CROPS OF THE
WEST AFRICAN
SEMI-ARID TROPICS

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FOREWORD

The Savanna zone of West Africa was favoured by relatively good rainfall for several years in the early sixties. The resulting natural forage growth led to a substantial build-up in the sizes of the grazing herds of the area. This favourable situation was followed in the late sixties and early seventies by several successive years of rainfall substantially below normal. The resulting drought brought widespread hunger and suffering, the decimation of herds by starvation and slaughter, extensive human suffering, and a very substantial migration of people toward population centres to the southward of this zone.

World attention has been directed to the problems of these areas and numerous projects and programmes have been undertaken to alleviate them, to give immediate relief to human suffering, and to devise ways and means to avoid similar disasters in the future. There is a scarcity of reliable information readily available to the technicians and planners in usable form on the crops, cropping conditions, ecological parameters, and cultural practices required for reliable and sustained production in the area.

In this volume, the author has attempted to pull together the available information on the major crops of the region in the hope that this will help those who are concerned with the establishment of a safe, stable and prosperous agriculture; and to gain a better understanding of the production requirements of the region, for so doing.

Dr. R.W. Cummings, director
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PREFACE

This review deals with three aspects, i.e., ecology, cultivation, and diseases and pests, of 23 crops which are grown in the West African Semi-Arid Tropics. These crops form six groups: cereals, legumes, roots and tubers, vegetables, fibres, and other crops.

The review no doubt has many errors. For these I express my apologies and hope that they would be brought to my attention so that correction can be made.

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Hyderabad, India A.H. KASSAM

INTRODUCTION

AREA

In West Africa the area between the humid equatorial High Forest and the desert bio-climates of Trans-Saharian Africa comprises of a variety of semi-arid tropical regions which have in common a number of physical and biological features. The natural vegetation in these regions is dominated by grassland with varying densities of scattered trees or shrubs. Ecologically, the varied assemblages of vegetation within these regions are described as Savanna. Differentiated by variables of climatic gradients but particularly by a seasonal amount and distribution of rainfall, resulting in water regimes with marked rainy and dry seasons of varied duration and intensity, these regions carry their own characteristic vegetation. Because the dominant climatic factors and elements affecting the distribution of Savanna vegetation have very pronounced gradients along the north-south axis, the area of the West African Savanna is in consequence a strip of territory lying nearly parallel with the equator (Cocheme and Franquin, 1967).

The area extends from the Atlantic Ocean in the west to Central Sudan in the east. The uniformity of the pattern is broken further east by the influence of the Ethiopian mountains and the Red Sea. The southern limit of the Savanna area successional to the humid High Forest cannot be sharply defined. However, from the vegetation maps of the Savanna regions (Phillips, 1959) the approximate limit of the southern boundary in respect of latitudinal (LA) and longitudinal (LO)[1] position may be described by the equation, $LA = 8.2 - LO/11.9$. Thus, for example, at $LO = 0$, the southern boundary is approximately at 8.2°N latitude.

The northern boundary of the Savanna area lie along the fringes of the arid zone of the Sahel-Sahara sub-desert with ground cover that varies locally from open to sparse, supporting woody and sometimes spinose elements, xerophytic grasses and various lowly sub-shrubs and herbaceous vegetation. The northern boundary may be described approximately by the equation, $LA = 18.9 - LO/9.4$. Thus, for example, at $LO = 0$, the northern boundary is approximately at 19°N latitude.

LO is algebraically positive east of Greenwich and negative west of Greenwich.

The total area of the West African Savanna can be thus defined as a strip of territory some 4,500 km long between 16°W and 30°E longitude, with the southern and northern boundaries described by the above equations, averaging about 1,100 km in width. This area of some 4,950,000 sq km includes portions of the territories of the following countries: Senegal, Mali, Mauritania, Upper Volta, Ivory Coast, Togo, Ghana, Niger, Dahomey, Nigeria, Chad and Cameroon.

LAND USE

The rural landscape of the Savanna often gives the appearance of a disorganized activity with scattered and small fields that are irregular in shape, have ill-defined borders and include scattered tree stumps. Such a landscape represents a non-intensive system of land use but in areas with high population density, agriculture there is 'intensive' and the countryside presents an orderly look totally committed to arable agriculture. However, arable farming and herding are usually separate activities, although crop residues are utilized by stock animals owned and handled by special tribes. Livestock remains a major economic asset much to be desired, with livestock herding (cattle, camel, goat and sheep) mainly confined to the northern areas free of tse-tse.

A large number of food and cash crops are grown in the West African Savanna. Sorghum, millet, groundnut, cowpea and cotton are the major rain-fed crops occupying approximately 60 to 80% of the cultivated land. Other crops in the Savanna region include root crops, vegetables, maize, tobacco, sugar cane, rice, and these occupy about 15% of the cultivated land. The distribution of crops and cropping pattern is largely dependent on the amount and distribution of rains and the resulting length of the growing season. The rainfall in the West African Savanna has a definite pattern in relation to the latitudinal and longitudinal position in terms of the amount and the length of the rainy period. This is reflected in the distribution of crops which in broad terms conforms to the following pattern.

The northern parts of the Sahel Savanna and sub-desert areas, between about 19° and 16°N latitude and extending from the 0 mm isohyet to the 350 mm isohyet, have a rainy season of less than 70 days. This area is utilized for rangeland grazing. The productivity of this region is low and economically the area must be regarded as marginal for efficient arable production.

The southern parts of the Sahel Savanna, between about 16° and 14.5°N latitude and extending from the 350 mm isohyet to the 550 mm isohyet, have a rainy season of between 70 days and 100 days. In this region settled arable farming is practised based on millet, but farmers run the risk of failure due to drought.

Extending from about 14.5° to 9.5°N latitude in the Sudan and Northern Guinea Savanna lies the main cereal production area of the West African Savanna. Here millet and sorghum are the main food crops. The rainfall in the Sudan Savanna is between about 550 mm and 900 mm, in the Northern Guinea Savanna it is between about 900 mm and 1,250 mm. Millet and sorghum are seldom grown in pure stands but are interplanted with cash crops and other food crops. The principal cash crops in the area are groundnut and cotton. Cowpea, pepper and vegetables are also grown to supplement the cereal diet. Rice, both paddy and upland, is produced in some areas. During the dry season temperatures are low enough for the production of temperate crops such as wheat using irrigation. In upland areas potato is grown as a cash crop but by far the most important cash crops grown during the dry season are onion, tomato and sugar cane.

