour of such maize material in other locations in Nigeria.

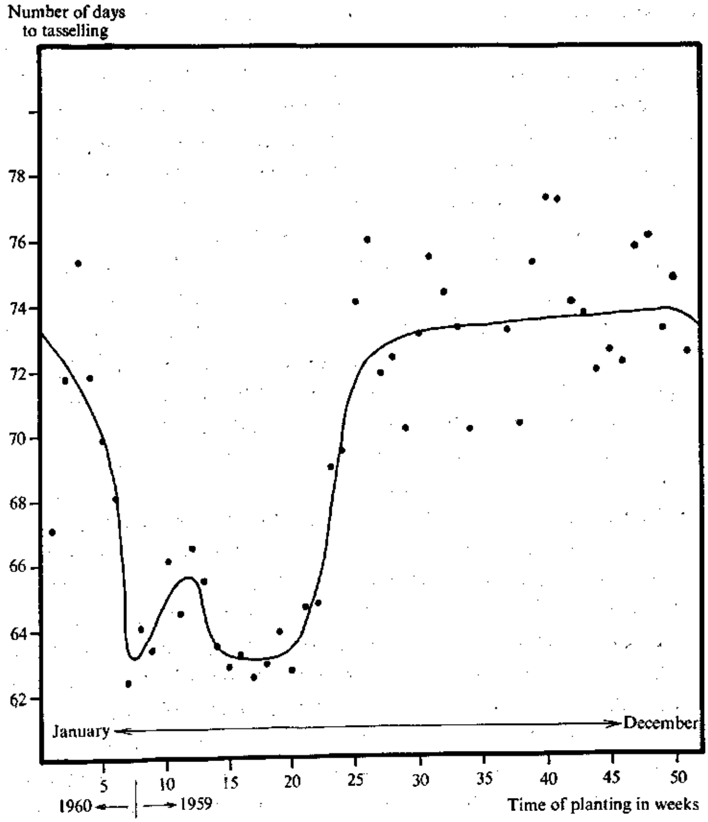
5.5.3. *Time of planting and time to anthesis*

Mention has been made of the longer period needed by various varieties of maize to attain tasseling time in more northerly locations. As a rule, the same varieties also take longer to reach this stage when grown during a late season at Ibadan compared with an early season planting in this location. Experimental evidence for these observations was obtained by sowing some varieties of maize at regular intervals throughout the year both at Ibadan and at Samaru. The variation throughout a year of the tasseling time of the maize variety Mexico 5 is illustrated in figure 9 in which the average tasseling time is plotted for groups of thirty maize plants sown every week from March 1959 till March 1960 at Ibadan. Care was taken that undue water stress did not occur.

Photoperiodism comes immediately into the mind to explain the cyclical variation of the tasseling time with the date of planting. Originally maize was known to be a short-day plant of which vegetative development is reduced and flowering is hastened by a short length of day (85). This is demonstrated by the extreme earliness of most non-tropical maize material introduced into Nigeria, a phenomenon which renders it useless, unless its day length reaction is altered by back-crossing and selection. Investigations carried out in other parts of the world have revealed that maize varieties can vary from extreme short day plants, especially the tropical maizes, to day neutral types, occurring in the northern extremities of the area where maize is cultivated.

From repeated regular plantings with Mexico 5 and other varieties of maize (Lagos White, EAFRO 254) it could be shown that the changes from relatively long tasseling times to shorter ones normally occur around mid-February and from the shorter tasseling time to the longer tasseling time again in the latter part of June. However, occasionally the relation seems to be reversed. For instance in 1958 normal tasseling times were observed during the early season, but the late season maize crop tasselled several days more quickly. It seems therefore unlikely that day length is the major factor in determining the observed cyclical

FIGURE 9. Tasseling response of the maize variety Mexico 5 to time of planting.



variation at Ibadan. If day length plays any part, it is obviously surpassed in importance by other factors.

Replication of the periodical planting of maize varieties throughout the year at Samaru in Northern Nigeria proved that the same variation in tasseling time occurred at that latitude. The only difference was that in Ibadan short and long tasseling periods meant 64 days and 74 days respectively, but at Samaru 80 days and 120 days. The variation of long and short tasseling times coincided at Samaru quite markedly with longest and shortest photoperiods in the year. In this case the correlation of tasseling time with the average length of day for the month of planting was quite significant ($r = -.88$; $P < .001$). At Ibadan such correlations were not found to reach a significant level.

Maize is normally planted early in the rainy season at both these latitudes, that is, before the planting date at which the maize will take longer to tassel. If the farmer is compelled to plant considerably later than normal, he should be well aware of this phenomenon, which tends to make his 'three month' maize into a 'four month' crop.

An attempt has been made to relate tasseling time to some meteorological observations such as average daily temperature, maximum and minimum temperatures and average sunshine duration. Significant correlations were found to occur with the average minimum temperature. At Ibadan this correlation coefficient reached a value of –.71 ($P < .01$) and at Samaru of –.61 ($P < .05$).

The negative value for the correlation between time taken to reach tasseling stage and the prevailing minimum temperatures during the first four weeks of the plant's development are to some extent corroborated by findings elsewhere. In Iowa, SHAW and THOM (115) came to the conclusion that a rise in the average temperature during the first sixty days of the development of the maize shortened the time to anthesis. Temperatures below 70°F are reported to retard the flowering time of maize considerably. Such temperatures, however, only occur occasionally, during the harmattan period. The negative correlation indicates that lower minimum temperatures coincide with a longer time to tasseling. Higher minimum temperatures would then encourage the development of the tassel from its initiation (stretching period), as the actual initiation of the tassel occurs at a more or less fixed time during the plant's development, as will be shown in the following paragraphs.

The variation of the natural day length at Samaru covers a range of approximately 86 minutes from 11 hours 24 minutes to 12 hours 50 minutes, which is almost twice as much as at Ibadan, where it has a range of 48 minutes. A more pronounced effect could therefore be expected at Samaru. The explanations are as yet only tentative, as it is impossible to decide from field data, whether the length of the day which is closely related to the minimum and maximum temperatures occurring throughout the year, influences the tasseling period or conversely, whether the day length is a secondary factor whilst the temperatures cause the differences in development. Only experiments in which various factors can be controlled independently, can supply more information to solve this problem of the yearly cycles of the tasseling times of maize.

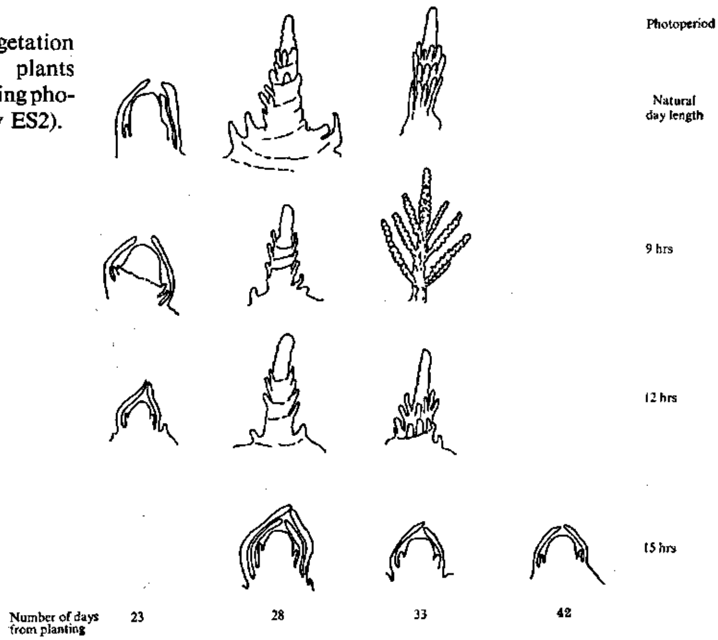
5.5.4. *Initiation of the tassel*

Some observations were made on the time of initiation of the tassel at the vegetation points of maize plants grown at various photoperiods. The daylengths ranged from nine hours to fifteen hours. The variation of daylengths occurring in Nigeria falls well within these limits. This study was made in the months of July, August and September 1962 at Ibadan with the maize variety ES2.

Our series of observations is represented in figure 10 by sketches of the vegetation points of plants dissected at various numbers of days from sowing and grown under four different photoperiods. These were obtained by transferring the plants daily into and from a tent of black lightproof cloth, if daylengths shorter than the natural daylength were required. Longer daylengths were obtained with the aid of fluorescent light tubes connected to an automatic time switch.

The sketches of the vegetation points indicate that this maize variety is without doubt a short day plant. The tassel initiation, that is the beginning of the reproductive phase, is prevented or at least retarded by a long photoperiod

FIGURE 10.
Sketches of vegetation points of maize plants grown under varying photoperiods (variety ES2).



of fifteen hours and apparently encouraged by shorter lengths of day. The plants grown under normal day length showed a similar development to the plants under the twelve-hour day. This was expected as the natural day length in the period concerned varied from $12\frac{1}{2}$ to $11\frac{3}{4}$ hours. The plants grown under nine hours of light started tassel formation around the same time, that is approximately twenty seven days from planting, but the tassel seemed to develop faster under this condition.

From a further series of photoperiodic experiments it could be inferred, that no differences occurred in the time of tassel initiation, if plants of the maize variety ES2 were grown under lengths of day varying from twelve hours to thirteen and a half hours. Tassel initiation always occurred at approximately twenty seven days from planting.

The experiments have shown that under the temperature regime prevailing at Ibadan during the months of July, August and September 1962, the time of onset of the generative phase was not altered in the ES2 plants, if subjected to a range of photoperiods varying from nine hours to thirteen and a half hours. The influence of temperature on the time of tassel initiation of this maize variety has not yet been studied. There seems to be little doubt, that many of the Nigerian maize varieties, which reach anthesis sometimes within thirty five to forty days from planting, will initiate their tassel much earlier in their development than the medium to late maturing variety ES2, studied at Ibadan.

From the facts now available, it appears that the time to tasseling should be subdivided into the period from seed emergence (or planting) to tassel initiation, which proved to be quite constant in the variety of maize studied, and the first part of the reproductive phase, usually indicated as the elongation period. It is this stretching period which probably accounts for most of the variation occurring in the tasseling time; anthesis of the tassel concludes this period.

5.6. Conclusions

The higher yields obtainable by the cultivation of several introduced varieties, instead of local varieties (see section 4.3 and 4.4), appears partly understandable from the retention of a larger active leaf area by the introduced variety. This shows the need to select within the local variety for this character or to transfer this character to otherwise acceptable local varieties.

The utilisation of varieties of maize with a longer duration of pollen shed appears advantageous from the rainfall point of view, even if the percentage of natural self fertilisation might increase to some extent.

When artificially pollinating maize plants in Nigeria, the ear bags can be removed safely on the fourteenth day from silk emergence. The silks have died back by then and the removal of the covering paper bag allows for a free development of the pollinated ear and will also reduce the occurrence of insects and bacterial or fungal rots.

The maize seed is approaching maturity very rapidly around the 30th day from seed set. The moisture content of the grain at harvest proved to be much lower in local varieties than in introduced varieties. This low moisture retention might be correlated with shorter lived leaves. The use of wider spacings between rows of plants did not seem to be effective in reducing the moisture retention. The low moisture retention of the grain at harvest is one of the desirable features of many of the local varieties.

The importance of an accurate assessment of maturity time caused us to study the occurrence of anthesis in some detail. Some type varieties were suggested as provisional standards for the identification of various maturity classes. In Nigeria, the tasseling time of a maize variety apparently passes through a cyclical variation with the time of the year in which it is planted. This variation seems to depend on that of the period from the initiation of the tassel to anthesis, the elongation period.

6. INSECT PESTS

6.1. INSECTS RECORDED

Records of insects observed on maize plants or on maize grains have been collected since 1910. Some of the species recorded are of major importance to the maize growers; most of them, however, have merely been observed and no damage to the crop could be associated with them. In the first instance reference was made to weevils and lepidopterous larvae, stemborers and army or 'cut' worms, of which the latter were said to be especially important on late maize by JEMMET, who published a list of insects affecting maize in southern Nigeria in 1910 (65). This was followed by a second list collated by LAMBORN in 1919 (75) and still another compiled by GOLDING in 1946 (55). Information was recently completed by GREGORY, in cooperation with CASWELL, who made at University College, Ibadan, weekly collections from a variety of crops over a period of more than three years. Additional information was collected from HARRIS and STANTON (19, 58, 123).

The various insects observed on maize are listed under the relevant taxonomic categories in table 12.

TABLE 12. Insects recorded on maize plants in Nigeria (19, 55, 58, 65, 75, 123).

	Plant parts on which the insects were recorded	Stage of the insects attacking plant parts	Importance
COLEOPTERA			
Anthribidae			
Araecerus fasciculatus Deg.	–	–	–
Bostrychidae			
Rhizopertha dominica F.	Grain	Larvae, adults	–
Cetoniidae			
Grametis sanguinolenta Oliv.	Leaves	Adults	Minor
Pachnoda tridentata Oliv.	Leaves, tassels	Adults	Minor
Coccinellidae			
Epilachna chrysomelina F.	Leaves	Adults	Minor
E. sahlbergi Muls.	Leaves	Adults	Minor
E. similis Thnb. var. *assimilis* Muls.	Foliage	Adults	Minor
Curculionidae			
Sitophilus oryzae L. (sensu lata) probably *S. zea-mais* L.	Ears, grain	Larvae, Adults	Major
Nematocerus acerbus Fst.	Leaves, ears, silks	Adults	Minor
Siderodactylus sagittarius Oliv.	–	–	–
Elateridae			
Melanotus umbilicatus Gyll.	–	Adults	–
Galerucidae			
Buphonella africana Jac.	Leaves	Adults	Minor
Monolepta goldingi Bryant	Leaves	Adults	Minor

	Plant parts on which the insects were recorded	Stage of the insects attacking plant parts	Importance
Hispidae			
Dactylispa spinulosa Gyll.	Leaves	–	–
Dorcathispa bellicosa Guer.	–	–	–
Lagriidae			
Chrysolagria cuprina Thoms.	Leaves	Adults	Minor
Lagria villosa F.	Leaves	Adults	–
L. viridipennis F.			
Malachiidae			
Hapalochrus azureus Er.	–	–	–
Meloidae			
Cylindrothorax westermanni Makl.	–	Adults	–
Epicauta oculata F.	Leaves	Adults	Minor
Mylabris bifasciata Oliv.	Leaves	Adults	Minor
Melolonthidae			
Pseudotrochalus concolor Kolbe	Leaves	Adults	Minor
Nitidulidae			
Brachypeplus pilosellus Murr.	–	–	–
Carpophilus demidiatus F. (sensu lata)	–	–	–
C. marginellus Mots.	–	–	–
Tenebrionidae			
Curimosphena epitragoides Haag	–	–	–
Tribolium casaneum Herbst.	Ears, grain	Larvae, adults	Major
T. confusum J. Duv.	Grain	Larvae, adults	–
Trogositidae (Ostomidae)			
Tenebroides mauritanicus L.	–	Larvae, adults	
HEMIPTERA			
Aphididae			
Rhopalosiphum maidis Fitch.	Leaves, Tassel	Nymphs, Adults	Major
Cercopidae			
Locris maculata F.	Leaves,	Nymphs, Adults	Minor
Poophilus adustus Walk.	Leaves	Adults	Minor
Sepullia murrayi Sign.	Leaves	Adults	Minor
Coccidae			
Pseudococcus brevipes Ckll.	Leaves	Adults	Minor
Coreidae			
Anoplocnemis curvipes F.	Leaves	Adults	Minor
Homoeocerus pallens F.	–	Adults	–
Delphacidae			
Sogata furcifera Horv.	Leaves	–	–
Derbidae			
Diostrombis grahami Dist.	Leaves	Adults	–
Proutista fritillaris Boh.	Leaves	Adults	–
Jassidae (Cicadellidae)			
Cicadulina sp.	Leaves	Adults	–

	Plant parts on which the insects were recorded	Stage of the insects attacking plant parts	Importance
Lygaeidae			
Oncopeltus famelicus F.	–	Adults	–
Pentatomidae			
Diploxys bipunctata A. & S.	–	–	–
Halydicoris scoruba Dall.	Ears	–	–
Stenozygum alienatum F.	–	–	–
Plataspidae			
Coptosoma nubila Germ.	Leaves	Adults	–
Pyrrhocoridae			
Dysdercus fasciatus Sign.	–	Adults	–
D. superstitiosus F.	Ears	Adults	–
LEPIDOPTERA			
Arctiidae			
Diacrisia lutescens Walk.	Leaves	Larvae	–
D. maculosa Cram.	Leaves	Larvae	Minor
	–		
Eucosmidae			
Agyroploce leucotreta Meyr.	Ears	Larvae	–
Lymantriidae			
Dasychira georgiana Fawc.	–	Larvae	–
Euproctis fasciata Walk.	–	Larvae	–
Noctuidae (Agrotidae)			
Busseola fusca Fuller	Stems, leaves, ears	Larvae	Major (stem-borer)
Leucania loreyi Dup.	Leaves	–	–
Laphygma exempta Walk.	Leaves	Larvae	Major
L. frugiperda S. & A.	Leaves	Larvae	–
Plusia acuta Walk.	Leaves	–	–
Prodenia litura F.	Leaves	Larvae	Minor
Sesamia calamistis Hmps.	Stems, leaves, ears	Larvae	Major (stem-borer)
S. penniseti Tams & Bowden	Stems, leaves, ears	Larvae	Major (stemborer)
S. botanephaga Tams & Bowden	Stems	Larvae	Major (stem-borer)
Spodoptera mauritia Boisd.	Leaves	–	–
Nymphalidae			
Acraea zetes L.	–	Larvae	Minor
Pyralidae			
Coniesta ignefusalis Hmps.	Stems	Larvae	Major (stem-borer)
Chilotraea argyrolepia Hmps.	Stems	larvae	Minor
Eldana saccharina Walk.	Stems, ears	larvae	Major (stem-borer)

	Plant parts on which the insects were recorded	Stage of the insects attacking plant parts	Importance
Cadra cautella Hb.	Grain	Larvae	–
Mussidia nigrivenella Rag.	Ears	Larvae	Minor
ORTHOPTERA			
Acrididae			
Acrida rufescens P. Beau	–	Adults	Minor
A. sulphuripennis Gerst.	Leaves	Adults	Minor
Locusta migratoria migratorioides R. & F.	Leaves	Adults	Major (during an invasion)
Morphacris fasciata Ab. *sulcata* Thmbg.	Leaves	Adults	Minor
Nomadacris septemfasciata Serv.	Leaves	Adults	Major (during invasion)
Oxyahyla minor Sjest	Leaves	Adults	–
Ornithacris cyanea cavroisi Finot.	–	Adults	–
Spathosternum pygmaeum Karsch.	Leaves	Adults	–
Zonocerus variegatus L.	Leaves	Nymphs Adults	Major (in certain years)

6.2. Observations on particular pests

The majority of the above insect species has not been studied in detail and knowledge depends mainly on incidental observations. The stemborer complex was studied to some extent, although most work was done on their occurrence in other grain crops such as guineacorn and millet. In the following paragraphs of this chapter the facts known about some of the more important insect species noxious to the maize crop in Nigeria, are summarised.