South of the 9.5°N latitude, in the Southern Guinea Savanna, increased amounts of root crops are grown, forming a mixed cereal-root zone. Yam, cassava, cocoyam are the predominant root crops either as intercrops with cereals such as sorghum or in pure stands. This cereal-root zone also includes a variety of crops normally not grown outside the zone such as sesame and soya bean. In addition to cowpea and minor crops such as groundnut and cotton, the zone also supports larger areas of rice and maize.

In the Derived Savanna, bordering the High Forest areas, root crops predominate. Maize (sold green on cobs), cowpea and various vegetables are also produced.

Accurate statistics on distribution and production of major crops in the West African Savanna do not exist. FA0 estimates of production on country basis and various other sources have been used to indicate the present production and mean yields of crops. However, within the West African Savanna yields of crops vary from region to region and year to year due to variations in the seasonal pattern of availability of water and the length of the growing season, solar radiation, soil fertility, cultural practice and incidence of diseases and pests. Only those crops which are extensively grown or whose potential has been established by research work in West Africa and elsewhere are considered here. Readers are referred to Purseglove (1974, 1975) for a comprehensive account of tropical crops, and Irvine (1974) for a general account of the crops in West Africa.

CROP PRODUCTION

One of the major features of the indigenous crop production practices in the West African Savanna is the low crop productivity per unit area of land. The growing demands for food and cash have been met largely by cultivating more land. In areas which carry high population densities productivity has decreased in recent years as a result of decline in soil fertility, overgrazing and soil erosion. However, considering the farmers' total environment, including natural, economic and socio-institutional, crop production has been in reasonable equilibrium with the resources available. The farmer makes the most of the natural fertility through the bush fallow rotation system of cultivation while the field near the village and areas of high population densities receive a considerable amount of manure (animal manure, ash, household refuse, compost). The farmer practises intercropping which under his present conditions satisfies both his security and profit motives (Norman, 1972). And despite all the difficulties arising from low capital, unfavourable price relations, unsophisticated markets, rudimentary infrastructure, the indigenous farming system well matches the total resources available to the farmer in maintaining low but adequate and steady production. In all this, there appears little room for improvement in productivity without an increase in the resources and services made available.

Most farms provide little more than a subsistence and their size is restricted to the area that can be cultivated by hand. Also, the period of cultivation is limited to the rainy season and this imposes another restriction in the size of the farm that one man can operate. Both these are labour restrictions rather than land restriction *per se* and force the farmer to limit the area under cultivation to a size which he knows he can handle effectively using his simple hand tools. Because nearly the whole of the rural population is engaged in subsistence farming, labour is not readily available during the periods of peak demands even if a farmer had money available to hire labour. The average farmer is therefore limited to the labour of his own family. Since the farmer is limited in the amount of land he can cultivate and has to produce all the food for the coming year during the wet season, he has evolved the technique of multiple cropping largely based on the simultaneous principle of growing more than one crop simultaneously on one piece of land and thereby achieving a land equivalent ratio (LER2) of greater than one

Manure refers to sources of plant nutrients which are not products of industrial processes, to differentiate them from fertilizers which are.

The ratio of the area needed under sole cropping to one hectare of intercropping at the same level of management, to give an equal amount of produce. LER is the sum of the ratios or fractions of the yield of the intercrops relative to their sole crop yields.

(Andrews and Kassam, 1975). However, because of the subsistence nature of the agricultural economy, the farmer gives first thought to the production of food to satisfy the needs of his family. Consequently, this natural and primary pre-occupation with food crops, has resulted in a situation whereby cash crops occupy a second place, are given attention only after the farmer is satisfied of his food supplies, are planted late and do not receive comparable level of husbandry (Ramsey, 1968). All these factors reduce the yield of cash crops. However, the present system of farming offers great advantages to the farmer within his subsistence setting.

There is no doubt that the application of simple but improved technology can result in increased levels of production in the West African Savanna. Accumulated knowledge from past and current adaptive research on crop science in the West African Savanna indicates that improved resources of seeds, fertilizers and crop protection technology and the knowledge of how best to use these resources within the available natural resources of climate and soil are sufficiently advanced to enable vast increases in productivity of crops (Charreau, 1974; Kassam *et al.*, 1976). It would be foolish to conclude that all technical problems related to crop production have been solved or can be solved. In the final analysis technical solutions to problems of crop production at a high level on continuous basis can be only solved on a continuous basis, hand in hand with the changes occurring in the farmers' total environment. At a given point in time the available production technology and its adoption by the farmers influences the farmers' total environment but having influences an existing situation the change created itself influence future problems likely to arise and the technical solution to these problems. The problems of agricultural development in the West African Savanna are immense. However, there is no doubt that to the extent that the first generation technical solutions to problems of crop production exist, their application will have little impact on production and economy at large without parallel improvement in support facilities and incentives both off and on the farm.

PART I

CEREALS

SORGHUM *(Sorghum bicolor)*

The crop appears to have been domesticated in Ethiopia some 5,000 years ago and taken to West Africa at an early date across the Sudan to the Upper Niger river (Doggett, 1970). Sorghum is grown primarily for grain for human consumption as a thin porridge or thick paste or in beer. White or yellow corneous grains without a sub-coat are preferred for flour, which is prepared by pounding the seed in a mortar to remove the pericarp and further pounding or grinding to produce a fine granular powder. Sorghums with red or brown bitter grains are preferred for brewing beer. Local cultivars are typically large and tall plants and crop residues are used as building material, fuel and feed. Sorghum has a number of other uses including silage and grain for livestock. Accounts of sorghum as a world crop are given in Doggett (1970) and Rao and House (1972).

Estimated total production of sorghum in West Africa in 1971 was about 5.8 m tonnes from an area of about 9.7 m ha, corresponding to a yield of about 590 kg/ha. However, yield figures from individual countries vary between about 420 kg/ha in Senegal and Togo and 750 kg/ha in Cameroon and Ghana. Within a country yields vary between 300 and 1,500 kg/ha depending on soil fertility and moisture conditions. Generally yields are higher in the Guinea Savanna than in the Sudan Savanna because of the longer growing season and higher natural soil fertility. Good experimental yields of local sorghums under improved cultural practice is about 1 tonne/ha in the Sudan Savanna and about 2 tonne/ha in the Guinea Savanna; those of improved photosensitive sorghums about 2 tonne/ha and 3.5 tonne/ha respectively; and of improved short-season photoinsensitive sorghums about 2.5-3.0 tonne/ha and 4-4.5 tonne/ha respectively (Webster, 1970; Barry, 1970; Andrews, 1970a, 1970b; Le Conte, 1970; Robledo, 1970).