6.2.1. *Stemborers*

The damage due to stemborers has been described as insidious, affecting every maize crop every year to a very variable extent. Stemborers are practically always present, though often not having a serious effect on yield. Yield losses due to stemborers are said to vary from ten per cent to complete crop failure, especially in the late season crop. In some areas of southern Ghana and southern Nigeria maize is not planted in the late season, because of past experience of the destruction caused by stemborers (101, 125). The stemborer populations tend to build up during the rains and in many areas they make an attempted late crop impossible. Early plantings normally escape serious attack as the initial population of stemborers is still low (58).

Between 1952 and 1957 spraying trials were arranged at Ibadan on a late maize crop to test a number of insecticides for their effect on yield reduction by stemborers. Maize plots treated with an endrin spray showed increases in yield of twenty six per cent above the controls. Under higher infestation levels far higher yield losses are known to occur.

In the northern provinces (north of latitude 10°N) the prevailing stemborer species on maize are *Sesamia* spp. (mainly *S. calamistis*) and *Busseola fusca. Eldana saccharina* is occasionally of importance. In the Middle Belt *Sesamia* spp. are of greatest importance, although, locally, any of the stemborers recorded on maize, may be the primary pest. In the southern part of Nigeria, especially in Western Nigeria, *Busseola fusca* is generally the most important stemborer species. *Sesamia calamistis* is an important subsidiary borer, sometimes locally dominant (2, 4, 5, 7). It may be mentioned here that most stemborers have quite a wide host range, comprising some cultivated crops (guineacorn, millet, rice) and wild grasses *(Pennisetum purpureum, Panicum maximum*, etc.). Details are given by HARRIS (58).

The adults of *Busseola fusca* mate from a few hours after emergence, which often takes place between 7 and 9 p.m. In the day time they tend to be quiescent. Oviposition starts in the night following that in which the females emerged. The adults die within a week from emergence. The eggs are invariably laid on the inner surface of the leaf sheath. A female lays about four hundred eggs, although cases of a thousand eggs per female moth have been noted. The eggs hatch on the sixth or seventh morning after the oviposition. The larvae crawl over the leaf surface. They tend to congregate in the funnels of the maize plants and gradually penetrate deeper into the closely packed young leaves. When they reach the growing point of the seedlings, this is destroyed. The appearance of 'dead hearts' can occur within four days from hatching, but can be delayed for up to fourteen days. In older plants the larvae may leave the growing point intact. During the wet season the average larval period is thirty-three days. In the dry season, however, the larvae enter a diapause of six to seven months before completing this development, during which time they remain in the stem of the host. The larvae pupate within the stem and take nine to fourteen days to emerge. The dry season diapause of the larvae of *B. fusca* ends when the dehydrated larvae can absorb water at the beginning of the rains. Pupation then occurs within a week and the adult moths appear between a fortnight and a month after the germination of the various grain crops.

The life cycle of *Sesamia calamistis* is completed in forty-three to seventy days. The adults emerge in the late evening and behave very much like *B. fusca*. The females lay about three hundred eggs each, and the adults die in approximately five days from emergence. Shortly after hatching the larvae bore directly into the stem under the leaf sheath and only leave the stem when they migrate to other plants, which occurs rarely. Even under the severe dry season conditions at Samaru (Northern Nigeria) there is no resting stage in the life cycle and this stemborer breeds throughout the year.

The above details of the life cycle of the two most important borers of maize, *Busseola fusca* and *Sesamia calamistis* were taken from the extensive study made by HARRIS on cereal stemborers in Nigeria (58). More details on subsidiary borers can be obtained from this source.

Control of the stemborers can be approached from several angles. Crop sanitation seems to be a first important method. It has often been observed that the stemborer infestation rate in maize fields showed a decreasing gradient from trash areas. Prevention of stemborers through sanitation can only be obtained on large fields of maize, if all remains of a previous grain crop are removed from the field, burnt or buried. It was observed, that borers in maize stalks perished when buried under a few inches of earth (40).

Combating of the stemborers by the application of insecticides has proven to be possible; the yield increases however rarely paid for the extra cultivation costs of the crop. For example at Ibadan on a late maize crop an application of endrin at a concentration of six ounces active ingredient per acre, at eight to fourteen days after planting, gave an increase in yield of only 260 lb. above the control of 747 lb. of dry grain per acre (5). An attack by *B. fusca* can be combated with this type of insecticide. *Sesamia* sp. and *Coniesta* sp. however enter the stem immediately after hatching and do not crawl over the leaf surfaces prior to their boring stage. They are therefore far less vulnerable (58). The high toxicity of endrin to mammals is another serious drawback to this insecticide.

Although the use of 2.5 per cent DDT dusts have proven to be effective in other parts of Africa, these did not prove succesful in trials arranged on late maize crops in Western Nigeria (7, 133).

Various records are available on differences in resistance to stemborers amongst various maize varieties. HARRIS (58) suggests that natural selection of the Nigerian maizes rendered them less susceptible to the prevailing stemborers than the newly introduced, higher yielding ones. It was presumed that material selected for resistance to the European cornborer (*Pyrausta nubilalis*), destructive to the maize crop in parts of the corn belt of the United States, could possibly carry a similar resistance to the West African maize stemborers. Five inbred lines from Minnesota (A250, A277, A294, A404 and A42.645), carrying the resistance factor observed in the South American maize variety 'Maiz Amargo' (100), were introduced. The original material was extremely susceptible to diseases and furthermore flowered within a few weeks from sowing, probably a reaction to the short length of day prevailing at Ibadan. Their crosses with the variety Mexico 1 and the backcrosses (first stage) to the Mexican parent were therefore screened on the field at Ibadan, as a late maize crop, for resistance to stemborers. Only the back cross (A42.645 × Mexico 1) × Mexico 1 was significantly more resistant than other progenies including the local variety. The F_1 (A42.645 × Mexico 1) proved to be the most susceptible (36). This would suggest the segregation of recessive genes for resistance which would be in accordance with conclusions reached elsewhere for the reaction to the European cornborer.

PAINTER (100) lists many other sources of resistance to the European cornborer which have not been tested yet in West Africa. Up till now only a few preliminary studies have been made on resistance to the West African stemborer species. The fact that the 'Amargo' resistance factor proved to be of value against the field population prevalent at Ibadan (*Busseola* and *Sesamia*) is however encouraging.

6.2.2. *Weevils*

As stated by PHILIPS (101) weevils are always troublesome especially in stored maize. He suggests that some varieties with open ended cobs, that is relatively too short husks, which leave the ear tip uncovered, are particularly prone to an early infestation on the field. Positive correlations between husk projection beyond the ear tip and infestation in the field with weevils have been recorded in several instances (2, 118). A variety notorious for the shortness of its husks is 'Sicaragua', otherwise an acceptable variety in parts of Nigeria's Middle Belt and of proven value in our breeding programs. The value of selecting for long husk projection was questioned when investigations elsewhere revealed that the tendency exists for a selection for this character to be synonymous with selection for shorter ears and lower yields (100). This should be carefully considered if such selections are to be made.

The most important weevil attacking maize grains is *Sitophilus oryzae* (or *Calandra oryzae*) of which the larvae are confined to cereal grains. Eggs are laid singly in a cavity in the grain made by the female, which is sealed over afterwards. The larvae feed and pupate in the grains and will consume five to seven per cent of the maize grain. Attack begins already before harvesting. In stored grains the infestation continues with a new generation about once a month (19).

STANTON (123) investigated varietal differences in infestation of maize ears by weevils (*Sitophilus oryzae*) at the time of harvesting. The observations were made on a first season crop. The infestation varied from an average of eight adults per twenty ears for one variety, to sixty one adults per twenty ears for another. The floury local variety gave an infestation rate of thirty one adults. The varieties Mexico 1 and Mexico 13 (floury flints) and Cuba Amarillo (flint) were significantly lower in infestation rate. Three other floury flints (Mexico 5, Mexico 7 and White Tuxpan) showed a higher rate of infestation. The number of ears infested per variety showed a similar variation from seven to nineteen per cent of the ears infested, with the local variety midway at twelve per cent. Both observations were highly correlated ($r = +.88$) and are therefore interchangeable when selecting for field resistance.

The above observations do not seem to warrant the general opinion that floury maize varieties are usually more severely infected with weevils than the harder grain types. What the differences in attack are when stored, is, of course, a completely different proposition. Other characteristics than the nature of the endosperm are therefore likely to influence the field infestation rate.

Control of weevils in storage has been subject of investigations both within and without Nigeria, but will not be discussed here, as this does not seem to be directly relevant to the purpose of this study.

6.2.3. *Army worms* (55).

Army worms, also called cut worms (*Laphygma* spp.), derive their name from the enormous numbers which congregate to 'march on' in search for food. Maize is one of their favourite foods. The most important local species is reported to be *L. exempta* Walk. The moth migrates at night in swarms and the females deposit their eggs on grasses. On hatching, the larvae migrate in great numbers and if they encounter a field of maize, the bulk of the plants is completely destroyed in a remarkably short time.

This insect usually occurs in May and occasionally in September. It has been observed almost throughout Nigeria. The larvae are very susceptible to most of the common insecticides. The only problem is to locate the pest in time as the crop can be decimated in a matter of one or two days. No resistance to this insect pest has as yet been observed.

6.2.4. *Aphids*

Numerous individuals of *Rhopalosiphum maidis* are found on tassels and upper leaves of the maize plants. Damage caused by these insects has not been assessed in Nigeria, although it is apparent that sometimes the tassels are prevented from shedding pollen. Occasionally this occurs on a large scale and presumably could influence the production of grain. At Ibadan it is a particular nuisance in the maize breeding plots as the aphids seem to multiply at a tremendous rate on bagged tassels and this is always correlated with a low or no production of pollen.

A number of inbred lines produced in the United States of America are reported to carry resistance to this aphid by PAINTER (100). However, he relates from data available in the literature that this resistance is often unsatisfactory and furthermore appears not to be simply inherited. It is doubtfull whether at the present stage of the Nigerian maize breeding programs breeding for resistance to this aphid should be advocated.

6.3. CONCLUSIONS

As has been shown, a host of different insect species besieges the maize crop when it is growing in the field. Only a few of the obviously important insects have been investigated to any extent, but even on these, insufficient data are as yet available. The insects listed as being found on maize plants have been marked of major or minor importance, or the relevant column left empty, because of lack of information. It is expected, that several insect species will be marked of major importance when detailed study can be made of the various viruses prevailing in the maize crop. Some information on these virus diseases, especially the streak virus and the leaffleck virus, will be given in a following chapter (see 7.2.3.5. and 7.2.3.6.).

Apart from possible insect vectors spreading the above-mentioned virus diseases, stemborers are the main problem for the late maize crop, although occasionally army worms can also be of major importance.

7. DISEASES

The warm and humid climate of the southern parts of the countries bordering on the Gulf of Guinea must, no doubt, have encouraged the occurrence of many diseases of maize, from its earliest date of cultivation. Very little was known of the diseases attacking the maize plants in West Africa, until recently. New diseases must have attacked the maize crop causing the crop to react through natural selection processes. Some aspects of this interplay between the crop, its diseases and its environment have been studied in detail. The sudden occurrence of a disastrous rust disease on maize in 1950 gave impetus to a close study of this disease and others.

7.1. DISEASES RECORDED

The first list of fungi affecting maize on Africa's West coast was compiled in 1928 in Ghana (16). This was followed by a short list of diseases in Nigeria in 1938 (138). It was only after the second world war that many more records became available, especially after the explosive appearance of the American maize rust. On the basis of these data a list of maize diseases was compiled.

TABLE 13. List of Fungi, Bacteria and Viruses recorded on maize in Nigeria (up to 1963) (9).

* = of doubtful parasitic nature

FUNGI:	
* *Alternaria spp.*	on pollen grains, on leaves
* *Aspergillus spp.*	on germinating grains
* *Blakeslea trispora* Thext.	on leaves
Botrydiplodia theobromae Pat.	on leaves and grains
* *Cephalosporium acremonium* Corda	on germinating grain
Cochliobolus heterostrophus (Dreschl.) Dreschl.	leaf blight
Corticium solani (Prill. & Delacr.) Bourd. & Galz.	Banded sheath and leaf rot
Curvularia lunata (Wakk.) Boedijn	leafspot
Curvularia pallescens Boedijn	leafspot
Diplodia macrospora Earle	on ears and leaves
* *Epicoccum sp.*	on leaves
Giberella fujikuroi (Saw) Wollenw.	on tassels
Giberella zeae (Schw.) Petch.	on ears and tassels
* *Malustela aeria* (Batista) Sima & Vas.	on leaves
Macrophomina phaseoli (Maubl.) Ashby	on leaves
Marasmius sp.	on leaves
* *Neurospora sitophila* Shear & Dodge	on cobs (after cooking)
* *Nigrospora oryzae* (Berk & Br) Petch.	on leaves and ears
* *Nigrospora sphaerica* (Gacc.) Mason	on leaves and ears
* *Penicillium sp.*	on germinating grains
Phyllosticta zeae Stout	
Physoderma maydis Shaw	brown spot
Phoma insidiosa Tassi	on husks

Puccinia polysora Underw.	American rust
Puccinia sorghi Schw.	rust
Pyricularia grisea (Cke) Sacc.	grey spot on leaves
Pythium aphanidermatum (Edson.) Fitzp.	stem rot
* *Rhizopus sp.*	on germinating grain
Sclerotium sp.	on dead husks of ear
Trichometasphaeria turcica Luttrell	leaf blight
Ustilago maydis (D.C.) Corda	smut

BACTERIA:

* *Aerobacter aerogenes* Chester	from stalk rotted plants, associated with *Pythium*
* *Erwinia carotovora* (Jones) Holland	from stalk rotted plants, associated with *Phytium*

VIRUSES:

Streak virus
Leaf fleck and Pellucid Ring pot
Leaf Distortion

In Ghana and Sierra Leone several other fungi on maize are recorded, which have not yet been reported in Nigeria. The following are listed by LEATHER (77) and PIENING (102) for Ghana, and by DEIGHTON (32) for Sierra Leone.

TABLE 14. Fungi on maize in Ghana and Sierra Leone, not recorded in Nigeria.

Cercospora sorghi Ell. and Ev.	Sierra Leone
* *Chaetomium globosum* O. Kunze ex Fr.	Ghana
* *Cladosporium herbarum* (Pers) Link ex Pf.	Ghana
Cochliobolus sativus (Ito and Kur.) Dreschl. ex Dastur	Ghana
Colletotrichum graminicola (Ces.) Wilson	Ghana
* *Curvularia geniculata* (Tracy and Earle) Boedijn	Ghana
* *Epicoccum neglectum* Desmaz	Ghana
Hetasphaeria sp.	Sierra Leone
Pythomyces chartarum (Berk and Curt.) M. B. Ellis	Ghana

Most of the diseases listed in the tables have been merely recorded and only a few have been studied in detail. If available, such data are given in the subsequent parts of this chapter.

7.2. OBSERVATIONS ON PARTICULAR DISEASES

7.2.1. *Puccinia polysora*

7.2.1.1. Introduction and present distribution

The great majority of the present information on *Puccinia polysora* in West Africa is owed to the excellent work of Dr R. H. CAMMACK, who studied this disease at Ibadan from 1952 to 1958. This discussion follows in great lines his various publications on this subject.

The American or polysora rust, as *Puccinia polysora* is often called, was endemic in the Central American and Caribbean maize areas. Its first record dates back to 1897, when it was described by UNDERWOOD in Alabama on *Tripsacum laxum*. On maize this disease was first recognised as *P. polysora* as late as 1941 in Peru. However, many old herbarium specimens from this area proved to have been wrongly classified as *P. sorghi*, also occurring on maize (20).

DEIGHTON reported the American rust on maize in Sierra Leone in 1949. During the next year it spread throughout the entire maize growing area of Ghana and Dahomey and it reached the south west corner of Nigeria. In 1951 the disease reappeared in Western Nigeria and spread quickly east- and northwards. The rust subsequently reached Kenya in 1952, and later invaded Madagascar and the Isles of Mauritius and Réunion (20). The rapid spread of this rust over the African continent is illustrated in figure 11.

It may be of interest to note that another source of infection was established in Malaya at the same time as the onset of the African polysora epiphytotic. In 1950 *P. polysora* was identified in Malaya, in 1952 in North Borneo and in 1956 in Siam, on the Philippines and on the Christmas Islands (25). Recently, word was received on the occurrence of the pathogen in New Guinea and in North Australia. The fungus has now spread over the whole tropical belt of the world and is a factor to be reckoned with in any breeding program for maize intended for humid tropical areas.