ECOLOGY

Sorghum is one of the principal sources of food in the Sudan and Northern Guinea Savanna, but it remains an important cereal in the Southern Guinea and Derived Savanna. Sorghum production reaches its greatest concentration where rainfall varies from 600-1000 mm or more per year.

The local cultivars are photoperiodic and because they flower at the end of the rains their growth cycles range from 120-135 days in the northerly areas in the Sudan Savanna to 240 days or more in the southern areas. The number of nodes and height therefore varies between 15 and 30 and 3 and 6 m respectively depending on the length of the growth cycle (Curtis, 1967; Kassam and Andrews, 1975). However, sensitivity to photoperiod is modified by temperature (Cocheme and Franquine, 1967).

An important adaptive feature of local sorghums is that by means of photoperiodism, the date of heading is closely related to the average date of the end of local rains (Curtis, 1968a; Bunting and Curtis, 1968) so that seed set occurs as the weather becomes dry. In this way the grains are not attacked by moulds and insects as they would be if heading was earlier in the rains. Local cultivars were therefore found to yield better in their own region than in regions north or south, because heading in the new locality was still related to the average date of the end of the rains in its original locality (Curtis, 1968b). This behaviour could not be explained entirely by responses to photoperiod in terms of a critical daylength requirement, and Bunting and Curtis (1968) have suggested that the stimulus may have been the number of successively shortening days after June 21 rather than their absolute length which controlled the date of heading in local sorghums.

Date of sowing has a marked effect on yields of local and improved photosensitive sorghums. Because heading is at the end of the rains the crop forms its yield largely on the moisture stored in the soil. However, if heading is late due to late sowing or if there is an earlier than normal cessation of rains, grains fail to fill completely. Under indigenous practice, local sorghums are sown as early as possible though often after millet so as to capture most of the mineralised nutrients and to minimize the possible damage from shoot-fly, stem-borers and weeds. The effect of delay in sowing on delay in heading in a normal season is comparatively small in local and improved photosensitive sorghums but can have a significant influence on yield particularly when rains start or end earlier or both. The grain filling phase of local sorghum is about 35-40 days and those of improved photosensitive sorghums 45-50 days. When sowing is late, not only is the plant size and its root system smaller, but because of the delay in heading grain filling occurs that much later and under relatively worse soil moisture conditions, which can cause a shortening of the grain filling period. Thus, at Samaru the date of heading in local Farafara in an average season was linearly related to the date of sowing over an 8-10 week spread in sowing date. Heading was on 6 October when the crop was sown during 12-16 May but then onwards each week's delay in sowing caused a delay in heading of about 0.9-1.3 days (Curtis, 1968a; Andrews, 1973). The delay in heading was about 2 days per week's delay in sowing during the season when rains ended earlier than normal while the earliest sown crop on 16 May still headed on 6 October with a consequent progressive decline in yield from later sowings of about 200 kg/ha (about 12.5% of the maximum yield) per week's delay in sowing after 30 May (Andrews, 1973). In the improved dwarf and tall photosensitive sorghums each week's delay in sowing has been shown to delay heading date by 2 days or more. In the Northern Guinea Savanna, Andrews (1973) showed that each week's delay in sowing after the optimum sowing date in May and early June decreased the yield at the rate of about 300-600 kg/ha corresponding to about 15% of the maximum yield. Similarly a decrease of about 360 kg/ha (10% of the maximum yield) per week's delay in sowing after 26 May over a 10-week spread in sowing date at Samaru was found by Kassam and Andrews (1975). In the Southern Guinea Savanna where the normal growth cycle of local sorghums is 200 days or more, experiments (Andrews, 1975a) exploring the possibility of using improved photosensitive cultivars from more northerly areas by mid-season sowing have shown that each week's delay in sowing delayed heading date by about 2 days and yield decreased at the rate of 810 kg/ha (25% of maximum) per week's delay in sowing after 2 August with insecticide control of stem-borers. Without insecticide control the rate was about 375 kg/ha (17% of maximum) per week's delay in sowing after 26 July.

Later sowing of improved photosensitive sorghum SK 5912 has been shown (Kassam and Andrews, 1975) to reduce the normal length of vegetative period of 98 days from sowing to floral initiation by about 4.5 days per week; the normal length of the head development period of 42 days from floral initiation to heading by about 0.4 day per week; and the normal length of the grain filling period of 48 days from heading to physiological maturity by about 0.9 days per week, corresponding to a total reduction of the normal growth cycle of 188 days by about 6 days per week. Further, both total dry weight and leaf area index decreased with later sowing, contributing to the observed decreases in the number of heads per plant and number of grains per head. The delay in heading, reduction in grain filling period and smaller root system contributed to the observed decreases in the grain size and grain to head ratio. It is likely that some of the decrease in yield due to the decrease in head number per plant and grain number per head could be reduced by sowing the crop at higher densities when sown late.

In general, when moisture and nutrient supplies are adequate, about 110-120 days are required to produce a high yield. Cultivars with longer growth cycles produce lower yields or show no extra yield advantages because the increase in the length of the growth cycle is mainly in the length of the vegetative phase. Further, the longer the crop occupies the land the greater the risks of attack from pathogens and pests. Yields drop sharply if the growth cycle is less than 80 days but with 90-100 days to maturity yields are lower by about 20% to those obtained at 110-120 days. By virtue of photoperiodism local sorghums at present escape head mould attack and produce grain of good quality despite the variation in sowing date from region to region and within a region from season to season. However, their yield potential is low and they occupy the land for a period longer than that required to produce a high yield per unit of input per unit time within the period when soil moisture supply is most favourable. Yields of local sorghums drop severely when rains end earlier than normal; and in years when rains commence late also, they may fail to produce a yield. The use of cultivation techniques to conserve rainfall, by preventing run-off, and to improve the soil surface infiltration rate have been found to be beneficial to the yields of sorghum crops in dry years. Thus, Lawes (1966) from a series of field experiments over six seasons at Samaru, found that mulches of groundnut shells and dead grass increased yields by 270-400 kg/ha and 190-415 kg/ha respectively; tying all ridges and leaving alternate furrows open increased yields by 113-216 kg/ha and 103-157 kg/ha respectively during dry years only; and deep vertical mulching in all furrows, and alternate furrows left open, at high level of fertility increased yields by 295-302 kg/ha while deep and shallow vertical mulch in all furrows at low level of fertility increased yields by 423-436 kg/ha.

For improved grain yields, cultivars responsive to high fertility at increased plant population are required. However, for improved photosensitive cultivars, to minimize the effects of soil moisture deficit during the grain filling period when higher plant densities are used, the crop should flower as early as possible consistent with maintaining acceptable grain quality. High yielding, mould resistant photoinsensitive cultivars do not exist at present but high yielding, photosensitive cultivars which flower 8-14 days earlier than local sorghums have been produced for the Guinea Savanna (Andrews, 1970a, 1970b). These produce a high yield of good quality under improved practice when sown at normal sowing dates common in the indigenous practice in the Sudan and Northern Guinea Savanna. In the Southern Guinea Savanna these cultivars when sown appropriately late have been shown to produce yields of over 3 tonne/ha in about 120-140 days which is 2-3 months less than the length of growth cycles of local cultivars (Andrews, 1975a). Further, experimental photosensitive hybrids have produced yields up to 6 tonne/ha in the Guinea Savanna (Andrews, 1975b). High yielding photoinsensitive cultivars of 90-120 days to maturity have been produced which if sown appropriately late will flower earlier than local cultivars and set seed with little trouble from mould and soil moisture deficit (Goldsworthy, 1970a; Andrews, 1970b). These improved cultivars are most suitable for one crop per season in the Sudan Savanna and for multiple cropping as a second late-sown crop in the Guinea Savanna. However, in the Guinea Savanna late sowing of short-season cultivars leads to problems with crop establishment due to pest attack, requiring chemical control, and very wet soil conditions. The eco-physiological aspects related to crop growth, development and yield of local, improved photosensitive and short-season photoinsensitive sorghums in Nigeria have been discussed by Goldsworthy (1970a, 1970b, 1970c) and Goldsworthy and Tayler (1970), while Eastin (1972) has reviewed the physiology of yield in sorghum in general.

Sorghum is adapted to a wide range of ecological conditions. It can tolerate hot and dry conditions better than maize and can tolerate periodic waterlogged conditions which occur in the months of August and September in much of the West African Savanna. It has a marked degree of drought endurance and can tolerate a wide range of soil conditions. It grows well on heavy soil including the black soils but will grow satisfactorily on lighter sandy soils. It has an advantage over maize because of its better ability to endure drought and soil acidity but in the Savanna areas, including the Sudan Savanna, where soil moisture regime is favourable maize produces higher yields per unit of input. Sorghum can be grown in soils of pH ranging from 5.0-8.5 and can tolerate salinity better than maize.

Total crop water use of a 180-day long-season sorghum between sowing and harvest in the Guinea Savanna has been reported to be 657 mm (Kowal and Andrews, 1973), corresponding to water use efficiency of about 270 g water per g total dry matter. Response to fertilizer depends on the region (Goldsworthy, 1967) and cultivar. However, an improved sorghum crop yielding 4066 kg/ha in Senegal has been reported to remove N, 132 kg/ha; P_205, 28.5 kg/ha; K_20, 69 kg/ha; CaO, 57 kg/ha (IRAT, 1972). Growth and nutrient uptake in high yielding sorghums has been discussed by Vanderlip (1972).

CULTIVATION

Sorghum is grown as a rain-fed crop but some is produced as a dry season crop on residual moisture on the flood plains of Lake Chad. The indigenous practice is to sow it as early as possible, but after millet, in the wet season. Seeds are sown on ridges, or on the flat and often ridged later, at about 30-45 days after sowing. Most of the sorghum is grown in mixture with other crops in 2-5 crop combinations involving early millet (Gero), late millet (Maiwa), groundnut, cowpea and cotton, but the most common combinations are those involving early millet, cowpea and groundnut. About 25% of the total area under sorghum was found to be sole crop sorghum in village studies in the Guinea Savanna (Norman, 1972) while sorghum in mixtures is sown in intricate patterns with other crops (Fig.l). When grown sole the spacing is generally about 0.60-0.90 m (about 12,000-18,000 stands/ha) while in 2-3 crop combinations stand population is in the range about 12,000-15,000 per ha, and in 4-5 crop combinations about 6,750-7,000 (Norman, 1972). Usually early millet is sown first followed by sorghum. In the sorghum/millet/cowpea mixture, cowpea is undersown on the same ridge as sorghum when the millet is harvested; the millet is sown in the furrows between the ridges sown with sorghum. The time of sowing is governed by the time of arrival of rains and sowing is therefore later in the Sudan Savanna than in the Guinea Savanna. Sorghum is generally grown in the fields closer to the villages and often on a continuous basis. The fields receive a certain amount of manure but little or no fertilizer is used. Cultivation, sowing, thinning, weeding and harvesting is done by hand. Early sowing and control of weeds is most important to enable the crop to capture most of the mineralised nutrients before they are leached or taken up by weeds. It has been suggested that undersowing of the legume in the latter part of the season may contribute some nitrogen to the system beneficial to the standing sorghum crop (Bunting, 1972). As the heading date of local sorghum is related to the date of the end of the rains, days to maturity and harvest time varies from region to region: sorghum in the Sudan Savanna being harvested first. The grain after harvest is often stored in the head in simple storage structures (Bugundu, 1970; Hill, 1972) and is *very* subject to insect attack. The grain to head weight ratio is about 70-75% while the grain to total dry weight ratio (harvest index) is 7-15% (Goldsworthy, 1970a).

Improved long-season photoperiodic cultivars and short-season photoinsensitive cultivars are sown when the rains have established, or sown appropriately late so that the crop is harvested soon after the rains have ended. Treated seeds are sown at a spacing in the range 0.1-0.3 x 0.45-0.90 m depending on the cultivar and days to maturity. Semi-dwarf photosensitive cultivars are generally sown at a density of about 40,000-80,000 plants/ha while dwarf, photosensitive, long-season and photoinsensitive, short-season, cultivars at 100,000 plants/ha or more. Responses to nutrients vary from area to area (Goldsworthy,1967; Vaille, 1970; Heathcote, 1972) but for yields over 3 tonne/ha, experimental rates of 60-140 kg/ha of N and 35-90 kg/ha of $P_2 0_5$ are applied[1]. Chemical control of shoot-fly and stem-borers can be necessary particularly when the crop is sown late in the Guinea Savanna. Harvest index of improved sorghum is 20-40% (Goldsworthy, 1970a). Improved sorghums show extra yield advantages when grown in mixtures with millet under high management but responses have been shown to vary with cultivars (Andrews, 1974). Yield advantages of up to 55% have been reported (Andrews, 1972a and 1974; Baker, 1974) while a greater total nitrogen uptake has been reported in a sorghum/millet mixture compared to sole sorghum (Kassam and Stockinger, 1973).