The introduction of this pathogen and its explosive subsequent development on maize in Africa is probably due to the fact, that the rust caught up with its

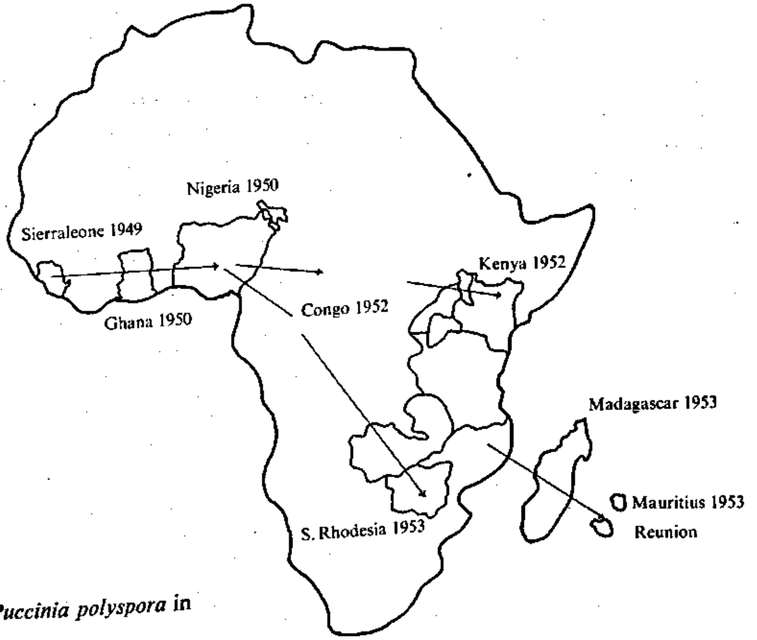


FIGURE 11.
The spread of *Puccinia polyspora* in Africa.

host after a period of independent evolution (119). During this period the maize material lost its resistance to the absent rust, from which it escaped when migrating as grain to the African continent.

How the polysora rust could cross the 3,500 miles of ocean between the source of infection and Africa, has been a difficult point to solve, unless it is assumed that urediospores were brought over on living plant material. It seems very unlikely that wind was the agency which carried this rust to Africa. Urediospores have only a small range of temperature tolerance and a short viability. That urediospores probably have been introduced on living plant material is not just a hypothetical assumption, as it is known that large quantities of maize grains and of maize on the cob were introduced during the second world war, and the immediate post war years (22, 110). It may be that this is an example of man's unconscious cooperation in the spread of plant diseases.

The West African Coast affords near optimum climatic conditions for rust development and this accounts for the success of the epiphytotic (20, 110). Both the optimal ambient temperature of 27 to 28 °C, with a small diurnal and seasonal change and the high relative humidities prevalent during most of the year contributed to this.

In accordance with its humidity requirements, the rust proved most intense in the coastal rainforest areas and decreased in intensity to the north. Comparative assessment figures for the intensity of the disease are given below.

Sudan Savannah	Intensity: 0.5
Guinea Savannah	Intensity: 1.6
Rainforest	Intensity: 2.8

These figures were obtained with a quantitative assessment key, ranking the quantity of urediosori (means of observation on 3rd, 6th and 9th leaves) with a scale ranking from 0 to 4, the latter figure indicating abundance of urediosori.

The severity of the losses in yield expressed itself in the maize belt of the neighbouring country of Dahomey by a 500 per cent rise in the price of maize in 1950. In Nigeria, losses were estimated at 40 to 50 per cent of the normal yield in the early years of the onset of the rust. These figures are based partly on results from sulphur dusting trials in which the undusted plants gave yields of 50 per cent of the treated ones (128). It is noteworthy that *P. polysora* was recognised on various islands of the Caribbean Archipelago in the years 1945 to 1948; the damage to the crop was however always described as negligible (25). Soon after its onset in Nigeria the resistance to the rust and also human endeavour caused a reduction of the losses in yield due to this pathogen, the one as a result of a very sharp natural selection in the early years and the latter by introduction of maize germplasm from the place of origin of the rust, where resistance factors were already naturally selected. The introgression of these introduced types into the Nigerian local maize is apparent when visits are paid to local farms and to agricultural shows, where besides the original local and introduced varieties, many recombined types of maize can be found.

7.2.1.2. Pattern of the attack on the maize plant (STANTON, CAMMACK, 128)

A very early infection of first leaves only occurs in the late cropping season. Normally a few urediosori or pustules occur on the lower leaves. The intensity and the rate of spread increase rapidly in proportion to the host's development. Maximum intensity of attack is reached at tasseling time. Up to that time the rust may only retard the plant in its growth. From then onwards the rust starts its killing phase and attacks all plant parts apart from the true stem. Pollination is mostly completed before the rust is able to attack the tassel seriously and is therefore not interfered with.

Loss in yield appears to depend less on the velocity of the attack than on the date of onset of the rust on the host. The earlier the rust is available, the more leaf area will be infected by it at tasseling time. Any retardation of the disease after tasseling time will benefit the growing grains and therefore the yield.

In 1950 and 1951 incidental observations pointed to a very great influence of the date of planting on the onset of the rust. A rust susceptible variety, Lagos White, was planted at ten day-intervals throughout a year. Yields from these sequential plantings fell sharply from eleven hundred pounds per acre on plots planted in April to six hundred pounds per acre in plots planted in June. Thereafter the yields rose steadily, till in March a yield as high as thirteen hundred pounds was reached.

The time of onset of rust was at seven weeks of age of the maize plants sown in March. This period decreased with subsequent plantings till the July plantings were attacked at three weeks of age. Thereafter the time of onset slowly reverted to the seventh week in the plant's development. Although the time of onset of the rust no doubt influenced the yielding capacity of the maize, the depressing effect of the rust on the yield must have been accentuated by the general decrease in fertility during the rain, of soils subject to the alternating dry and rainy seasons under high temperature regimes.

7.2.1.3. Some facts on the fungus

Aecidial and pycnidial stages of *P. polysora* are not known. Teliosori have been found on moribund maize material at Ibadan, in the beginning of the dry season (December). It proved however impossible to bring these spores to germination. This rust is therefore supposed to be microcyclical. The regeneration time of the urediospore at Ibadan is only nine to ten days and this contributed to its success (24, 110).

The seasonal reappearance of the rust is dependent on the survival of a spore stage or mycelium or on a reintroduction, which seems unlikely. In many places maize can be found during the dry season, especially in swampy areas along the coast. Much of this material was found to be infected with rust, although only in a light degree. The dry season environment is not conducive to the fungus (110).

Studies were made of the number of urediospores produced by the rust from its urediosori on fully susceptible and on tolerant maize plants. This was followed by a study of the quantity of airborne inoculum available at various times of the year, with the aid of a HIRST-spore trap.

On susceptible varieties urediosori were estimated to produce 1500 to 2000 spores per day for eighteen to twenty days. On less susceptible varieties it varied from 600 to 1100 per day for the same period. The general use of such maize material would therefore not prevent the continuous availability of airborne inoculum.

In 1954 CAMMACK (24) made a continuous record of the spores of *P. polysora* in the air. The variation of the number of spores with the time of the year showed the following pattern at Moor Plantation, Ibadan.

January to May	.2	urediospores per m^3
June	5	urediospores per m^3
July to November	100–300	urediospores per m^3
December	6	urediospores per m^3

The levels proved to vary with the years, but similar curves occurred. The subsequent analysis of several year's records of the urediospore contents of the atmosphere at Ibadan, has shown that the time of outbreak of the rust can be forecast each year. Onset of the rust in the field can be expected when the atmospheric urediospore content rises above five spores per cubic meter (108).

These observations do not appear to tally with the rise in yield and the increasingly later onset of rust, on maize planted from July to October as mentioned in a former paragraph. The high level of inoculum available in the air should continue to cause an early onset of the rust during these months, as it did in July plantings.

7.2.1.4. Races of Puccinia polysora

When discussing one of the *Puccinia* species one is immediately reminded of the behaviour of rusts on oats and wheat (*Puccinia coronata, P. graminis* and others), which developed a large series of biotypes or physiologic races; this phenomenon rendered newly developed resistant varieties of the crop susceptible. Although, as pointed out earlier, *P. polysora* does not go through a complete sexual cycle in West Africa, with its innumerable possibilities of reorganisation of genotypes by segregation, this should not be taken to indicate that different biological races of this pathogen do not yet occur, or will not arise in due course (119). The chance of the appearance of new virulent strains of rust by genetical recombination may be lessened because of the absence of a sexual cycle, but mutations can still be responsible for a change in the existing spectrum of biotypes (110).

The relative susceptibility of a series of twelve different varieties grown in assay plots in virtually all recognised vegetation zones of Nigeria, Southern Cameroons and Ghana, proved to be the same at all locations. This could therefore indicate, that in 1953–54 no differentiation of the fungus had yet occurred, although the possibility still remained, that this whole range of maize material reacted similarly to various biotypes (121). Later, however, a number of observations became available, which pointed towards the existence of such biotypes. In East Africa two different biotypes, distinguishable only by the reaction of some different maize types, were actually proven to occur (124). That races of *P. polysora* are likely to exist in West Africa, is based on the results of a number of inoculation experiments and on the occurrence of 'mixed reactions'.

In the Caribbean area and in Central America the American rust finds an alternative host in *Tripsacum laxum*. Transfer of urediospores from maize plants to these hosts in West Africa was however not possible. It may be mentioned here, that the *Tripsacum laxum* material was clonal material introduced from the Caribbeans, and was therefore genetically identical to material, proven to be susceptible in the Caribbeans (107). The inoculation of *Euchlaena mexicana*, another alternative host for *P. polysora* in Central America, originally proved to be unsuccessful too. However in 1958 CAMMACK (108) succeeded in obtaining a rust reaction on this plant species with the Ibadan strains of the rust. A definite answer to this problem can only be expected if cross inoculations of similar host material with rust collected from various locations and hosts are organised. This however still lies in the future.

The most convincing indication of the existence of biotypes of the American rust is the occurrence of different types of urediosori on one and the same leaf, inoculated by a quantity of urediospores obtained from the field (at Ibadan). Photograph 1 shows various types of reactions on the leaf of an inbred line of Mexico 5. The reactions range from the fully susceptible type (class 4 urediosorus) to true hypersensitivity (class 1). This mixed reaction strongly suggests the development of discreet forms of *Puccinia polysora* (108).

A final argument is the behaviour of a maize line Tanag II, introduced from East Africa and carrying the Rpp^1-gene for resistance to one of the two rust races occurring in East Africa. This line showed a greatly reduced number of urediosori on its leaves, when grown at Ibadan on the field, but the urediosori which developed were of a susceptible type.

The reasons behind the suggestion that physiological races or biotypes of *P. polysora* have developed in West Africa, have been given in detail in order to stress the necessity of distinguishing these forms. The importance of such a screening test cannot be overemphasized. If the present declination in severity of this rust is not watched carefully, it might be an unwelcome surprise if a new virulent biotype were to develop.

7.2.1.5. Inoculation and assessment

Several methods of inoculation of maize seedlings with urediospores were tried (128). The best method proved to be to wet the leaves by passing them through moistened fingers, thus removing the bloom from the leaves, and then spreading urediospores with a soft brush on the upper third of the second and third leaves, at the stage when the third leaf has grown clear. The seedlings are then sprayed lightly with water from an atomiser and covered with a polythene hood for forty eight hours. Spraying the inside of the hood ensures high humidity throughout the incubation period. The seedlings can be assessed on the tenth day after inoculation, by which time the pustules are mature.

It appears that the *P. polysora* produced qualitatively different reactions on various maize materials. This means that these can be classified on the basis of homogeneous reactions (all urediosori belonging to a certain class of resistance or susceptibility). After several alterations CAMMACK and STANTON drew up the following qualitative scale for rust reactions on three weeks old seedlings at ten days from inoculation (3, 129):

class	*host*	*rust reaction*
0	Immune	no detectable effect on inoculated leaves
1	Highly resistant	hypersensitive flecking
2	Resistant	urediosori minute, abortive, isolated, surrounded by sharply defined chlorotic areas visible on the under surface of the leaf.
3	Moderately resistant	pustules small, rupturing the epidermis to show very few urediospores.
4	Susceptible	urediosori large, numerous, in extensive clusters. Chlorosis indistinct or absent.

Many observations and much work preceded the establishment of this key, which still must be used with great care. Perturbing facts are that the qualitative reaction is significantly influenced, for example, by the phosphate availability in the rooting zones. Higher phosphorous content apparently increases the susceptibility rating by reducing the chlorotic area around the pustules, thus degrading the painstakingly composed qualitative key. This particular factor can of course be controlled by a balanced nutrient supply to the seedlings.

Another factor, which causes considerable difficulty is that the seedling reaction has still to be checked on the adult plant. It was found that susceptible seedlings (qualitative reaction 4) always proved to be susceptible in the adult stages, however class 1 or class 2 seedlings were not always resistant in the adult stages (3).

It may be concluded here that the question whether *P. polysora* causes real qualitatively different reactions on various types of maize material or rather differences of a more quantitative nature is still open for further investigations, which are all the more necessary when the occurrence of races of this pathogen is considered.

It remains now to summarise the present position of the rust problem from the point of view of the causal agent. The lifecycle of the pathogen and its response to environmental factors are now sufficiently known. However, the symptom expression of the pathogen on various types of maize material or, alternatively, of various biotypes of the rust on similar maize material, remain to be studied.

7.2.1.6. Resistance to *Puccinia polysora*

Soon after the disastrous effect of the epiphytotic caused by the American maize rust, literally hundreds of varieties and types of maize were introduced from many maize growing areas. Part of these were sent with a view to obtaining figures on their susceptibility with the hope of forecasting future occurrence of the disease outside the infested area, that is from the Rhodesias, South Africa and so on. However, most of the maize material came from the Caribbean Isles, South and Central America. Some material was acquired from North America, Europe and some countries in Asia.

As pointed out earlier, losses in yield due to the American rust can partially be prevented by escaping the disease through early planting. This may be of value for maize on experimental farms and to some extent for peasants' maize, but the great majority of the farmers already planted their susceptible maize at the first possible moment after the onset of the rains and the losses were very severe, although less than if the maize were planted at a later date. Other control methods, although probably possible, proved impractical. A good example is the possibility of controlling the rust by an application of sulphur dust at three day intervals.

As has been the case with most important rust diseases on various grain crops one had to revert to a search for resistant material. This proved to be so in spite of the ever changing racial pattern of those rusts. As CALDWELL et al. described in 1958, resistance to plant rust fungi is mainly obtained through utilisation of a hypersensitive reaction in the host plant, preventing any development of the rust, and often determined monogenically (18). It usually gives a perfect initial protection to new varieties, followed by a breakdown of this resistance due to the development of new physiologic races. This tends to develop into a race between the versatility of the pathogen and the tenacity of the plant breeders, during which many physiological races in the pathogen are confronted with as many resistant counterparts in the infected crop. However, apparently several cases are known of varieties enduring a heavy rust attack without an appreciable decrease in yield. CALDWELL (18) stated that such a tolerance character should be more stable than hypersensitivity-induced resistance. When a new physiologic race of the pathogen does occur, a tolerant variety would not act as a rigorous sieve, through which all but the new race are filtered out. The development of new races would be slowed down considerably, as it then has to compete with the already available biotypes. It is in this type of situation, that the outbreak of the American rust occurred and our maize breeding program was orientated accordingly, as will be explained in the following paragraphs.

a. Sources of resistance

Early screening tests arranged to establish the presence or absence of resistance or tolerance factors in acquired maize materials, were solely based on the pustule density on plants grown in the field.

The Central and South American maize varieties all showed a relatively low pustule density. The maize varieties Mexico 1, Mexico 5 and Mexico 17 were outstanding in having more than 95 per cent of the observed plants with only single, isolated pustules on the leaves. Many of the remaining American varieties had the majority of the plants with isolated pustules or small groups of pustules. Material from Asia or Africa was invariably susceptible, headed by the Moor Plantation local variety, which had more than 95 per cent of the observed plants with extensive pustule groups and with extensive chlorosis preceding death of the leaves (20, 130).

b. Selection for resistance factors

Once the probable sources of resistance factors were thus located, greenhouse tests were arranged to test the juvenile reaction under more controlled conditions. This led straight towards a qualitative assessment of individual pustules in preference to an estimation of the pustule density, as it is difficult to induce a homogeneous infection of various plants and plant parts in a greenhouse. The originally chosen varieties Mexico 1 and Mexico 17 were not among the ones selected for a qualitatively resistant reaction. Even the variety Mexico 5 was dropped from this program on the long run. Immunity has not been recorded as yet and true class 1 reactions (hypersensitive flecking) were only found in derivatives of Mexico 13 (SLP 20–4A). Further details on reactions of various materials will be given in later paragraphs.

One major dominant gene also selected from Mexico 13, gave resistance to *P. polysora* in Kenya, segregating in hybrid populations in a three to one ratio. The existence of another gene was suggested, having an effect large enough to be of possible value, in some North American maize materials (130). It is worthy of note that neither the Kenyan material nor the material selected on the qualitative reaction of the seedling at Ibadan have ever given a reaction, indicating a high resistance in the adult stages on the field, apart from a few advanced stage inbred lines, derived from Mexico 13, which were apparently too weak even to sustain a parasite. Restoring vigour by intercrossing such lines invariably resulted in material with a low resistance in the adult plants.

It appears that the continued search for a qualitatively 'high resistance' factor led the selection for maize material, high yielding under the prevalence of the very infectious rust disease, on a sidetrack, which may be of importance in recognising various biotypes of the rust, if available, but which proved impractical for the selection of suitable maize varieties.

The available advanced stage inbred lines selected for a low rust reaction and derived from the variety Mexico 13, have been bulked in order to produce a vigourous population in which available resistance characters could be preserved. The inbred lines were mostly so weak as to make maintenance almost impossible. The population shows a low quantitative reaction to field inoculum at Ibadan, but under the present level of virulence of the rust it does not appear outstanding when compared with other breeding materials. The population carries the name of 'rust bulk' and has now been stored for the future in case virulent strains of the pathogen develop, or until such times as the facilities are available to make detailed studies of biotypes of the rust available in Nigeria.

In the following paragraphs names are indicated of maize varieties which proved to carry lower pustule densities on the adult plants than the very susceptible local variety of maize at Ibadan. Much of the material has not yet been studied in detail, but it might be of importance whenever the rust reverts to its virulent behaviour of the early days of the West African rust epiphytotic.

The varieties Mexico 1, Mexico 5 and Mexico 17 proved to be outstanding by having low relative pustule densities. It has been reported that both Mexico 1 and Mexico 5 became more susceptible in the years after their introduction, although they maintained their high yield levels (3).

Most of the Caribbean material especially the 'Trinidad' varieties, can be classified as tolerant to the rust. During a routine inspection of yield trials in the Southern Cameroons in 1959, the variety EAFRO 237 showed an outstandingly low pustule density at Barombi-Kang, where even varieties such as Mexico 1 and Mexico 5 were quite heavily infected.