DISEASES AND PESTS

Sorghum diseases in West Africa have been discussed by Delassus

[1] In this review the experimental fertilizer rates quoted are not necessarily the recommended economic rates unless stated otherwise.

(1970), Sauger *et al.,* (1970), and King (1972). Of the numerous diseases which attack sorghum the smuts are of the greatest economic importance. **Covered smut *(Sphaaelotheaa*** *sorghi)* **and loose smut *(S.*** *aruenta)* **are seed-**borne and can be effectively controlled by seed treatment at little cost and effort. Losses due to head smut *(s. reiliana)* and long smut *(Tolyposporium ehrenbergii)* are less severe and generally localised. Breeding for resistance is the only feasible approach to controlling these two smuts. Downy mildew *(Salerospova sorghi)* is one of the serious foliar diseases of sorghum. Local cultivars have adequate resistance to it which should make incorporation of genetic resistance possible in the improved cultivars. Charcoal rot *(Maarophomina phaseolina)* can be serious in the Sudan Savanna particularly during drought conditions. Head mould, caused by a complex of organisms, is most prevalent in sorghum which matures during the rains, rendering the grain unfit for human consumption. The incidence of these moulds is related to the atmospheric humidity and compactness of the panicle. Improved, long and short-season cultivars can escape a serious attack if sowing is timed so as to enable the crop to mature as the rains are ending.

Damage in sorghum by shoot-fly *(Atherigona sooaata),* stem-borers *(Busseola fusca, Sesamia* spp.J and midge *(Contarinia sorghiaola)* is relatively unimportant under the indigenous practice of early sowing and late harvest while local cultivars have adequate tolerance to stem-borer attack (Sauger *et al.,* 1970). However, in the case of midge, Harris (1961) has reported that midge attack can be severe particularly in the southern more wetter areas where the growing season is larger and alternate hosts more abundant. It appears that growing of sorghums of different growth cycle in one area may change the dynamics of these insect populations. Consequently, early maturing cultivars, sown later and harvested earlier than the long-season cultivars, may suffer from a severe shoot-fly and stem-borer attack while the long-season cultivars may suffer severely from midge due to population build-up from crop to crop. Incorporation of genetic resistance against these insects in the future seems promising but at present high yielding cultivars are very susceptible. Chemical control of *Busseola* (Barry and Andrews, 1974) and shoot-fly is effective but no effective control measures exist for ***Sesamia* spp.**

Sorghum, stored in simple granaries as threshed grain or in the head, is very susceptible to a large number of storage pests and losses can be high (Giles, 1964a, 1964b). Hard grains with corneous endosperm are less liable to attack. The most common pests include the rice **weevil** *(Sitophilus oryzae),* **and flour beetles** *(Tribolium* **spp**J **in** threshed grain, and the grain moth *(Sitotroga aevealella)* in grain stored in the head, and the grain borer *(nhizopertha dominiaa)*. Other storage pests include the grain beetle *(Oryzaephilus surinamensis)* and the khapra beetle *(Trogoderma granarium)*. Ambient storage temperature and humidity conditions and grain moisture content are critical factors influencing the extent of damage. Grain moisture content must be less than 10-12% (Giles, 1964a).

Damage to sorghum by Quelea *(Quelea quelea)* is a major problem particularly in the Sudan Savanna. At present no effective and economical technology exists for the control of Quelea (Crook and Ward, 1968).

Striga is a semi-parasitic weed which can cause serious damage to sorghums. Only *s. hermontheaa* and *S. senegalenisis* have been reported in West Africa, *stviga* seed requires stimulation by root exudates from the host to germinate. However, the moisture content of the soil environment appears to have a considerable influence on *striga* emergence (Ogborne, 1972a). Although a moist pre-treatment is necessary for germination, *Striga* seeds appear to undergo dormancy during wet conditions. In the Savanna regions severe *Striga* emergence occurs towards the end of the rainy season when the local cultivars are heading and forming their yields. However, in early maturing cultivars *Striga* emergence often occurs earlier. Several different methods of control have been tried with varying degree of success. These include hand weeding, trap cropping, high fertility, foliar and soil active herbicides and host resistance. Until very recently only hand weeding could be recommended to small farmers but now a foliar herbicide has been recommended: it must be directed at the weed with a cheap water pistol (Ogborne, 1972b). Some pre-emergent herbicides for sole crop of sorghum have been shown to be promising but in crop mixture involving sorghum more specific herbicides are required. Host resistance appears promising in the future although the host-parasite relationship is not fully understood.

MILLET *(Pennisetum typhoides)*

The crop is native to Africa and probably originated in the West African Savanna (Chevalier, 1934; Staph and Hubbard, 1934). Millet in West Africa is grown primarily for grain for human consumption. The grain is ground into flour after removing the husk and mainly eaten as a porridge but some is malted and made into beer. Lustrous, grey or slate-blue, corneous, seeds are preferred for flour. The husk is fed to poultry while crop residues are used as building material, fuel and feed. Millet has been used successfully as a green manure and forage crop. Both, short-season, nonphotoperiodic millet (Gero millet) and long-season photoperiodic millet (Maiwa millet) are grown, although the former is always dominant, probably accounting for about 80 per cent of the total area under millet (D.J. Andrews, personal communication 1975). Transplanted millet (Dauro millet), considered to be a specialized type of Maiwa, is also grown but on a very restricted scale. Maiwa millets are larger and taller (3-6 m) than Gero millets (1.5-3 m).

Estimated total production of millet in West Africa in 1971 was about 6.7 m tonnes from an area of about 11.5 m ha, corresponding to a yield of about 580 kg/ha. However, yield figures from individual countries vary between about 290 kg/ha in Mauritania and 690 kg/ha in Mali. Good experimental yields of local millets under improved practice is about 1-1.5 tonne/ha; those of improved millets about 2-2.5 tonne/ha in the Sudan and Southern Guinea Savanna, and about 2.5-3.5 tonne/ha in the Northern Guinea Savanna.