In 1961 some local and introduced maize varieties were tested for their quantitative reaction to the polysora rust by CRAIG (30). Plants were all inoculated on the field to prevent escape, although this is in any case rather unlikely at Ibadan. His findings corroborated earlier ones in that only Central and South American materials could be classified as resistant to the rust. Varieties in which low pustule densities were found are listed below, followed by their local progeny number in brackets:

Choco 328 (A14), Choco 335 (A15), Choco 338 (A18),
Choco 340 (A19), Choco 397 (A22), Maize dulce (A30),
Venezuela 443 (A38), EAFRO 269 (A77), EAFRO 239 (A79),
EAFRO 254 (A81), EAFRO 246 (A90), EAFRO 272 (A93).

7.2.2. *Cochliobolus heterostrophus*

7.2.2.1. The disease and its importance

One of the commonest leaf diseases in West Africa is caused by *Cochliobolus heterostrophus* (Dreschl.) Dreschler. This became especially apparent after the introduction of rust resistant maize material, part of which was extremely susceptible to this leafblight on the West African coast. It was first recorded for Ghana in 1928 and for Nigeria in 1933. This pathogen is well known in other maize growing areas, especially in the southern parts of the United States, where it is called southern leafblight as opposed to the northern leafblight, caused by *Trichometaspheria turcica* Luttrell. Detailed work on *C. heterostrophus* in the tropics has only been undertaken by ORILLO (98) in the Philippines; many of his findings seem to apply to West Africa.

CAMMACK (21) reports that the conidial form, *Helminthosporium maydis*, is widely distributed in Nigeria. However, this is mostly restricted to the humid rainforest areas, as is illustrated by the pattern of resistance shown by local varieties in Nigeria. This indicates that natural selection for resistance occurred mainly below the Niger and Benue rivers. The ascigerous stage, *Cochliobolus heterostrophus*, seems to be unknown in West Africa.

The fungus causes a premature dying back of the leaves from the base upwards, around the time of tasseling. Under heavy infestations susceptible plants lose their lowest leaves even earlier, and have no green leaf area left within approximately three weeks from tasseling, that is before the grains on the ears are properly formed. A typically infected plant was scored for its total leaf area and the area killed by the fungus, just prior to tasseling: the lowest leaf lost twenty per cent of its leaf area at that time, the second to the seventh leaf eight to ten per cent; higher leaves showed a progressively lower percentage attack. In all just over six per cent of the leafarea was already killed at tasseling time.

With the aid of spraying trials (weekly application of zinc dimethyl dithiocarbamate) it was possible to assess the reduction in yield due to leaf blights. During the early season, yield levels were raised from 1851 lb per acre to 2540 lb per acre by application of the fungicide, which amounts to an increase of approximately 37 per cent. During the late season, increases of only 13 per cent were observed. This is understandable as humidity drops quite significantly during the onset of the dry season, thus restricting the fungus in its development (45).

7.2.2.2. Symptom expression and assessment

A series of West African local varieties was selected by simple field screening methods. With this material a program of selection for resistance to the pathogen was to be started and careful consideration was given to the symptom expression on susceptible and resistant material in order to devise an assessment key and to facilitate critical discrimination between more and less resistant lines of maize. A key was drawn up based on many field observations and is represented in figure 12; it contains diagramatic representations of various lesion types and sizes, based on one week old lesions.

The key is based partly on a qualitative character: the presence or absence of a light green or dark grey halo around the lesions. The presence of a light green halo was indicated with the negative sign (–), a dark grey halo with the positive sign (+) and the absence of either type by a circle (O). The use of this key depends secondly on the relative sizes of the lesions. The lesion sizes depend again on the number of days from inoculation that the observations are made.

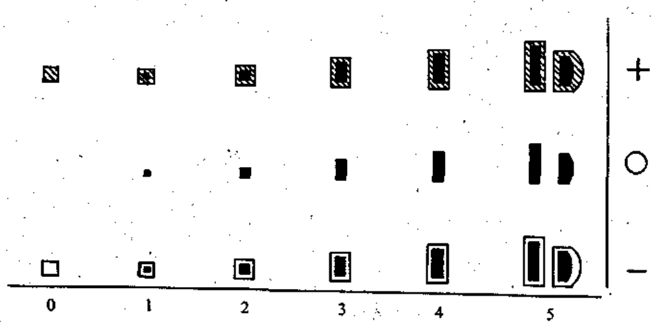


FIGURE 12. A key for the assessment of lesions on maize plants, caused by *Cochliobolus heterostrophus* (Details in text).

Inoculations were made by pouring ten cc of a suspension of macerated *C. heterostrophus*-cultures (on corn meal agar) into the leaf whorls, 'funnels', of fourteen days old plants. The newly emerging leaves show symptoms in two days, but observations were made at six days from the inoculation.

This key can also be applied on the field and allows for a critical observation of individual lesions, rather than a superficial estimate of the number of lesions, which could be caused by many other pathogens (*Curvalaria lunata*, *Pyricularia grisea* and so on). The lesion of *C. heterostrophus* is rather characteristic and can be easily recognised on close inspection. See photograph 2.

Two types of lesion diagrams are given for class 5 in the proposed key, as the larger lesions (above ten mm length) tend to cross the veins of the leaf, whilst the lateral extension of the smaller lesions is apparently checked by these veins. From comparisons with intensities of lesions on naturally infected plants, it appears that higher susceptibility expressed by higher lesion densities is correlated with larger lesion sizes at six days from inoculation of two weeks old plants and also that the presence of a light green halo, the absence of a halo and the presence of a dark grey halo can be significantly correlated in this order with an increase in size of the lesions. Selection of lesions with light green halos will therefore give an opportunity to identify the more tolerant plant material.

The age of the tested plant is important for the expression of its reaction to inoculation with *C. heterostrophus*. This was studied on the variety Mexico 1, very susceptible to this pathogen, and ES2, which has been selected for resistance to leafblights. On the same date and from both varieties plants were inoculated, which varied in age from twelve to thirty-three days. At nine days from inoculation lengths and breadths of lesions were measured. The averages are presented in figure 13.

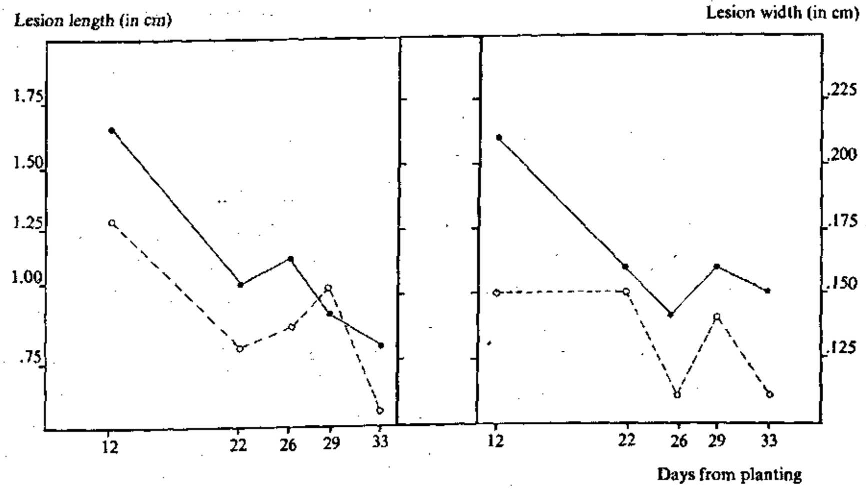


FIGURE 13. Mean lengths and breadths of lesions caused by *Cochliobolus heterostrophus* on plants of two varieties of maize and of varying ages. The dotted line represents lesion measurements on ES2 and the continuous line those on Mexico 1.

This difference in susceptibility of seedlings and older plants was already pointed out by ORILLO in 1953 (98).

Another series of observations relevant to an understanding of various factors influencing the symptom expression is related to a series of inoculations made twice a week on seedlings of fourteen days old and of the same S_1-inbred line (EWD1) from June to December 1962. A tremendous variation occurred in the average length of lesions on this serial planting. This stresses the point that expression of the susceptibility or resistance can be influenced to a very high degree by environmental factors, which are difficult to regulate.

Both the age of the plant and environmental factors can induce such variations in the size of lesions that whenever screening tests are arranged, the result should always be related to the symptom expression of a constant standard, of which the reaction is known. In practice we have used the S_1-line EWDI, which shows a low lesion density, when grown on the field, where it was selected for its cleanliness.

Research into the pathogen-host interaction for *C. heterostrophus* has only just been started in Nigeria. Many aspects remain to be studied before a satisfactory method for assessment can be designed. The question of the relation between juvenile and adult resistance remains largely unsolved. Both types of resistance are of importance, as we found a correlation of only .38. Both early and late tests on susceptibility appear therefore necessary.

Much could be learned from a study of how exactly this fungus attacks the maize leaf, of the significance of light green and grey halos around the lesions, or the absence of a halo. The destructiveness of this leaf blight certainly warrants a detailed study.

7.2.2.3. Resistance

It was mentioned earlier that many Nigerian varieties of maize were scored for their resistance to *C. heterostrophus*. This was done rather crudely by assigning the varieties to three intensity classes.

Class 1: lowest intensity
Class 2: medium intensity
Class 3: highest intensity

The scoring was made on the collection of local material grown on the same field at Moor Plantation, Ibadan under natural infection. The results were mapped against the place or origin of these varieties. This is represented in figure 14.

The more resistant varieties came mostly from the rainforest areas of Nigeria. East of the river Niger, however, a broad front of less resistant varieties invades the densely populated areas of Eastern Nigeria. Within this triangle the varieties have white or yellow, floury or flinty grains, and are obviously a mixture of southern and northern maize types. The Western Nigerian varieties are very distinct from the northern types. The same is true for varieties outside the 'wedge' referred to in Eastern Nigeria.

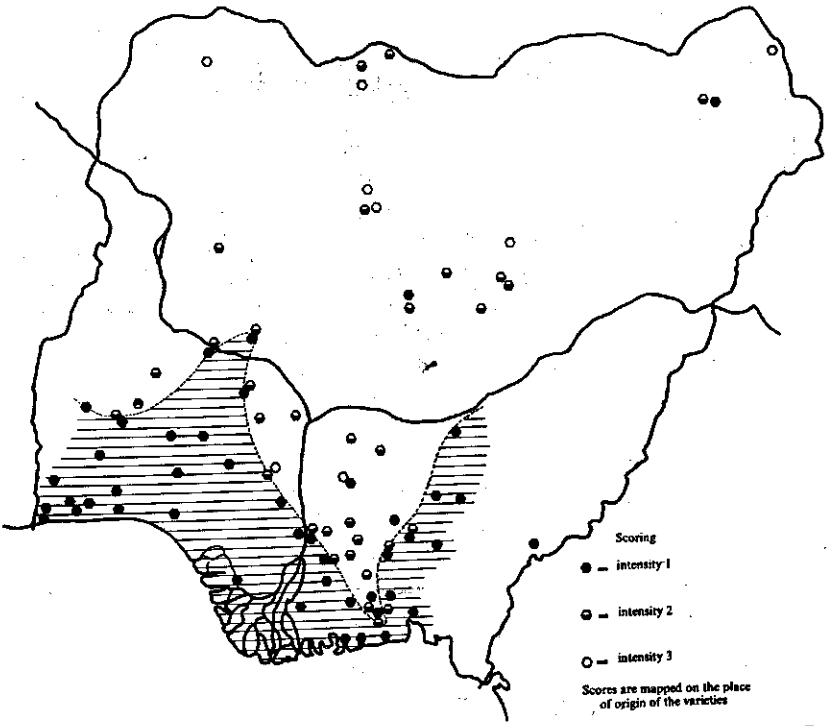


FIGURE 14. Map of Nigeria showing the distribution of susceptibility and resistance to *Cochliobolus heterostrophus* in local maize varieties (from 42).

The intensive trade in maize grains from the Middle Belt southwards, and incidental movements of maize grains, are probably responsible for the phenomenon of maize varieties susceptible to this leafblight, occurring in a zone where natural selection would have eliminated them and actually did in the remaining parts of the forest belt. It is suggested that the resistance to *C. heterostrophus* in the southern varieties of maize is a recessive character, based on several genes. The fact that Western Nigerian varieties all had a relatively high resistance to this leafblight would tally with the fact that there is little trade of maize *into* the area, although the maize trade within and from this area is quite extensive. The influx of seed into Eastern Nigeria could then explain the higher susceptibility of the maize varieties in this area (42).

The most resistant plants of Nigerian, Ghanaian and Dahomeyan maize varieties with a low lesion intensity were inbred for three generations under continuous field selection in order to separate promising materials. These S_3-lines (102 lines) were then screened for their juvenile and for their adult reaction by artificial inoculations in a greenhouse (49). All observations on these lines were related to those made on EWD1. Approximately half of the tested lines proved to have a lower reaction (smaller lesions) than EWD1 when inoculated at two weeks, and at 4 weeks, after planting (juvenile and adult reaction).

Quite arbitrarily, nineteen S_3-lines were selected for further work, by choosing only those lines on which the lesion length was less than seventy five per cent of that on the concurrently inoculated EWD1-plants at both dates of inoculation. The selected S_3-lines are now to be intercrossed in isolation under open pollination in order to allow for the establishment of a population combining the resistance characteristics of all these lines, originating from several distant areas within West Africa. This population can then serve as a basis for new selections, carrying a higher degree of resistance than is presently available in individual inbred lines and for transfer of the resistance to improved material (49).

The synthetic variety ES2 is outstanding in that it always shows the lowest score for leaf blight attack when compared with other material available in West Africa. It has been composed from eight inbred-lines selected, in part, for their resistance to leafblight. All available selected inbred lines (EWD-, EWS- and EYF-lines) show a lower degree of attack by *C. heterostrophus* than their source varieties. Any material susceptible to leafblight is automatically discarded from the breeding programs, unless carrying a particular, desirable characteristic.

The West African varieties from which the nineteen resistant S_3-lines were selected, are:

Adizebli 3	Keta 5
Ashanti 14	Oloto 4
Brazilian maize	Ondo 2
Dahomey 49	Orlu 2
Eniong 1	Togo 2
Eniong 2	

Finally CRAIG (30) selected in a field screening test (with artificial inoculation) at Ibadan a number of sources of resistance, which are given below:

Akwa 3 (L60)	EAFRO 239 (A79)
Atebuta (L57)	EAFRO 254 (A81)
Bida 6 (L71)	EAFRO 269 (A77)
Blidse 2 (L78)	EAFRO 270 (A74)
Choco 328 (A14)	ES1 (A87)
Choco 335 (A15)	H 503
Choco 336 (A16)	Ifonyintedoflour (L297)
Choco 338 (A18)	Valle 362 (A36)
Choco 340 (A19)	Venezuela 661 (A41)
Choco 341 (A20)	Venezuela 976 (A43)
Choco 397 (A22)	

7.2.3. *Other diseases*

Little is known on most of the other maize diseases in Nigeria. A few facts available on some of them are recorded in the following paragraphs.

7.2.3.1. *Corticium solani*

This fungus causes banded leaf and sheathrot, which can cause important losses during very wet periods. The worst type of damage is done when the husks are attacked, preceding the subsequent invasion of the ear by bacterial rots. On husks have been found micro- and macro-sclerotial strains. The symptoms are shown in photograph 3.

In 1954 important losses due to this fungus were reported from the Ivory Coast (109). Maximum infection was said to occur only on plants which had reached tasseling stage. Young plants were not killed by *Corticium solani* unless they were growing under unsatisfactory conditions and exposed to heavy infections.

7.2.3.2. *Pyricularia grisea* (10)

The pathogen causes corn grey spot, most seriously occurring on young maize plants of one to three weeks old. It was for the first time recorded on maize in 1959, at Ibadan. There proved to be large variability in reaction amongst various types of maize. The variety Trinidad was extremely susceptible. The maize varieties Lagos White (local), Mexico 5, Mexico 13 and Tsolo were less susceptible. On photograph 4 characteristic lesions are shown.

7.2.3.3. *Pythium aphanidermatum*

This fungus causes a serious stemrot on adult maize plants in the fields. The stalkrot was recorded for the first time in 1958 at Ibadan, where it caused dramatic losses up to forty per cent of the plants. The disease is characterised by a rotting in the first and second internodes above ground level (107). The symptoms are illustrated in photograph 5.

Originally the stemrot could only be associated with the presence of two bacteria, *Aerobactor aerogenes* and *Erwinia carotovora*, which were later thought to be secondary. The primary causal agent of this stemrot was proven to be *Pythium aphanidermatum* (117). The most severely affected varieties of maize were the entire Caribbean collection, Mexico 1 and Mexico 5.

The stemrot remained restricted to experimental plantings at Ibadan, Fashola and Ilora in Western Nigeria. In the first year (1958) the onset of the disease occurred in the early season at eight to nine weeks from planting; in the late season it came three weeks earlier in the development of the plant (108).

7.2.3.4. *Trichometaspheria turcica*

This leafblight goes under several names: leafscorch, leafscald, white blast, helminthosporiose. CAMMACK reported it in 1956 as one of the most generally distributed and troublesome diseases of maize in Nigeria (21). At present the disease may be generally distributed, but is certainly not troublesome. It does occur regularly in much of our maize materials, but is never comparable in importance with *Cochliobolus heterostrophus*.

Although an early planted crop generally escapes infection until, at tassel emergence, the older leaves are affected, it is our contention, that this fungus sometimes develops on a three to four weeks old, early maize crop even when the early part of the rainy season has been quite dry.

7.2.3.5. Streak disease

WEST (138) reported the occurrence of a virus disease, causing yellowish streaking of the leaves and sometimes deformation and stunting of the plant. In East Africa the streak virus is transmitted by *Cicadulina storeii*, *C. mbila* and *C. zeae*. This has not been confirmed in West Africa. STANTON (124) reported that there seems to be a danger in the distribution of rust resistant maize material of distributing also the streak susceptibility from Columbian and Mexican materials.

Although, in general, streaked plants occur with a low frequency, more in the late than in the early season, occasionally an outbreak can be very severe. In 1959 a two acre field at Ilora planted to Mexico 5 had ninety five per cent of its plants affected by this virus.