ECOLOGY

Millet is the most important cereal in the Sudan and Northern Guinea Savanna but it remains an important cereal in the Southern Guinea Savanna. Gero millets are of 75 to 100 days to maturity while Maiwa millets 120-280 days. Like the local sorghums, Maiwa millets appear to be adapted to flower at the end of the rains. At Samaru the date of heading in a Maiwa millet (ex-Mokwa) was linearly related to the date of sowing over an 8-week spread in sowing date. Each week's delay in sowing delayed the heading date by about one day (A.H. Kassam, unpublished 1974). This effect, although small, can lead to decreases in yields when the crop is sown late or rains cease earlier than normal or both, for reasons similar to those explained in the case of photoperiodic sorghums. The main reason why the area under Maiwa millet is small is because Gero millet is higher yielding and produces a yield much more quickly. Also, farmers prefer to grow photoperiodic sorghums whose duration is similar to Maiwa millets but are higher yielding. However, on lighter soils farmers prefer to grow Maiwa millets rather than sorghums. Further, Maiwa millet matures slightly earlier than sorghum because of its shorter grain filling period; and this appears to enable the farmer to spread his labour demand for harvesting the late-season crops.

Gero millets are resistant to head mould attack and have a better ability to ripen good grain in wet conditions than Maiwa millets. Consequently, Gero millet is usually the first crop sown because the farmer's food supply is *very* low at the end of the dry season and he needs a crop as soon as ever possible. A 90-day Gero millet crop normally sown in May in the Northern Guinea Savanna therefore matures and is harvested in August, the wettest month, without a great deal of difficulty from pests and diseases.

The northern limit of millet in West Africa is around 200-250 mm isohyets in the Sahel Savanna where sorghum can no longer be safely grown as a rain-fed crop. Here, millets of 55-65 days to maturity are grown. However, it is in the Sudan Savanna where millet reaches its greatest concentration occupying equal status with sorghum. Agronomic and eco-physiological aspects of millet have been reviewed by Ferraris (1973). In general, millets are known to be well adapted to conditions of lighter soils, high temperature and high solar radiation and can have a very high rate of growth and water use of efficiency for total dry matter under favourable rain-fed conditions (Begg *et al.*, 1964). Thus, Kassam and Kowal (1975) reported that total water used by an 85-day crop of Gero millet was 330 mm equivalent to water use of efficiency of 148 g water per g total dry weight. Furthermore, once the millet crop has established itself, it has a marked degree of drought endurance. Millet is grown on both light and heavy soils but it thrives best on light loams. Unlike sorghum it cannot tolerate waterlogged conditions. Millets are less susceptible to damage from stem-borers, *striga* and weeds but they suffer badly from bird attack.

Millets in general are able to take up large quantities of nutrients because of their high growth potential. However, as a grain crop local millets are inefficient users of nutrients because of the low harvest index. There is a very large scope for improving millet for intensive grain and forage production. Indeed crop improvement research in West Africa, particularly in Senegal, has achieved a large measure of success in breeding high yielding dwarf cultivars which *can* utilize nutrients more efficiently. These experimental cultivars have a harvest index of 40-50% and mature in 75-100 days (Bilquez, 1970; Jacquinot,1970; Etasse, 1970; OSTROM-IRAT, 1970-1971). An improved recommended cultivar yielding 3,130 kg/ha in the West African Savanna has been reported to remove N, 132 kg/ha; P2O5, 63 kg/ha; K20, 78 kg/ha; CaO, 78 kg/ha (IRAT, 1972) which is greater than for an equivalent yield of maize.

CULTIVATION

Millet is grown as a rain-fed crop and the indigenous practice is to sow it as early as possible in the wet season although some is sown dry followed by transplanting or second sowing to fill the gaps. Seeds are sown on the flat and occasionally ridged later or in the furrows. Nearly all the Gero millet is sown in mixture with other crops in 2-5 crop combinations involving late millet, sorghum, cowpea, groundnut. Maiwa millet is sown as a sole crop to some extent and about 28% of the total area under Maiwa millet was found to be sole crop millet in village studies in the Guinea Savanna (Norman, 1972). On the light soils, in mixtures, millet is sown in the furrow between the ridges sown to sorghum (Fig.l) but on heavy soils it is often sown on ridges with sorghum in the furrows. The spacing is generally about 1-2 x 1 m while the stand population for Gero millet varies between 7,500-8,500 per ha in 2-4 crop combinations and 7,000 per ha in 5 crop combinations (Norman, 1972); and for Maiwa millet between about 8,500 per ha when grown sole and 5,800 per ha in 3-4 crop combinations. Gero millet is harvested in July and August in the Guinea Savanna and August and September in the Sudan Savanna, while Maiwa millets are harvested in the dry season before the harvest of the sorghum crop. Because of heavy basal tillering generally two or more harvests are taken. The grain to head weight ratio is about 50-60% while the harvest index is 10-20%.

Improved Gero millets as sole crops are sown when the rains have established. Treated seeds are sown at spacings of 0.1-0.3 x 0.45-0.90m, depending on the cultivar and days to maturity. Tall Maiwa millet and semi-tall Gero millet cultivars are generally sown at a density of 40-80,000 plant/ha while with dwarf Gero millet cultivars over 100,000 plant/ha or more are necessary. Responses to nutrients vary from area to area but for yields over 2.5-3.0 tonne/ha, experimental rates of 60-125 kg/ha of N and 35-80 kg/ha of P_2O_5 are applied. Harvest index of improved Gero millets is 20-35%. Improved Gero millets show extra yield advantages when grown in mixtures with sorghum under high management and yield advantages of up to 80% have been reported (Andrews, 1972a; Kassam and Stockinger, 1973; Baker, 1974).