From Rhodesia, it was reported that resistance to streak was recorded in the varieties EAFRO 235 and Sicaragua (61). In South Africa, resistance was recorded in the varieties 'Peruvian Yellow', 'Yellow Bounty', in the Mexican inbred lines Mex 37–5, URQ 54 and Gro 29–29A–5–4 and in the Rhodesian inbred line 3NA (56).

7.2.3.6. Leaf fleck

This disease originates as small, circular, translucent spots near the tips of older leaves. In the most susceptible varieties the spots become necrotic and surrounded by concentric pellucid rings. The leaf tips and margins start to die back and the whole leaf may be dead in ten days. The symptoms are shown in photograph 6. The similarity to symptoms of the leaffleck virus, described elsewhere for maize, is suggestive of the causal organism (23). Some symptoms of reaction, small pellucid spots with tiny necrotic centres are indicative of toxicogenic feeding by insects.

This disease is quite widespread and should be considered as a maize disease of importance. It was first recorded in 1955 at Moor Plantation, Ibadan. The intensity of spotting was up to twenty-two spots per cm^2 (110). Mechanical transmission of the causal organism failed. A preliminary screening of varieties indicated the following degrees of symptom expression in various maize materials (108):

Severe reactions:	Mexico 1, Mexico 5, Trinidad, EAFRO 225–275, Sicaragua.
Intermediate:	Mexico 13, Tsolo, Minnesota x Mexico 1.
Slight reaction:	Lagos White, Ikom, Akwete.

7.2.3.7. Leaf distortion (116)

In 1961 leaf distortion occurred at Ilora. This abnormality is very conspicuous in the field by virtue of lateral rolling of the leaves and outgrowth of the underside of the leaf veins (enations). The worst affected plants grew no higher than two feet and eventually died. Many of the early affected plants, however, recovered from this disease. It has been noticed in the Ibadan area and in Ado Ekiti. The cause is as yet unknown, although it is suggested that it may be linked with the occurrence of various insects.

7.2.3.8. Four more common diseases

Some of the diseases not mentioned in the above paragraphs are still of importance in restricting the yielding performance of the maize crop in Nigeria or bij degrading the quality of the harvested grains. For Nigeria only the symptoms and the causal organisms are known. See photograph 7.

7.3. CONCLUSIONS

At the end of this chapter we may re-appraise the present disease situation. To what extent various diseases can reduce the yields of maize was only realised in Nigeria with the onset of the American rust, which decimated the crop so severely, that in many areas food shortage existed. This attack has now subsided possibly only temporarily; introduction of Central American maize materials has helped to a considerable extent to safeguard the maize crop of the farmer.

More serious losses are at present caused by various leafblights, of which *Cochliobolus heterostrophus* is the worst, probably followed, not closely, by *Curvularia* sp. and perhaps by *Trichometasphaeria turcica*. The suspected virus disease, leaf fleck, however probably rates as high as *C. heterostrophus* in importance. For resistance to both the southern leafblight and the leaf fleck we are depending on local materials, selected conjointly by the Nigerian farmer and his environment.

The interplay of man, his crop plants, diseases of the crop plants and the environment has been illustrated clearly in describing the present knowledge on various maize diseases in Nigeria. If natural selection had not catered for the production of tolerant material, man would not have been able to meet the rust problem as quickly as proved possible in this case. Further problems still exist, but the presence of the necessary range of susceptible, resistant or tolerant varieties to the leafblight and leaf fleck diseases, promises the possibility of breeding acceptable maize varieties withstanding those pathogens.

8. IMPROVEMENT OF THE CROP

8.1. Introduction

8.1.1. *The problem*

Information has become available, which has given us an understanding of the place of maize, as it is grown and utilised in Nigeria. The improvement of its productivity, in the first instance the increase of the quantity of dry grain produced per unit area of land, is the focal point of research into this crop. This can be achieved partly through agronomic practices. However these can only be fully effective, if they are combined with the use of maize varieties which have an improved yielding potential when compared with that of the local varieties cultivated at present. This led to a careful scrutiny of maize material at hand, collected from the area itself or obtained elsewhere, in order to find sufficiently variable and suitable germplasm to allow for the selection of new varieties. If such new cultivars are to reach the maximum yielding potential and also to express this, then use should be made of breeding techniques, suited to the prevailing circumstances and leading to materials applicable in and adapted to the Nigerian environments.

It is intended to sketch the development of the breeding programs rather than to discuss the possible range of maize breeding techniques, which have been adequately treated elsewhere (69, 118). The choice and the application of breeding methods in the particular ecological, agrotechnical and social environment, pertaining in Nigeria constitute the subject at stake.

8.1.2. *The environment*

A constant point of discussion between various agricultural workers consists in whether work should be based on the actual state of cultural management of the crop, or on the ideal agronomic circumstances, as far as known, as a yardstick for the applicability of newly developed cultivars. This is especially important for a breeder, as his program cannot be concluded in a few years. Neither of the two alternatives would be correct, and one should try to assess the progress of the farmers' developing understanding of new agricultural techniques. There is little doubt, that the Nigerian farmer will soon accept new ideas, if the profits are clearly demonstrated. The time when the cultivation of crops will be more and more centralised in larger areas per crop within the farms, and when the scatter of farming fields per peasant will be reduced, should not be in the too far distant future. Application of the main fertilizers, nitrogen, phosphorus and potash, should also become general practice within the foreseeable future. It is for these reasons, that our maize breeding work has been performed in large scale plantings, basing the selections rather on the production per unit area of land than on yields per plant. This last criterion would only be of importance if the maize crop were to be improved for its use on the cob. For this purpose maize is normally planted in small areas around the compounds, and this practice is likely to remain. The best available practical cultural methods should be utilised in the course of the selection programs. The most important ones are: correct time of planting, optimum spacing, economic fertilizer application.

The desirable agronomic milieu to be created within the natural environments occurring in the maize growing areas, appears at present quite different from that on many farms. In the forest areas in southern Nigeria it is often still the custom to cultivate the maize in small pockets cleared from the forest, and in the savannah areas much of it is grown in the fadamas and other outstandingly moist or fertile places. Fortunately, there are indications, that varieties of maize suited to the forest areas in Nigeria, will also perform well on the fadamas in the savannah area, where a sufficient supply of moisture prevails, although those varieties tend to be longer maturing in more northern locations than they are in the south. Upland farms in the savannah areas are considered to be the probable areas where varieties to be developed in Northern Nigeria should have their main application.

Maize breeding programs were started initially on Moor Plantation, Ibadan, situated on the northern fringe of the lowland rainforest in Western Nigeria. This lies in the centre of the main maize belt of Nigeria. Most of the investigations on breeding techniques and selections of maize materials have been accomplished at this location. The programs are being extended towards Mokwa, just north of the river Niger in the province of that name, to serve savannah areas, and towards Umuahia province in the wet rainforest areas of Eastern Nigeria.

8.1.3. *Aims*

In the foregoing chapters prerequisites have been given, which would be of great importance for the success of maize varieties in the various maize growing areas of Nigeria. It should now be possible to summarize these requirements. This will serve the purpose of setting a definite aim to the breeding programs.

A variety suited to the forest areas in Nigeria should show at least the following characteristics in addition to a satisfactory yielding potential (110):

1. Young seedlings should be tolerant to a drought period of two weeks, as at the beginning of the rains the precipitation can be very erratic. This is particularly important in view of the fact, that the crop should be planted with the first available rains in order to give maximal yields.
2. During their development, seedlings are subjected to many leaf diseases; of prime importance are the American maize rust caused by *Puccinia polysora*, and the southern leafblight caused by *Cochliobolus heterostrophus*. A good degree of tolerance or resistance is vital for maize varieties intended for southern Nigeria. Less importance may be attached to this requirement for cultivars bred for Northern Nigeria.
3. The frequently tall growing plants should show a good degree of resistance to the often violent storms of short duration preceding or accompanying heavy rains. Really heavy storms of this nature, often exceeding speeds of eighty miles per hour, occur irregularly, but certainly three or four times during the

development of the crop. They can cause major havoc through stem lodging (snapping of the plants) or root lodging (uprooting of the plants).

4. The maize varieties should be adapted to the very humid conditions prevailing at harvesting time. The grain must not contain more than twenty to twenty two per cent of moisture at harvesting time or at approximately fifty days from tasseling for medium to long maturing varieties.
5. In a large part of southern Nigeria any new maize cultivar should have white grains with a floury endosperm, that is: grains which allow for a high return of flour per unit of weight, when processed with mills and sieves. In other areas harder grain types may be utilised.

The first four of these specific requirements relate to the reliability of the crop for the farmer, and the last one to its acceptability to the consumer. All these requirements and several minor ones have been discussed in extenso in earlier parts of this publication and the reader is referred to these.

A few considerations are still to be given regarding the question of yielding potential. The increase of the production of dry grain was said to be the overall aim of the maize breeding program. The lowest cost of production of this staple is another factor to be considered, which is most likely to be achieved with cultivars of a longer maturity in preference to short maturing ones, which would make for a less efficient use of the growing season. Cultivars with a longer period of development, have as a rule a much larger leaf area per plant than shorter maturing varieties and are able to give a higher yield per unit area of land.

For the individual farmer it may be profitable to grow a maize variety with a short period of development. He will harvest his ears long before late maturing varieties would be ready, and so he may benefit from the often considerable price differential existing between the time, that the first maize is harvested and that the bulk of the crop comes on the market. From the point of view of the country's economy there would be little doubt, that the use of long maturing varieties to decrease the cost of production, coupled with the promotion of satisfactory storage methods of the produce, would be advantageous. Such procedures should also prevent the occurrence of a 'hungry gap', for which the maize usually serves as the filler crop. Similar arguments may be advanced, when discussing the advisability of early or late maturing cultivars for use in the second or late season, during which a maize crop is usually grown in most of Western Nigeria. It is only in marginal savannah areas, that short maturing varieties of maize should be advocated. Elsewhere we found that the late maturing varieties as a rule retain their relatively higher yield level even when the rains happen to stop earlier than normally. The absolute yield levels are however seriously affected in such cases. More security for the late season maize crop could probably be achieved by advancing the planting date by one or two weeks. If the argument of cheapest production is also considered in respect of the late season maize crop, it appears that it would be advantageous to produce the necessary maize grains during the early season. The late season could then profitably be used for cash crops or other food crops more adapted to the late season environment.

It is with the future in mind, that we strongly recommend that the medium to late maturing varieties should form the backbone of Nigeria's maize industry. This applies to the maize cultivated for the purpose of dry grain, on a field scale. Where, however, the maize is grown on the compounds for use on the cob, the argument might well be in favour of short maturing varieties. It is with this in view, that some short maturing maize material is now being developed in Nigeria's Middle Belt, whilst all other breeding programs are directed towards the production of suitable, medium to long maturing maize cultivars.

In a former chapter it was shown how a higher or lower degree of retention of active leaf area after seedset is closely associated with the higher or lower productivity of the maize crop. This knowledge provides a tool for improvement of the yielding potential within a variety, which might be specially advantageous in improving low yields of local varieties, whilst retaining their many advantageous characteristics. A selection for longevity of the leaves could be one of the criteria, when establishing inbred lines from these maize varieties. It is less suited to a mass-selection method, as the character can only be judged after pollination has taken place.

Two more facts must be taken into consideration. The first is, that in the near future, the farmer will depend on governmental departments to furnish him with seed of newly developed varieties. Even if those departments were solely concerned with the production of certified or registered seed of these cultivars for issue to farmers directly, a tremendous organisation would be required to accomplish this effectively. Given the situation that at present no intermediate organisations, such as seed firms, exist in Nigeria and that the farmer will for some time continue to multiply his own seedstock, another prerequisite for new cultivars is necessary. New materials should reproduce true to type, when grown in comparative isolation for at least such a number of generations, as will allow for new varieties to become available. Eight generations, that is, four years for varieties developed for southern Nigeria, where two crops can be raised annually, should suffice.

The second factor again relates to the present position of the farmer, especially in southern Nigeria. Whilst in the Middle Belt the upland farm and fadama maize crops are normally harvested when matured and the compound crop for use as immature ears, no such separation generally occurs in the south. The field crop is harvested partly for sale prior to maturity and the remainder is left to mature. In this case the produce of such dual purpose varieties should therefore be acceptable whether harvested in the immature state or as dry grain. The problem is however alleviated by the fact, that even in obligatory white floury areas in southern Nigeria, yellow flint varieties are, as a rule, preferred as maize on the cob. The value of white grained varieties should therefore be mainly judged upon their dry grain produce. The acceptability of their immature ears is of less importance, as a completely different type of maize is preferred for this type of food. Specialisation in the cultivation of various food crops is another feature, which the future no doubt will bring.

On basis of these considerations we can now appreciate, how new maize cultivars should fit in Nigeria's pattern of food crops in the near future. Only the major requisites are mentioned:

1. High yielding, medium to long maturing cultivars suited to the main cropping season in the rainforest areas of southern Nigeria. The grains should be of a white colour and should yield a high return of flour per unit weight of grain, when processed. Resistance to the American maize rust and various leaf blights are of prime importance for this material. The cultivars should be able to withstand violent rain storms, which may be accomplished by a combination of strong stalks and vigorous root systems or by shortening of the stem. At maturity the grains should have a low retention of moisture, even when ripening at the height of the rains.

These cultivars should be acceptable, where the crop is grown mainly for dry grain production in Eastern and Western Nigeria. They might be of value in the Middle Belt, if cultivated on the fadamas or other more fertile and/or moist areas.

2. Yellow and white flinty or floury flint cultivars should be developed for the savannah areas. They should be high yielding and of medium to long maturity time. A good resistance to rain storms and an ability to withstand long periods of drought, early in the plant's development, are essential prerequisites. The material should be suitedto upland farm areas.

3. Of secondary importance is the development of preferably short maturing cultivars suited to southern rainforest areas or to compound farming in the Middle Belt and meant for the production of maize on the cob. These materials should be of yellow grain colour and of a good taste, when harvested between the milk and dough stages of maturity. The production of several ears per plant would be advantageous.

In the rainforest and derived savannah areas where a second crop of maize is taken, cultivars of medium maturity would be of importance. The grain type and other characteristics should be as given for the early season cultivars. But one major feature should be added; these cultivars should be resistant to stem-borers, which are often the limiting factor for the cultivation of late maize crops.

4. Much of the maize crop is presently used for human food; however, there is already a tendency for part of the grain production to be diverted for use as feed for poultry. This outlet will probably also include pigs and cattle in the future. Hence the need for maize cultivars having the prerequisites of those listed for the early maize crop, raised in rainforest areas, apart from its grain type. The grains could be of a yellow flinty type.

When the programs for improvement of the maize crop were started, only a few of the desirable traits of cultivars to be developed, were realised. In the course of visits to farmers, millers and consumers, of discussions with workers in the agricultural field and of the development of the present breeding programs, the picture given above evolved gradually.

The breeding programs at Ibadan and the future program in Umuahia province will cover the requirements mentioned for the first group of cultivars. The second group of cultivars is pursued by a breeding program initiated in Niger province during 1960. The requirements mentioned under groups three and four are not yet met, although one long maturing, yellow, flint variety was issued for the purpose of feed-grain, which had been developed in an attempt to test chosen breeding techniques.

8.2. Breeding programs

8.2.1. *Introduced versus local varieties*

The complete absence of resistance or tolerance in the local maize varieties to the American maize rust, which severely decimated the crop after its onset, shaped the first approach towards an improvement of the maize crop into large scale introduction of maize materials from all over the world. As explained earlier, all material was grown at Ibadan and much of it had to be discarded. Reasonably yielding introductions, which all came from Central America, went into yield trials at Ibadan and when found satisfactory, also in other locations. This procedure is still continuing with newly acquired materials and will be repeated, when alternative breeding programs are initiated, serving different environments. This is possible, as all acquisitions are maintained in a viable condition by the use of airconditioned seedstorage facilities, at a temperature of eight to nine degrees centigrade and a relative humidity of fifty per cent.

On the basis of this preliminary testing work some varieties, such as Mexico 1 and Sicaragua, later followed by Mexico 5, were chosen soon after the outbreak of the rust epiphytotic, for issue to farmers, although insufficient data were yet available. The need for new varieties withstanding the rust attack, was very great indeed during the first five years after its onset. Now much more care is advocated in connection with the release of new maize varieties.

For the breeder, however, these preliminary yield trials were of great importance as the relative behaviour of local and introduced varieties and some of the potential of these new acquisitions had already been demonstrated before the breeding program was initiated in 1956. The available information has been discussed in the chapter dealing with maize material available in Nigeria. In short: widely distributed and high yielding local varieties of maize were, apparently, not in existence prior to the coming of the rust disease, either in Nigeria or in other parts of West Africa, and some introduced varieties gave tremendous increases in yield above the level of the locally grown maizes. The first thought was, therefore, to replace the existing maize varieties with altogether new ones, rather than to introduce tolerance or resistance to the rust into the local cultivars. The policy was successful in parts of the Middle Belt area, but not so in many parts of the rainforest, due to the fact that the new grain types were not acceptable. The screening of local and introduced varieties was the first step towards the recognition of promising maize materials. This first step was to be followed immediately by selection work, which should serve to improve the adaptability and the suitability of the new varieties.

8.2.2. *Towards synthetic varieties*

A first choice to be made was whether the possibilities present in the phenomenon of hybrid vigour should be fully exhausted by production of narrowly based two-, three- or fourway hybrids, or whether the aim should be directed towards materials with a wider genotypic base. The latter would, in all probability, be better suited to the variable environments encountered than materials with a narrower genotypic base and therefore with more specific requirements. The first selection within white floury flint maize varieties belonging to the Mexican Tuxpeño race, and enumerated above, within yellow flint varieties from Trinidad and South Africa and within white floury materials from Western and Eastern Nigeria, was made with a view to an initially intravarietal improvement with the aid of breeding techniques for the composition of synthetic varieties. These techniques had been developed in the cornbelt of the United States of America, where investigations on the performance of multiple hybrids, combinations involving more than four inbred lines, were made when searching for cheaper ways to produce hybrid seed. This led to performance tests on synthetic varieties, which term is used to designate the advanced generations of a multiple hybrid, obtained under open pollination (118). The use of the synthetic variety had already been advanced in the early years after the discovery of the hybrid vigour, but its acceptance lasted until the presentation of critical data on such cultivars by LONQUIST (79, 80, 81). It was then realised how important it is to incorporate only materials with a high combining ability in these composites.

Synthetic varieties were set as an aim to meet the requirements of the maize growers in Nigeria, because with the synthetic varieties the breeder can make sharp selections, achieve large increases in yielding potential and retain its reproducibility by simple cultivation in isolation. The synthetic varieties seem therefore by far preferable to F_1-hybrids, which are not reproducible at the farmer's level, as a satisfactory organisation for the production of F_1-hybrid seed is not available yet. Synthetic varieties also allow for a wide genotypic basis to be retained.

The choice of synthetic varieties as a direct aim of the maize breeding programs does not rule out the direct application of the hybrid vigour in F_1-combinations, but only postpones it. The program for the production of synthetics leads to a careful selection of varieties, suitable for the establishment of inbred lines, which themselves are selected again for their desirability and which may be entered into the synthetics. The bank of inbred lines thus established, will, however, also be available for combination into suitable, locally adapted F_1-hybrids.

The production of synthetic varieties was to form the framework of the breeding program and is geared towards the production of high yielding maize cultivars as outlined earlier. Various resistance factors (to rust, blights, stemborers) and other desirable characteristics could be brought into these synthetics by introduction into the component inbred lines by a backcrossing technique. Similarly the traits could be incorporated straight into the synthetic variety, thus establishing a new basic population from which a second cycle of inbred lines can be selected carrying the particular factor. This recurrent selection is a feature which can be applied on the best synthetics realised and would guarantee the availability of a continuously improved basic breeding material, provided sufficient variability is maintained by inclusion of material from several sources.

The decisions taken whilst the maize breeding program took its shape are thoroughly vindicated by recommendations made at a conference of African maize breeders, held in Dakar in 1962. The text of the recommendation is repeated in full:

> 'The symposium (on savannah zone-cereals) recommends the use of synthetic maize varieties in traditional farming conditions, such varieties being obtained by recurrent or cumulative systems of selection, providing for progressive and easily applicable improvements to be achieved in several stages.'
>
> 'It recommends that hybrids be used in modern cultivation, provided that they have proven well adapted to the environment by observations, conducted over several years.'

8.2.2.1. What are synthetic varieties?

The present subject has already been mentioned in former paragraphs and will be discussed in more detail here. It was indicated that the idea of synthetic varieties originated in the United States of America from the desire to produce cheaper hybrid seed in multiple hybrid-combinations. This led to the use of the advanced stages of these hybrids and to the realisation of the reproducibility of such cultivars by simple mass selection practices, when grown under open pollination in isolation. The prerequisite for this last condition is that the cultivar must have been composed from basic material with good combining ability. The interest in this type of cultivar was simultaneously fostered by the rising opposition to the limitation of most maize breeding programs to a straightforward utilisation of inbreeding, followed by a final hybridisation, as practised, when the breeder intends to produce high grade F_1-hybrids. The synthetic variety is, for reasons given earlier, preferred to the classical single or double hybrids, which however might be a corollary to the selection of synthetic varieties in restricted, well defined environments. This return from very specifically adapted, to more versatile cultivars is part of a more general movement to incorporate a larger range of germplasm into crop varieties. The large acreages planted to cultivars, developed with refined techniques under specific environmental conditions, clearly demonstrated that such selections suffered severely from a loss in 'plasticity'. The question arose, whether it should not be preferred to substitute pure lines in normally inbreeding crops or classical hybrids in outbreeding crops, by mixtures of pure lines or by progenies of mixed planted hybrids. BRIEGER (13) indicated that in crop improvement programs pure lines might well have to be replaced by populations, that is, groups of individuals with the same mode of reproduction and influenced by the same genetic movements and selection pressures but with a broader genotypic basis and therefore a better adaptability. In an outbreeding crop such as maize, this means that one tends to work with more variable populations, containing a much wider range of genotypes than are available in the classical hybrids, although this range is reduced by the selection practised, compared with open pollinated varieties. Especially if the cultivar is to be grown under an extensive range of conditions, a varietal mixture or a synthetic variety based on differing component parts would be a more likely safeguard for the farmer against the vagaries of the weather than a single varietal genotype. This is still more valid when comparison is made with F_1-hybrids which are as a rule very specialised in their environmental requirements (53). The application of synthetic varieties has shown promise in several instances, although detailed information still remains rather scarce (41, 81, 113, 142). In any case, it transpired that considerable increases in yield above the source materials were achieved, which remained however below the potential of locally well adapted hybrids.

Synthetic varieties apparently make a gradual use of the phenomenon of hybrid vigour, which is exhausted usually within the first one or two generations, when a standard F_1-hybrid is cultivated. This hybrid vigour is rooted in the fusion of well combining genotypes. If a larger number of genotypes, carefully selected for a high combining ability to each other, is utilised in composing the synthetic variety, then a slower exhaustion of the heterosis effect may be conceivable because of the multiplicity of new genotypes occurring in the next generations. The original sharp selection in favour of high combining ability in the material brought into the composite, presumably leads to a good combining ability of the newly occurring genotypes. In how many generations this residual heterosis effect will level out is as yet unknown. Indications are available that a simple negative mass selection by removal of undesirable plants, may even lead to an increase in yield potential of the composite within the first eight generations (81).

8.2.2.2. Synthetic varieties, scheme of selection

The actual selection work had to be started after a choice had been made of varieties, partly based on their performance in yield trials and partly on their having specific good qualities, of importance for future cultivars. The selection was initiated with an evaluation of the combining ability of inbred lines, tested against their source variety. It was intended to narrow thus the gene basis of each of the chosen maize varieties and to obtain higher yielding cultivars by intravarietal selection. This was to be followed by the production of intervarietal composites, after a thorough search for varieties carrying a high degree of general combining ability.

The scheme of selection for combining ability followed can be described as follows:

1. Material from which the best combining individuals are to be used for the establishment of the synthetic variety, is selected.
2. All individuals (be it plants, progenies, ear samples or inbred lines) are topcrossed to one or more tester varieties.

3. All topcrosses are entered into statistically laid out yield trials, preferably repeated at several locations, in order to identify the highest yielding topcrosses.
4. The yield levels of the topcrosses indicate which parent lines had the best yielding capacity, when combined with the tester. These best combining materials are selected from amongst the original group of individuals.
5. The highest combining materials are crossed pair by pair; the combinations, thus obtained, are mixed in equal quantities and multiplied under open pollination in isolation to produce the synthetic variety.

The last step, the actual composition of the synthetic variety might be arranged by mixing equal quantities of seeds from the components and allowing for a multiplication in open pollination, if sufficient seeds are available to ensure success. If one works with small quantities of seed as in the case with half ear samples, when utilising S_0– or S_1-materials as components for the synthetics, the controlled pollination of pairs of the components would safeguard the results.

The synthetic variety composed in this way, can then be tested for its yielding capacity and further agronomic or other characteristics. Any suitable synthetic can be used for a subsequent (recurrent) selection of material to produce second cycle-synthetics.

8.2.2.3. Synthetic varieties, components

As in the case of multiple hybrids, originally only advanced stages of homogeneous, nearly homozygous, inbred lines were utilised for inclusion in the synthetic varieties. However, one realised that, apart from shortening the period of selection, there might be added advantages in the use of earlier stages of inbreeding, which are less homogeneous and more adaptable (72). At Ibadan considerable yield increases were even obtained by the selection of ear samples, half of which were used for the testing of topcross combinations with the parental source variety for their combining ability, whilst the other half was retained in a seedstore. The remnants of the best combining ear samples were combined into the synthetic variety ES1, which gave on the average a thirteen per cent increase in yielding capacity over the source variety during the first three generations from its composition (41). This gametic selection procedure had been followed as a quick test of the methods of topcrossing and selection for combining ability prior to the availability of inbred lines in our program.

This gametic selection method has a major advantage over others in that no artificially controlled pollination techniques are necessary. Only the topcrosses need carefull attention, as they are to be produced by interplanting them between the source variety in an isolated field, that is, apart from any other maize. The 'ear rows' are to be detasseled in order to make sure that they are all fertilised with the same parental pollen mixture.

A sharper selection by the application of inbreeding techniques was however thought necessary and in the first instance the use of first stage inbred lines, indicated as S_1-lines was considered. Combinations of S_1-lines had already been used extensively in Mexico for the production of F_1-hybrids. These proved not to be exceeded in yielding potential by any F_1-hybrids, developed from advanced stage inbred lines selected from the same materials. The S_1-lines apparently can be maintained in their rather heterozygous condition by open pollination in isolation. Care should be exercised however to safeguard these lines from contamination, which will change, and often reduce, the combining ability. This could also occur, if an insufficient sample size is used for the maintenance. A great advantage exists in that S_1-lines generally are quite vigorous and easy to multiply (136).

The question arose as to whether under the given circumstances it would be more advisable to develop synthetics from S_1-lines or from more advanced stages. This choice in favour of one or the other seems to depend only partly on the range of microconditions under which the synthetics are to be used, that is on their required versatility or adaptability. This would favour the use of early inbred stages. Of major importance, however, is the segregation of the combining ability characteristic in early and later stages of the inbred lines. As explained earlier, the value of synthetic varieties depends on the gradual expression of residual heterotic effects, on account of the ability of the segregating genotypes to recombine within the synthetic during its more advanced generations. It is conceivable, that S_1- lines breeding true for a high combining ability, would be acceptable basic material for composition into synthetic varieties. However inclusion of S_1-lines which would give rise to mainly low combining advanced inbred lines, despite their own high combining ability, would be disastrous. The use of the last type of S_1-lines could only be allowed in F_1-hybrids, of which the seed is reproduced from the basic lines continuously.

Prior to the availability of data on the transmission of the combining ability characteristic in various generations of inbred lines, selected from the material suited to Nigerian conditions, it was decided to restrict temporarily the selection of inbred lines to S_1-stages. However, as explained in the next paragraph, this decision has had to be reversed.

8.2.2.4. Selection for combining ability and its inheritance

We have been gradually introducing the term combining ability as a desirable characteristic of selected maize materials. It is useful to repeat here the relevant definitions given by JOHNSON in 1952 (66), in order to clarify the subject under discussion.

General combining ability is the relative performance of material, when outcrossed to a broad base of heterogeneous germplasm, for example open pollinated varieties.

Specific combining ability is the relative performance of material, when outcrossed to a narrow base of homogeneous germplasm, for instance an inbred line.

Average combining ability is the relative performance of material, when outcrossed to several homogeneous testers. With increasing numbers of testers these values should approach the general combining ability.

When considering the production of synthetic varieties the general combining ability of the components will be of great importance. The specific combining ability will be most important when selections are made in preparation for the production of F_1-hybrids. Some information became available in the United States of America on the relative importance of a selection for general or for specific combining ability. Synthetic varieties made up on the basis of lines from the same parental source, selected for specific or for general combining ability differed significantly in yield in favour of the general combining ability-group (82). Our attention has therefore been given to a selection for the general combining ability of the inbred lines developed.

A test on combining ability serves as an important screen for singling out from available collections materials on which new synthetics are to be based. Only those materials are usually included in these tests, which have satisfactorily developing plants with a sufficiently strong stem and rootsystem, a well developed tassel with a good production of viable pollen, a low incidence of disease, and other desirable traits. The ability of selections to give, in combination with others, a synthetic variety with higher yielding capacity than the source material, is presumed to express itself in the relative yield levels of test crosses of those selections with a tester variety. The choice of a correct tester is very important in this respect and should relate to the materials to be included in the final synthetic variety to be produced. It has been pointed out that in Nigeria a generally accepted and widely distributed maize variety of good performance was not available at the time that this program was initiated. It was thus, that the decision was taken to commence the selection program by improving the yielding ability and adaptability of the most promising varieties within themselves. An extension of the program to the recombination of selections from different maize varieties was postponed, until more information was gained on intervarietal combining ability of these cultivars with the aid of yield tests on varietal hybrids. The open pollinated parent variety was chosen as the tester, as this is the only one which represents, more or less, the various genotypes met within the material to be selected, and which still retains the sufficiently broad genetic variability, necessary to obtain from the test crosses a picture of the general combining ability. That the tester should be related to the genotypes of any future counterparts with which the selections should recombine into high yielding synthetic varieties can be concluded from the fact, that often various testers give different rankings in combining ability to selections, with which they were topcrossed (57). The parent variety then seems the only possible choice for an intravarietal improvement program. This question will be considered again, when the investigations with varietal hybrids will be discussed.

The advantage of testing inbred lines for their combining ability in the early stages of inbreeding as opposed to the use of advanced inbreds has been under study for many years (39). It is a problem directly related to the question, whether the components for a synthetic variety should be early or advanced stages of inbred lines. In order to study the inheritance of the combining ability, the yields of topcrosses of a number of S_1- lines were compared with each other to identify S_1-lines with a high general combining ability. In the meantime those

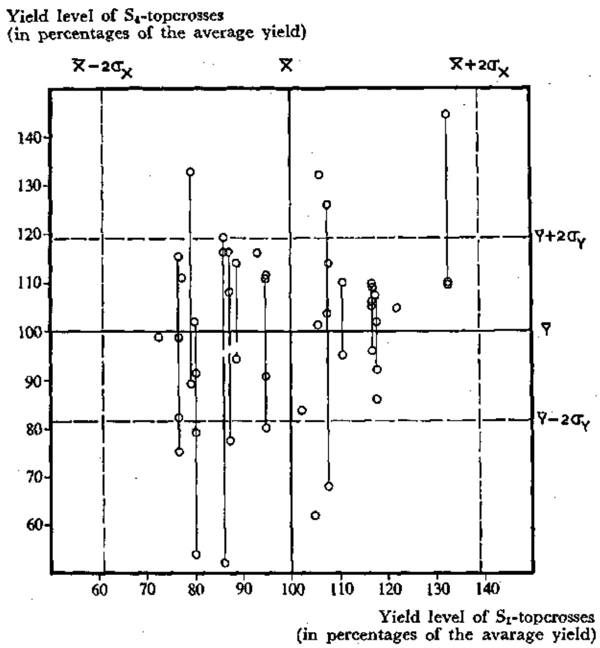


FIGURE 15.
Performance of S_1- and related S_4-topcrosses derived from the maize variety Mexico 5.

S_1-lines were inbred further and selected until the fourth inbred generation was attained. A subsequent yield trial with topcrosses of this S_4-material with the same parent variety was carried out in order to shed some light on segregation into low and high combiners. This comparison of S_1-topcrosses and related S_4-topcrosses was carried out with materials, selected from the variety Mexico 5. The results are graphically represented in figure 15. The yield levels of the S_1-topcrosses expressed as a percentage of the mean yield of the trial, are indicated on the abcissa and those of the S_4-topcrosses on the ordinate. Points indicating yields of S_4-topcrosses originating from the same S_1-line are joined with vertical solid lines.

Horizontal lines at a distance equal to twice the standard error of a mean from the average S_4-topcross yield (= Yor 100 per cent) indicate which S_4-topcrosses gave performances significantly better than the average. The same was done with vertical lines for the trial with the S_1-topcrosses.

The first characteristic of the distribution of the points is their scattered appearance, which indicates the low correlation between the S_1- and S_4-topcross yield levels. The picture could have been confused partly by the apparently high standard error in the yield trial on S_1-topcrosses. The main point of interest, however, is the great variability existing in S_4-topcrosses derived from the same S_1-line. The comparisons are only subject to the lower standard error, obtained in the trial with the S_4-topcrosses. Eight of the twelve S_1-inbreds, represented by two or more S_4-progenies gave a very wide range of yields, varying from three to six times the standard error of the mean and therefore highly significant. From the graph can be seen that both above and below average combining S_1-lines gave rise to the four high combining S_4-lines. Furthermore, there was no clear tendency for low combining S_1-lines to segregate into low combining S_4-lines, nor was this conversely the case for the high combining ones. It would appear that in this case it would be more profitable to continue the selection for general combining ability to further advanced inbred stages than the S_1-lines.

It is realised that the information now at hand is limited and only available for one of the maize varieties, used in our program for the establishment of synthetic varieties. However, as most of the high yielding, floury flint, source materials are of the same Tuxpeño race, it has been provisionally decided to restrict selections for combining ability to S_4-inbred stages, until such times as more data become available for the varieties concerned. This decision was also governed by the fact, that an attempt was made to compose a synthetic on basis of eight of the highest combining S_1-lines, derived from the variety Mexico 5. This attempt failed: the synthetic, ES2, gave, despite a careful selection for combining ability of its component S_1-lines, no increase in yield potential. The effect of the selection was only apparent in the far higher resistance to leafblights displayed by this variety.

The loss in variability, and therefore perhaps also of adaptability, due to the use of more advanced stages of inbred lines should be counteracted by the inclusion of more dissimilar materials, where practicable.

The views expressed above are partly confirmed in facts reported by LONQUIST in 1950, who emphasized that where selfing is being done in previously unselected populations the frequencies of genes for undesirable characters might be so high as to largely nullify tests for yield prepotency, until some selection against them has been possible (79). This is indirectly applicable to much of the material now utilised in our synthetic programs, which are of an unselected origin apart from the variety Sicaragua and possibly also the Tsolo variety. LONQUIST (loc. cit.) also confirms, that selection within the later inbreeding generations can largely alter the combining ability of S_1-lines in the more advanced stages. He, however, draws the conclusion that an early testing procedure will provide a better basic material to continue the inbreeding process than a random selection of advanced inbred lines prior to such tests for combining ability, thus making his breeding programs considerably more efficient. Our data on the segregation of the general combining ability in later inbred stages of the variety Mexico 5 led us, however, to the opposite conclusion and caused us to favour a visual selection of desirable material up to a more advanced stage of inbreeding. With the varieties presently in use this seems to be the more advisable course of action.

For these reasons tests for combining ability of S_1-inbred lines were discontinued and attention was transferred to the more advanced S_4-lines, obtained from various sources. The first S_4-topcrosses went into yield trials during 1963 and in the course of 1965 the first synthetic based on S_4-lines might be initiated. The testing procedures for these S_4-lines had been changed in order to allow for the establishment of multi-varietal synthetics, a further development of the breeding programs, which will be discussed in the following paragraphs.