DISEASES AND PESTS

At present general disease and pest problems in millet are relatively minor in the Savanna areas (Sauger *et al.*, 1970; King, 1970a, 1970b). Green ear *(Salerospora graminiaola)*, a downy mildew, is the most serious disease of millet though susceptibility of a cultivar varies considerably with environmental conditions. In Nigeria average yield losses in Gero millet are reported to be about 10%. Maiwa millet seem to be less severely attacked by the disease, though yield losses of about 8% have been reported. However, downy mildew occurs almost annually in some parts of West Africa and it is not uncommon to find symptoms on 50% of the plants in a farmer's field. Symptoms of downy mildew are extremely variable but infection generally becomes systemic and infected plants commonly show both foliar and green ear symptoms. The primary source of downy mildew inoculum is apparently soil-borne oospores which enter through roots. Leaves of infected plants are generally pale in colour and sporangia appear on the surfaces of leaves. The importance of sporangia in spreading the pathogen from one plant to another is not clearly understood but sporangia are not considered to be as important in infection as are oospores. Environmental conditions, particularly during the first few weeks of plant growth, greatly influence the incidence of the disease, and high atmospheric humidity greatly favours infection. The only practical way to control downy mildew is through the development of resistant cultivars and sources of tolerance and resistance have been reported. Grain smut *(Tolyposporium penioillaviae)* is a common disease, but it is not of economic importance at present although it can be serious on occasions. The primary source of inoculum is the sporidia produced by spore balls surviving in the soil. Sporidia become air-borne and infection occurs through the flowers, which are most susceptible immediately before stigmas emerge. The fungus grows in the ovary and as the head matures the fungal spore-sacs are produced. Some or all the grains on the head are replaced by shiny green smut spore-sacs, which are usually larger than the grain and have smooth rounded apex. As the millet head matures, the spore-sac membranes become brown and brittle, and can be easily broken to reveal the black smut spores. Many of the spores adhere tightly to form spore-balls. Smut is commonly found at the lower portion of those heads which do not fully emerge from the flag leaf. Little can be done at present to control this disease but strict sanitary measures can help in its control. Ergot *(Claviaeps miaroaephala)* commonly occurs in millet but the incidence is generally not of economic significance. Infection occurs through the flowers. The primary source of inoculum is believed to be soil-borne sclerotia which produce air-borne spores during the month of July. Insects are important in spreading spores produced during the honey-dew phase of the disease from one spike to another. The fungus grows inside the grain and produces sclerotia of purple to black in colour. Cultural practice of timely sowing, use of cultivars with synchronous heading and burning infected heads do help in its control but no effective control measure exists at present. Other diseases include the rust *(Puaainia penniseti)* which occasionally becomes severe on late millet but is usually not found on early millet, leaf spots *(Gleoaeraospora* spp., *Pyriaularia* spp., *Ceraospova* spp. J which are commonly observed, and the stem rot *(Fusaviwn moniliforme).* However, these diseases are unimportant at present.

Normally pest damage to pearl millet is minimal. However, Coutin and Harris (1968) have reported that the millet grain midge *(Geromyia penniseti)* is widely distributed in the Savanna areas, and has the potential of becoming a serious pest. Further, since the abnormally low rainfall period of 1971-73, a lepidopterous insect, *Masalia* sp.„ has become *very* common throughout the northern Savanna areas, and has been reported from Nigeria, Niger, Upper Volta and Senegal. This pest causes severe damage to the panicle.

In store the usual cereal pests, *Sitotroga* cerealella and the small strain of *Sitophilus oryzae,* can be very damaging if storage is prolonged.

Damage to millet by Quelea is a major problem, particularly in the Sudan Savanna.

Millet is **attacked by** *striga* but the extent of attack and losses **are not** as serious as in sorghum. Gero millet generally escapes *striga* **attack** as it is harvested during the wettest part of the rainy season **when** *Striga* seeds undergo dormancy. However, *Striga* attack on Maiwa millet is comparatively greater.

MAIZE *(lea mays)*

Central America is considered to be the origin of this crop which reached West Africa probably during the early sixteenth century. It appears that the hard-seeded flint types were introduced into West Africa from the north across the Sahara while the soft-seeded, flour types came from South America (Porteres, 1955). At present maize reaches its greatest concentration in the humid Forest areas and Derived Savanna areas of West Africa. The lack of a high-yielding cereal which could be grown more extensively than rice in the Forest and southern Savanna areas, and historical reasons, resulted in research work being concentrated early on growing maize in the Forest areas of West Africa. In the north maize has never become a major grain crop because of the importance of sorghum and millet in the Guinea and Sudan Savanna. Local land races in the Savanna areas are grown in backyards or close to the houses as a garden crop, upland fields and the lowland *fadama)-* areas. Maize grown in the High Forest areas is largely consumed green on the cob as a vegetable while in the Savanna areas it is made into flour and consumed as a thick paste. Maize has been used successfully for silage in the Savanna areas (Couper and de Leeuw, 1971; Couper, 1972; Haggar and Couper, 1972) while elsewhere in the world maize has a wide variety of uses. Full accounts of various aspects of the crop are available (Berger, 1962; Aldrich and Leng, 1965; Miracle, 1966; Cunard, 1967; Milbourn, 1971).

Production figures for the Savanna areas alone are not available. Estimated total production of maize in West Africa both in the Savanna and Forest areas in 1971 was about 2.7 m tonnes from an area of about 3.4 m ha, corresponding to a yield of about 800 kg/ha. However, yield figures for individual countries vary between about 500 kg/ha in Dahomey and 1100 kg/ha in Ghana. Under local practice yields are larger in the Forest and Derived Savanna areas than in the Guinea and Sudan Savanna.

Fadama areas are the low lying areas which are seasonally flooded or have high water table and can be cropped during the dry season as well.

However, under improved practice at high fertility highest yields are obtained in the Guinea Savanna: yields in the Sudan and Derived Savanna and Forest areas being lower by 30-50% than those in the Guinea Savanna (Kassam *et al.*, 1975a). Good experimental yields of maize are 3-4 tonne/ha in the Sudan and Derived Savanna and 5-8 tonne/ha in the Guinea Savanna (Craig, 1967-72; Webster, 1969; Tatum, 1971; IITA, 1973a), although experimental yields of 10 tonne/ha or more are commonly obtained in the Northern Guinea Savanna.

ECOLOGY

Production of maize in the Savanna areas is expanding and it promises to replace a considerable portion of the current area under sorghum where moisture supply is dependable. Research has shown that the environment in the Savanna areas is suitable for intensive production of maize and recently considerable effort has been made in popularizing maize as a grain crop in the Guinea and Sudan Savanna where sorghum is normally grown. Major reasons for this are:

1. Average experimental yields of maize in the Savanna areas are consistently greater by two to three times than the average experimental yields of improved cultivars of sorghum and millet.

2. Experiments in the Guinea Savanna have shown that the yield potential of maize is much greater than that of either sorghum and millet; yields of 8-10 tonne/ha or more have been obtained with maize in the Guinea Savanna, whereas 4-5 tonne/ha appear to be the maximum yield obtainable from improved millet and long-season sorghum. (It appears that the theoretical yield potential of short-season, nonphotoperiodic sorghum is just as high as that of maize. However, the low quality of grain, lack of resistance to head mould and shoot-fly, and difficulties with sowing and harvesting under wet conditions make it unacceptable at present as an alternative sorghum grain crop).