8.2.2.5. Multivarietal synthetics

The use of the parent variety as a tester depended, as explained earlier, on its characteristic of representing to some extent the genotypes of all S_1-lines, selected from it, and the possible recombinations occurring in the later generations of any synthetic variety, made up from these inbred lines. In searching for components with a high combining ability and selected from more than one source, to be made up into synthetic varieties, the testing procedures should be altered accordingly. For instance, great interest exists in the composition of good combining materials from introduced floury flint maizes and from the local floury type of maize in order to make use of the high yielding capacity of the former and the acceptability to the consumer and the ecological adaptation of the latter.

In a first approach to identify the highest combining source varieties a number of good producing varieties was crossed with three open pollinated, dissimilar varieties, a white flinty flour and a yellow flinty variety of medium to long maturity and a flinty variety of short maturity (38). Twenty six Caribbean, six Mexican, one Venezuelan and eight varieties from Costa Rica were included in this investigation. The correlations of the rankings in combining ability given to the varieties tested on basis of their performance in combination with the three testers were quite low, varying from –.42 to +.22, indicating that it was really more a specific than a general combining ability which was measured. A few of the varieties however were ranked as the highest combiners by all three testers. Those varieties therefore proved to be indeed of a high general combining ability. Outstanding were acquisitions 772 (EAFRO 237) and 766 (EAFRO 231). The first variety is a yellow flint and the second one a white floury flint variety. Other promising varieties were acquisition 110 (Sicaragua) and the numbers 265 and 1017, two varieties of the Caribbean race of maize named tropical coastal flint (15).

This first attempt to identify varieties with a high general combining ability was made at random and pointed towards the usefulness in this respect of some yellow and white varieties. However, during the development of the maize research program a clearer understanding was obtained gradually of the characteristics required of new cultivars. As pointed out earlier, a medium to late, white grained cultivar with the acceptability of the local floury variety and also its low moisture retention at the time of the harvest, was one of the first aims of the breeding program. It is with this in mind that subsequent trials were arranged on all possible combinations of the white grained varieties from which, at the time, inbred lines were under selection. A study of the yielding performances was to provide information on the most promising individual combinations and on the general combining ability of these varieties. The materials which contributed to high yields would be acceptable as source materials for the formation of synthetic varieties. Another development from this scheme could be a reciprocal recurrent selection of any pair of varieties giving an outstanding heterosis effect in their varietal combination. Such a reciprocal recurrent selection would tend to congregate genes favourable for high yield expression.

From the results of these yield tests on intervarietal crosses it was concluded, to which varietal combinations cross testing of various inbred lines for the production of either synthetics or F_1-hybrids should be restricted. However, information available to date in Nigeria is limited to combinations between the floury variety Lagos White and the floury flints Mexico 1, Mexico 13, EAFRO 231 and Sicaragua.

The main interest of the trials on intervarietal crosses lies in the average performance of all combinations involving any one variety. The varietal hybrids were grown at three locations: Agege, Ibadan and Ilora, during an early and a late cropping season. The results have been averaged over locations and were expressed as a percentage of the average performance of the six tester varieties. The figures are presented in table 16.

TABLE 16. Average yields of six varieties of maize in all possible single, varietal, hybrid combinations, expressed as a percentage of the mean of all parent varieties.

	Early season	Late season
Lagos White combinations	136	156
Eafro 231 combinations	138	142
Mexico 1 combinations	124	139
Mexico 5 combinations	127	141
Mexico 13 combinations	131	138
Sicaragua combinations	142	155
Average performance of parent varieties	100	100

It has been gratifying to note that a considerable increase in yield occurred, which can be utilised in future synthetic varieties or other cultivars, by correct combinations of selections from the varieties tested. The general picture appears to be that the introduced variety Sicaragua and the local Lagos White, gave the highest overall score in both seasons for general combining ability. The variety EAFRO 231 followed closely with a high score in the early season trials. In the late season, it did not prove outstanding, although still third in performance. The results were especially encouraging, as one of the best combiners was found to be the local variety, Lagos White, which has the soft, floury graintype, so highly valued (43).

All varietal hybrids took the same period or a few days less to reach the tasseling stage, compared with the parent varieties. This fact illustrates that the observed increase in productivity expressed itself as a larger grain production within the same or a shorter length of growing cycle when compared with the average of the parent varieties. This same phenomenon has also been observed elsewhere (29).

Only six varieties could be included in this program at its initiation. The three good combining white varieties should now be used as testers for any new, promising, white grained varieties. Only when these varieties show a good combining ability towards the three selected tester varieties, should another series of trials be arranged to cross test only those in all possible varietal combinations.

Another outcome of the trials on varietal crosses under discussion is that prior to the establishment of synthetics based on floury and on floury flint inbreds, the lines from both sources should be cross tested for their combining ability. The flinty flour and floury S_1-lines of good combining ability which are available at present, were selected on basis of the yielding performance of topcrosses with a flinty flour variety. Earlier, insufficient information was available on the use of tester varieties to screen selections for their combining ability. At present some data are available on the value of three reasonably well adapted varieties in this respect and these should be utilised in future tests for combining ability. Inbred lines already available (floury flint EWD- and floury EWS-lines) should now be cross tested in topcross combinations with the new testers and especially those of opposite graintype, that is, the floury flint EWD-lines with the floury variety Lagos White and the EWS-lines with both floury flint testers (EAFRO 231 and Sicaragua).

The studies with varietal hybrids have also provided us with a firm basis for the establishment of multivarietal synthetics and eventually of hybrids. It is now clear that inbred lines are to be developed from the varieties EAFRO 231 and Sicaragua and also from the floury variety Lagos White. All these materials are to be tested against the three source varieties and only those selections to be retained which show promise in all three combinations. Fourth stage inbreds of these materials have been selected and at the time of writing this publication the first topcrosses were growing in the field.

At the end of this discussion it is again stressed that the present availability of varieties of a known high combining ability can be used to initiate a further stage in the search for such materials within the germplasm now available in Nigeria or still to be acquired. These new materials can be added to the series of testers or may even replace them, depending on their performance. Notably the range of real floury materials amongst the Nigerian local varieties of maize should be carefully screened for their combining ability.

The studies on varietal hybrids have hitherto been kept restricted to white graintypes. However, recently, the program was extended to include also intercrosses of a number of the best yellow grained, flinty maize varieties available, the most important ones being ES1, Tsolo, EAFRO 237 and EAFRO 250 (41, 50).

8.2.3. *Hybrids*

There is little doubt that for a number of well defined cultural environments hybrids will have to be established. The applicability of such cultivars was already referred to in an earlier part of this chapter, where the conclusion was reached, that hybrids cannot play a role until the educational and agrotechnical level of the farmer has been raised considerably.

The development of hybrids for an altogether new environment is a long term program. Some cases are known where hybrids introduced from elsewhere gave rise to a good crop of maize in Nigeria, but never far in excess of the best open pollinated cultivars. Most hybrids show a high degree of suitability only to the particular environment for which they were selected. This results often in a complete crop failure, when these hybrids are grown elsewhere, as was the fate of many hybrids introduced from the United States of America or from South Africa into Nigeria.

If hybrids are to be used, these will have to be bred locally. Any material to be included in the F_1-hybrids has to pass through a series of tests on general and subsequently on specific combining ability. Both stages include topcross performance tests. It may then be clear that the search for breeding materials, with a high general combining ability, pursued for the establishment of synthetic varieties, covers at the same time the first requirements for a hybrid program. The programs are therefore not alternative ones. On the contrary, the present selections and screening tests are laying the basis for future hybrids.

The congregation of favourable genotypes in synthetic varieties, as explained earlier, provides for a higher degree of adaptation in those composites as compared with the original varieties. The later generations of synthetic varieties may be used with advantage to introduce a second cycle selection for obtaining better adapted inbred lines (91), which may be another stepping stone to specifically suited hybrid material. Furthermore, in the event that synthetics were based on two different source varieties, another development should be a recurrent reciprocal selection in an attempt to produce both higher yielding synthetics and establish inbred lines for future hybrids (74, 118), whilst paying specific attention to the combining ability towards the alternative component of the synthetic variety or hybrid combination.

Results of a hybrid program cannot be forecast at present. A few facts however have emerged which should be taken into consideration. It was observed that a number of inbred lines, derived from some tropical maizes did show only a small degree of decrease in vigour, a character which is normally associated with inbreeding in maize. Examples of this are the cultivars Mexico 5 and Lagos White. Some other materials show a very severe reduction in vigour, especially in advanced inbred stages, for instance Mexico 13, and the West African local varieties Akwete White and Ikom White. It was originally feared that the apparent lack of decrease in vigour could perhaps indicate a smaller response to the heterozygotisation occurring in the F_1-hybrids, more so as a synthetic variety, ES2, composed from eight good combining inbred lines developed from Mexico 5, did not show a considerable increase in yield, as expected. The performance of combinations with inbreds selected from better combining sources could not be tested yet as these materials are still being developed. The increase in yield obtained with varietal hybrids as compared to the yield levels of the parent varieties is however very promising, also for Lagos White.

8.2.4. *New sources of variable breeding materials*

Selections can be carried out only when sufficiently variable material is available. Separation of the best materials and elimination of others will lead to the desired goal of upgrading the crop to be improved. Whilst large reservoirs of maize germplasm are still untapped by our maize program, with the available materials combinations can be made to serve as new basic breeding materials. In the first instance the synthetic varieties, especially those based on more than one source variety, provide for high quality material for selection. Such cultivars proved to be useful reservoirs from which undesirable gene combinations can be eliminated relatively quickly by recurring cycles of selection (12). This was corroborated by BROWN in 1953, when he came to the conclusion that the most effective sources of germplasm for the improvement of the maize crop apparently were derived from the random mating (panmixis) over a long time period of several races of maize, and stated that this probably was a matter of the residual hybrid vigour available in the mixture.

A similar train of thought resulted in the substitution by first inbred stages (S_1) selected for combining ability, of more advanced inbreds for the production of hybrids in Central America thus increasing the adaptability of these cultivars. A further development is the imitation of the random mating of various races of maize, which had occurred naturally in many parts of Central and South America in the long bygone past, as described earlier. This method was initiated some years ago in Mexico (26, 137) and has given substantial increases in yield above the source materials.

When this last method of producing new breeding materials is to be applied, many different types of maize must be grown in progeny rows. Remnant seed of materials which prove to have desirable features, is then bulked in equal quantities. This composite is grown in isolation to allow for a thorough mixing of the genotypes. If materials of very different maturity groups are included in these composites, it might be advisable to control the first combination stage by staggering the plantings according to the tasseling times in order to allow all material to reach anthesis at the same time. This will greatly enhance the mutual introgression. After a number of generations (six generations are suggested) a selection pressure for higher yields within this composite can be implemented by selection from all over the multiplication plot, of individual, high yielding and otherwise desirable plants. In Mexico this method proved to give twenty-seven per cent increase in yield above the original source population within three more generations (26, 137). It seems advisable to produce similar composites separately for the two main grain types, desired in Nigeria, that is, for floury and flinty grains, unless a selection for flouriness is to be practised within the composite. This last condition would go far to reduce the feasability of these simple field selections.

A similar, but slightly more involved, method of preparing basic breeding materials for the savannah areas of Nigeria is being applied to maize varieties chosen for their time to maturity (early, medium late and late varieties) and for their yielding performance. This material was brought to an upland farm area in Bida division of Niger province in order to attempt a selection within the varieties for a good performance under these conditions and thus to improve the adaptability prior to their composition for the development of populations, suitable for a successful selection. Materials of Nigerian and American origins were planted in progeny rows of approximately six hundred plants. Twenty to twenty five of the very best plants were selected prior to tasseling and inbred. The seeds from these plants were bulked by variety and grown during the dry season under irrigation. The bulked in bredlines were then, however, sibmated. The following cropping season this procedure was repeated and in 1963 the third cycle of selection took place.

A substantial increase in productivity was noted, especially in the short maturing materials which benefitted greatly from this selection technique. The most promising materials are now to be cross tested for their combining ability with each other in order to base a composite only on such varieties, as are likely to lead to superior breeding materials. Simultaneously a bulk variety will be made with this material, which will, after a sufficient number of generations to permit a random assortment of genes by inter-pollination, allow for selections to be initiated according to the methods applied in Mexico, and described earlier. The composite can be used as a source of inbred lines for the formation of synthetics or for the establishment of hybrids.

8.3. The breeding work reviewed

Yield is the central problem in agriculture. Larger yields per unit area of land are aimed at (114). Most breeding work tries either to improve plant characters directly related to its potential productivity or to safeguard this productivity against the hazards of the environment. These objects of the improvement programs are followed in importance by the improvement of the acceptability and palatability of the product.

A considerable part of the breeding program had been arranged to diminish the toll levied upon the maize crop in Nigeria by the American rust and several leafblights. In the course of this work the low yield potential of the West African local maize varieties was sharply contrasted with the performance of several introduced maize varieties. Since then the main trend of the maize breeding program has been a search for and selection of maize materials with a high yield prepotency in combination with others. An extensive use is being made of recent developments in maize breeding techniques which point to the importance of the exploitation of this combining ability. The phenomenon of residual hybrid vigour effects observed in advanced generations of synthetics (14) has given a powerful tool for the establishment of open pollinated cultivars, which can be maintained at a good yield level for a reasonable length of time even at farmer's level.

Originally it was attempted to obtain synthetic varieties with the aid of components which had been selected as little as possible except for their combining ability. Thus a successful intravarietal gametic selection scheme for combining ability resulted in the synthetic variety ES1, which is being widely distributed in Nigeria. A similar intravarietal scheme utilising S_1- lines selected from the variety Mexico 5 proved not to be successful and an investigation on inbred lines selected from this variety indicated that a more advanced inbred generation should be utilised. The loss in genotypic variation due to this sharper selection should be offset by a greater range of variation in the components, synthesized into the new cultivars. This led to the commencement of studies to investigate the occurrence of heterotic effects in varietal combinations, which resulted in the recognition of the three varieties Sicaragua, EAFRO 231 and Lagos White as the most promising component parts for multivarietal synthetics to be developed.

Data now available have established a basis on which further breeding work can be built. Only a few synthetic varieties have as yet been issued, but the issue of duly selected synthetics based on S_4-lines, selected from the floury flint varieties EAFRO 231 and Sicaragua and from the floury Lagos White lies in the very near future. A careful search through West African local materials and introduced varieties will no doubt yield many more sources of good combining material, which in composites will give rise to new variable populations for selection of still higher yielding cultivars.

This search for combining ability should then lead to the production of well adapted and reliable, high yielding synthetic varieties. An extension of this program with a study of the special combining ability of inbred lines selected from the most desirable materials will in its turn foster the establishment of locally adapted F_1-hybrids.

Apart from the general program for the improvement of dry grain yields, outlined above, several other breeding projects have been mentioned in the chapters where information was given relevant to the particular characteristic to be improved.

One of these is related to the improvement of the yield level of the local varieties, which was proven to be extremely low. One of the common physiological explanations of yield differences between varieties of a crop plant lies in differences in photosynthetic area. In maize as in other grain crops, only the photosynthetic active area of leaves, leafsheaths and other plant parts, persisting after ear emergence is directly concerned with the grain production. In the Nigerian variety Lagos White it was shown how the reduction of this photosynthetic area occurred much faster than in introduced varieties, which reached anthesis in the same period, but gave a far higher yield (48, 134). The recognition of this fact provides a tool for the improvement of local materials, which show sufficient variability of this characteristic.

Most other problems relate to the reliability of the crop and intend to safeguard the maize yields against extraneous factors. Of primary importance are the selections for an increase in the resistance of the maize crop to the rust and leafblight diseases. These are followed in importance by the need to improve drought resistance and standability and to decrease the moisture retention of the grain at harvesting time, factors which are directly related to the climatic environment under which the maize crop has to produce its grain.

9. MULTIPLICATION OF RECOMMENDED CULTIVARS

9.1. ORGANISING SEED MULTIPLICATION

It is only recently that multiplication of maize seed for issue to farmers has become of importance. With the progress of the maize breeding program in Nigeria more materials will steadily become available, which, once proven, have to be multiplied as fast as possible. As at present no commercial firms are available to take over the seed multiplication from governmental institutions, the latter will have to provide the facilities, at least for the early stages in the multiplication. There is a possibility that farmer's cooperatives might play a role in the last stage of the multiplication and in the maintenance of cultivars at a village level.

9.1.1. *Registration of seed materials*

As a rule four quality classes are distinguished for improved seed materials of cereal varieties, that is, Breeder's seed, Foundation seed, Registered seed and Certified seed (52). These are also applicable to open pollinated varieties or synthetics of maize, while some care is to be exercised when utilising the terms for inbred lines.

The first two terms are the most important ones. Breeder's seed is directly controlled by the originating plant breeder and is the source for initial and recurring production of foundation seed. The term foundation seed covers seedstocks 'handled as to most nearly maintain varietal genetic identity and purity' and are the first one or two multiplication stages derived from the original breeder's stock (52).

The remaining two terms can for the time be combined into one, as long as government departments only will be responsible for the major part of maize seed multiplication. The produce from any large scale multiplication scheme, available for issue to farmers, could be given a certificate, stating that it has been derived from foundation or other certified seedstocks. This certificate should also be issued in respect of materials produced by private farmers, cooperatives or other organisations, provided an inspection was made of the production area during the growth of the crop and also of the seed after the harvest.

9.1.2. *Multiplication schemes*

A scheme for the multiplication of recommended maize varieties could then be developed along the following lines:

1. The breeder retains the breeder's seed consisting of carefully selected seed, maintained with a high degree of constancy. In the case of synthetic varieties the breeder's seed should be reproduced regularly by compositing anew the basic inbred lines, which are to be maintained separately.
2. The breeder's seed should be released to agencies, charged with the production of foundation seed. This should at present be performed only by governmental organisations. It is essential that foundation seed is produced from either breeder's seed or other foundation seed, under very strict control for

contamination by pollination from outside. Removal of undesirable plants should be carried out conscientiously prior to tasseling.

3. The produce from final, large scale multiplications of material for distribution to farmers should be indicated as certified seed, as a guarantee that no admixtures are present in the seeds handed out. Although at present also this multiplication stage is in the hands of government departments, it might be possible to achieve communal efforts to cover this. Once a demand for certified seed exists, private farmers might undertake this multiplication stage.

The first varieties taken into multiplication for issue to farmers were materials, which proved to withstand the rust disease, soon after its outbreak in 1951. These cultivars were however not really adapted to the Nigerian environments. The names of the North American varieties Big Joe, Bounty, White Tuxpan and many others, are at present mere names, but were once considered for issue to farmers. Subsequent to these varieties some varieties, again straightforward introductions from Central and South America, were accepted by the agricultural authorities in Nigeria for purpose of issue. Pre-eminent amongst those were originally the varieties Mexico 1 from Mexico and Sicaragua from Venezuela (95). Because of its high moisture content at harvest, proneness to fungal grain diseases and the occurrence of germinated grains at the time of harvest, the variety Mexico 1 was soon replaced by Mexico 5. It is with this variety that in 1958 large scale multiplication of seed made its first appearance in the Nigerian maize picture.

The variety Mexico 5 was multiplied and issued both in Western and in Northern Nigeria. The variety still continues to give satisfactory yields in many parts of the Middle Belt, where the farmers do not object to its grain type (97). This type preference, which was discussed earlier, played an important role in southern Nigeria. Here, Mexico 5 was often not accepted as a palatable variety. This variety should be replaced by newly bred floury varieties, which are at present under development.

As mentioned earlier a yellow flint synthetic variety, ES1, became available in 1961 and has gone under wide scale multiplication in Western and Eastern Nigeria and to some extent also in Northern Nigeria (41). All attempts to multiply available maize varieties have been only partially successful as at present insufficient control is exercised over the produce from the multiplication fields. Factors involved in this are in the first place caused by the fact that no definite organisation has been established to handle or to inspect seed multiplication schemes, and secondly because as yet no trade in improved maize grains for planting purposes exists. Also, the farmer is not used to regularly substituting his own seedstock from other sources than his own farm, but this might change rapidly when he is really convinced of the advantages of growing other maize materials than the local ones.

9.2. Some difficulties encountered

Difficulties inherent in any multiplication scheme, practised under the present circumstances, have been demonstrated by a trial-multiplication scheme at

Ilorin with the variety Sicaragua, which was proven to outyield considerably the local varieties at this locality (83). A main bottleneck proved to exist in the lack of even an approximate estimate of seed requirements. This state of affairs of course will remain, as long as no records are available on exchange of grain for planting between farmers, which occurs in kind at planting time, to be returned again in kind at harvesting time. This difficulty is inherent in the present method of retaining part of the own crop for planting. It is only after multiplication and distribution schemes have been initiated, that it will be possible to base these on a sounder footing. Another drawback was that many farmers do not realise that a good open pollinated variety of maize can be rendered useless by contamination with foreign pollen from other varieties. In other words the farmers were lowering the increased yielding capacity already within a few generations from the issue of the seed.

Some success was achieved in Ilorin province, when the governmental seed multiplication scheme was limited to the production of small quantities of pure seed, which could be described as foundation seed. This seed was then issued to cooperative organisations of farmers in what was called a 'village maize multiplication scheme'. The cooperatives of some thirty to forty farmers chose a seed multiplication plot in isolation, which was run on a communal basis. This first stage multiplication was grown in an early season, and was followed by large scale plots in the late season, grown by the individual farmers, who selected the best ears for the next early season (or main) crop. Both the second stage multiplication fields and the maize crop were to be grown in isolation. No local maize was allowed within two hundred and fifty yards from plots planted to the maize variety Sicaragua. Seed produced under such circumstances could be awarded a certificate of purity, duly if inspected during the growing season and after harvesting by officials from the Ministry of Agriculture. This might be an encouragement for farmers to specialise in the production of pure seeds, which in turn might initiate a local seed trade.

9.3. CONCLUSION

Little experience with the seed multiplication of recommended cultivars is as yet available in Nigeria, but it is obvious that a farmer must be thoroughly informed of the advantages of such new varieties and of the need and possibility of maintaining them in a pure state. Haphazard systems of multiplication and distribution of improved seed, without education of the farmer, will merely be wasted effort. A positive promotion of a supply of pure planting materials on the one hand and realisation of its value by the farmer on the other, will work hand in hand to spread the use of improved planting materials. Both factors will also lead to private enterprises in seed multiplication and distribution, which will bring these planting materials much more effectively and quickly within reach of every farmer than governmental programs with limited funds can ever hope to achieve.

SUMMARY

The Nigerian maize crop values some £14 million annually and is the main grain crop in the southern part of Nigeria. Especially in the south western part of Nigeria it is of great importance as a staple food. The production of maize is rapidly increasing in the Middle Belt of Nigeria, where most of the crop is consumed as preparations derived from mature maize grains. In Eastern Nigeria a large part of the crop is consumed prior to maturity. In south western Nigeria a preference for floury grain types is expressed often. It was shown how this preference really depends on the yield of flour per unit weight of grains. The local varieties of maize show a corresponding geographical distribution of types. Floury maize varieties do occur in the western and eastern parts of southern Nigeria, whilst inbetween and also in Northern Nigeria flinty varieties prevail. The combination of this characteristic with several others made it possible to group the local varieties into four distinct types.

Some of the newly introduced varieties of maize proved to outyield the local varieties with a great margin. At least in one case this was proven to be caused by the more pronounced longevity of the leaves of an introduced variety when compared with a similarly developing local variety. A study was made of the seasonal variation of the period taken to reach the tasseling stage. The observed variability of this characteristic is apparently caused by the variability of the period from the initiation of the tassel to anthesis, the elongation period.

Although many insects besiege the maize crop in the field, only few have been investigated to any extent. Stemborers are of great importance especially for the late season maize crop. Some resistance to the field population of borers at Ibadan was found. Grain weevils, army worms and aphids are some of the remaining noxious insects.

More information is available on some of the diseases occurring on maize in Nigeria. A serious rust disease entered West Africa in 1949 and caused great alarm. Tolerance to the rust was found in a number of Central and South American maize varieties, which are now extensively used in the breeding program. Presently some leaf blights and a virus disease appear to be of even higher importance.

The information brought together by own observations and from literature allowed for a foundation to be laid for the Nigerian maize breeding program and for an appreciation of the aims to be set.

The phenomenon of residual hybrid vigour effects observed in advanced stage generations of synthetic varieties has given a powerful tool for the establishment of open pollinated cultivars, which can be maintained at a good yield level for a reasonable length of time even at farmer's level. Originally a successful attempt was made to produce a synthetic variety through an intravarietal gametic selection scheme for combining ability. However, later observations showed that in the variety Mexico 5, an important constituent for future synthetics, advanced stages of inbred lines should be utilised for this purpose.

The intravarietal selection schemes developed into intervarietal ones, which made it possible to recombine selections from the local varieties with those from the introduced ones. Intervarietal hybrids proved to give greatly increased yields and pointed towards the value of this approach.

Finally it was shown how the maize breeder's work is to be complemented by agricultural extension workers to make the utilisation of new cultivars feasible.

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SAMENVATTING

De waarde van de jaarlijks in Nigeria geproduceerde mais beloopt ongeveer £14 millioen. Het is het meest verbouwde graangewas in het zuiden van het land. Vooral in het zuidwesten is de mais een van de belangrijkste voedingsgewassen. In de 'Middle Belt' neemt de productie van mais sterk toe. Het wordt hier grotendeels gebruikt als rijp graan, wat ook in het zuidwesten het geval is. In Oost-Nigeria wordt een groot deel van de kolven onrijp geoogst en geconsumeerd op de manier van suikermais.

In het zuiden van Nigeria wordt vaak de voorkeur gegeven aan melige maisvariëteiten. Men blijkt deze te prefereren omdat hiermede na de gebruikelijke verwerking meer meel per gewichtseenheid graan verkregen wordt. De locale maisvariëteiten vertonen een geografische verspreiding, die overeenkomt met deze voorkeur. Melige variëteiten worden verbouwd in het zuidwesten en zuidoosten van het land, terwijl tussen deze twee gebieden in en ook in Noord-Nigeria voornamelijk flint mais voorkomt. Aan de hand van deze verspreiding en met behulp van enige andere kenmerken konden de locale maisvariëteiten ondergebracht worden in vier verschillende typen.

Een aantal van de ingevoerde maisvariëteiten bleek aanzienlijk meer op te brengen dan de locale. In minstens een geval kon worden aangetoond, dat dit toe te schrijven was aan de langere levensduur van het blad. De ingevoerde en locale variëteit vertoonden overigens een vergelijkbare ontwikkeling. De locale variëteiten hebben over het algemeen bij het oogsten een lager vochtgehalte in de korrel dan de ingevoerde.

Aandacht werd besteed aan de seizoensvariatie van de bloeitijd. De waargenomen verschillen bleken te berusten op verschillen in de duur van de strekkingsperiode, van de pluimaanleg tot de bloei.

Van de talrijke maisplagen zijn er slechts enkele bestudeerd. Stengelboorders zijn vooral schadelijk in het tweede maisgewas. Verschillende selecties bleken minder te worden aangetast dan de locale variëteit. Graanklanders, legerrupsen en bladluizen kunnen eveneens veel schade aanrichten.

Meer gegevens zijn beschikbaar over een aantal ziekten. Een zeer schadelijke roestziekte kwam in 1949 West Afrika binnen en nam zeer ernstige vormen aan. Enige Centraal- en Zuid-Amerikaanse maisvariëteiten bleken tolerant voor de roest te zijn. Deze variëteiten spelen nu een belangrijke rol in het veredelingsprogramma. Op het ogenblik schijnen een aantal bladziekten en een virusziekte van groter belang te zijn.

Gegevens over de mais, verkregen uit eigen waarnemingen en uit de litteratuur, maakten het mogelijk om een basis te leggen voor het maisveredelingsprogramma in Nigeria en hielpen de doelstellingen te formuleren.

De eigenschap van synthetische variëteiten om in latere generaties hoge opbrengsten te blijven geven, bleek een goed hulpmiddel om vrijbestuivende cultivars te produceren, die ook in handen van de boeren voor een redelijke tijd goed kunnen blijven opbrengen. Aanvankelijk werd een succesvolle poging ge-

daan om een synthetische variëteit te vormen met behulp van een gametenselectie voor combinatiegeschiktheid. Latere waarnemingen toonden echter aan dat bij de variëteit Mexico 5, belangrijk uitgangsmateriaal voor verdere synthetische variëteiten, betrekkelijk homogene ingeteelde lijnen gebruikt zouden moeten worden.

Selectie binnen de variëteiten werd op den duur vervangen door selectie in meerdere variëteiten en latere combinatie van de selecties. Dit maakte het mogelijk selecties uit locale mais te combineren met die uit ingevoerde variëteiten. Variëteitskruisingen bleken aanzienlijk meer op te brengen dan de wederzijdse ouders.

Tenslotte werd aangegeven hoe het werk van de veredelaar moet worden aangevuld door de landbouwvoorlichtingsdiensten om het gebruik van verbeterde maiscultivars mogelijk te maken.

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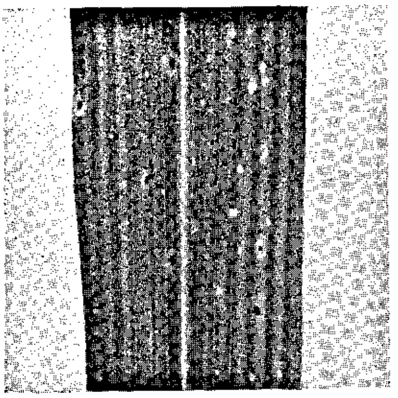
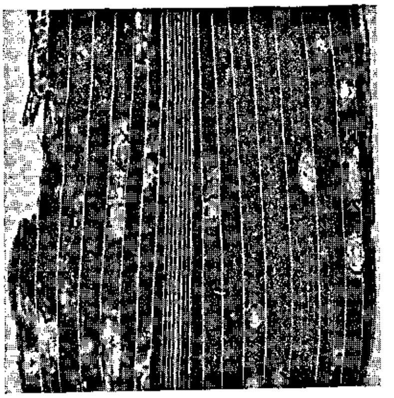
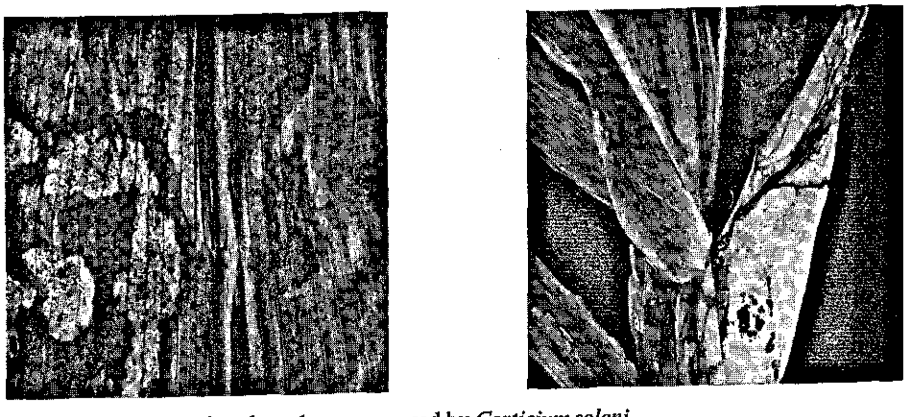


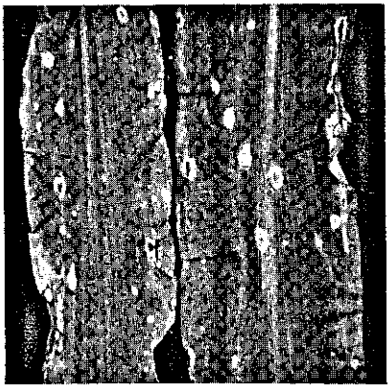
PHOTOGRAPH 1. Mixed reaction to a field inoculum of *Puccinia polysora* by an inbred line of the maize variety Mexico 5.



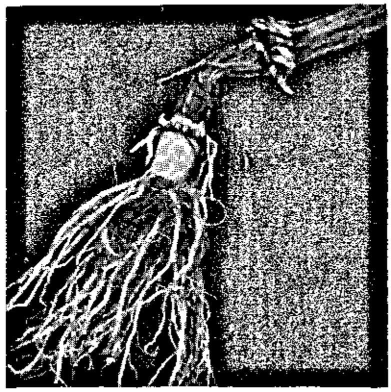
PHOTOGRAPH 2. Lesions caused by *Cochliobolus heterostrophus*



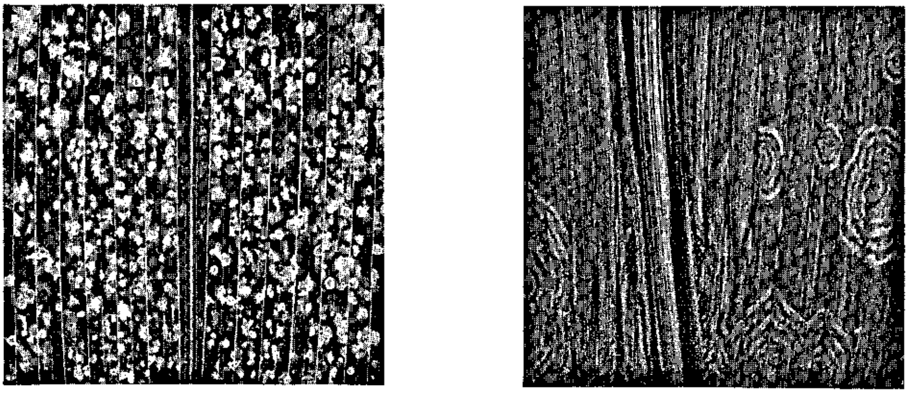
PHOTOGRAPH 3. Leaf and eardamage caused by *Corticium solani*



PHOTOGRAPH 4. Lesions caused by *Pyricularia grisea* on 3-weeks old maize plants

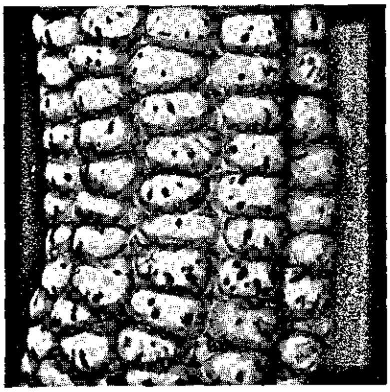


PHOTOGRAPH 5. Stemrot in maize

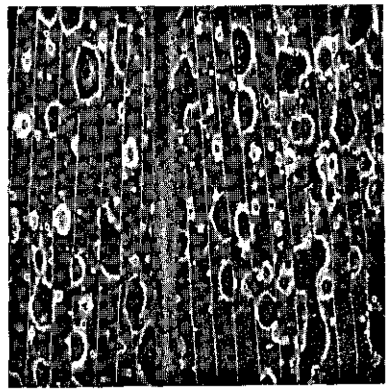


PHOTOGRAPH 6. Two types of reaction on maize leaves, similar to those reported for leaf fleck virus.

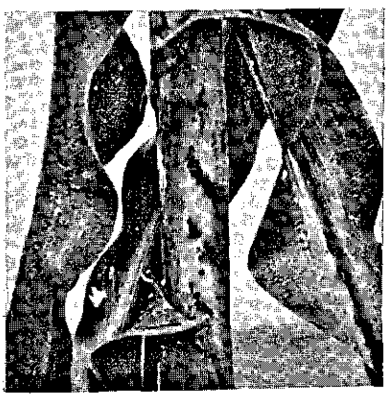
PHOTOGRAPH 7. Symptoms of a few important maize diseases.



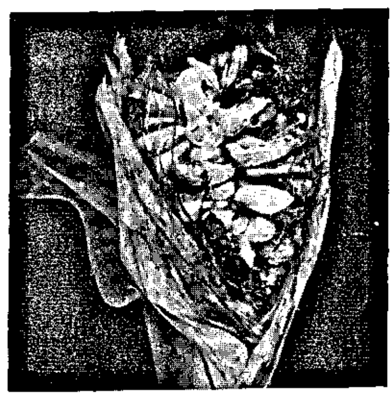
Botryodiplodia theobromae
Black grain disease



Curvularia lunata
Leafspot



Physoderma maydis
Brown spot disease



Ustilago zeae
Smut