3. Maize ears are protected by the husk against insects and from damage by rain during the ripening period.

4. Maize is resistant to bird damage.

The main reason for higher yields in the Guinea Savanna is because the pattern of water requirement of maize matches the pattern of water availability better than the long-season sorghum or millet (Kassam *et at*, 1975a). However, short-season sorghum of similar growth cycle with harvest index of 40-50% is likely to produce performance similar to that of maize and would not have to rely on residual soil moisture at the end of the season for grain filling. Short-season millet, although maturing before the end of the rains, produces lower yields because of its shorter growth duration and lower harvest index. In the low altitude Guinea Savanna areas 110-120 days growth cycle appears to be adequate to produce the highest yields. No advantage is obtained with cultivars having a longer growth cycle. Yields are lower in cultivars with growth cycles of less than 100 days, and this is one of the reasons why relative yields of maize in the Sudan Savanna are lower than in the Guinea Savanna. However, in the Derived Savanna and Forest areas yields are lower than in the Guinea Savanna because the rainfall pattern is bimodal, solar radiation receipts during the growing season are 20-30% lower, the incidence of pests and diseases is greater, and night temperatures are high leading to greater respiratory losses and poor dry matter distribution and harvest index. For example, at Ibadan on the High Forest/ Derived Savanna border the annual rainfall is about 1,140 mm spread over 9 months from March to November in a bimodal pattern resulting in a two crop season. The first season is long enough for 120-day maize crop but the balance between crop water requirement and water availability is tight with consequent periodic water stress. In the second season crop water requirement can be met without high soil moisture deficits only for 80-90 days. A 120-day maize crop therefore suffers severe water stress during the grain filling period. On the other hand, at Samaru in the Northern Guinea Savanna the annual rainfall is about 1,120 mm spread over 5 months from May to September in a unimodal pattern. Once the rains have established, precipitation soon exceeds crop water requirarent and water requirement of a 120-day maize is fully met (Kowal and Kassam, 1973a; Kassam *et al.*, 1975a).

Local land races in the Savanna areas vary in days to maturity between 80 and 140 days. Some of these have been found to have retained their high yield potential under local practices because they have been grown under relatively higher soil fertility. In the Guinea Savanna 90-100 day local maize has produced over 6 tonne/ha under improved practice (Andrews, 1972b; E.F.I. Baker, unpublished 1975) while early hybrids from local maize and early U.S. maize have produced yields of 7 tonne/ha in 90 days (Andrews, 1972b). In the Sudan Savanna 80-day local maize have produced 3-4 tonne/ha (Barry *et al.*, 1973). Improved maize produces higher yields but breeding efforts so far have concentrated more on adapted types for the Guinea Savanna than the Sudan Savanna, so that high yielding maize adapted to Sudan Savanna conditions have yet to be bred.

Maize is considered to be either a short-day or day-neutral plant (van Eijnattan, 1965). Date of sowing has been shown to have a great influence on yields of maize in West Africa (van Eijnattan, 1965; Akinbode, 1966; de Geus, 1970; Koli, 1970; Jones and Stockinger, 1972; Stockinger, 1972). In the Northern Guinea Savanna yields decrease if sowing is after about mid-June. Sowing in May either shows no advantage or lower yields depending on the rainfall conditions, than sowing during early to mid-June. Later sowing results in a decrease in cob number per plant, number of grains per cob and grain size. Eco-physiological causes behind this date of sowing effect are not clearly understood. van Eijnattan (1965) found that tasselling was earlier when the crop was sown earlier, and although there was significant negative correlation between tasselling time and minimum temperature both at Ibadan and Samaru, the significance of this in relation to the sowing date effect on yield could not be established either in terms of daylength or temperature. At Samaru, Jones and Stockinger (1972) found that before silking there was no significant difference in the cob number per plant and the number of potential seeds on each cob at different sowing dates. However, both the number of cobs and seed number per cob at maturity decreased in later sowings. Further, total dry weight did not differ significantly with sowing date. They therefore concluded that the yield decrease with lateness of sowing seemed to be related to conditions at or subsequent to silking; and in addition to poor soil moisture conditions during grain filling due to late sowing, other factors such as poor pollination or inefficient transfer of dry matter to the cob probably as a result of an imbalance in the minor nutrient status in the plant may be involved. Generally, leaf concentrations of iron and manganese have been found to increase in maize with decreasing soil aeration, as a result of waterlogging or a high water table (Lal and Taylor, 1970). However, in the study of Jones and Stockinger (1972) minor nutrient availability including those of iron and manganese decreased with later sowing indicating perhaps that excess moisture was not the cause of declining yields at Samaru. On the other hand in East Africa the date of sowing effect often seems to be associated with the rainfall pattern and water stress (Semb and Garberg, 1969). However, at Kitale in Western Kenya, Allen (1970) found that a date of planting effect existed even when rainfall was not limiting, and under these circumstances poor yields from later sown crops were related to excess moisture and impeded growth in the early stages of growth. However, Allen's (1970) hypothesis was not based on actual measurement of soil aeration, and later work by Cooper (1975) has shown that at Kitale the aeration status of the soil under young maize never reaches critical levels, even for late planted maize. Other work by Cooper (1974) and Law (1974) at Kitale suggests that the natural seasonal variation in soil temperatures may be the primary factor responsible for the observed reduction in yield of late planted maize. In the Sudan Savanna where the growing season is shorter and matches the crop growth cycle tightly, the delay in sowing causes yield losses principally due to a shortage of water during silking and grain filling. The reproductive processes and parts of maize are more sensitive to water stress than those of sorghum and millet. High temperatures and water stress at tasselling and silking result in pollen being shed before the silks are receptive, or in the death of the tassel and drying out of silk. This defect is one of the major reasons for poor yields of maize in the Sudan Savanna in years with a mid-season drought despite a high total dry matter production in such years. There is some evidence that an adequate boron nutrition is necessary for good pollination in hot and dry conditions.

Maize can be grown on a wide range of soil types but it prefers well drained loams. Maize can be grown successfully on soil with pH ranging from 5-8. Under low fertility maize often fails to produce a yield unlike sorghum and millet. High yields of maize are not possible without adequate nutrition. Response to fertilizer varies from area to area (Goldsworthy, 1968) but a crop yielding 5,440 kg/ha in Senegal has been reported to remove N, 138 kg/ha; P2O5, 65 kg/ha; K_20, 114 kg/ha; CaO, 16 kg/ha (IRAT, 1972). Growth and nutrient uptake in maize have been described by Hanway (1965).

Total crop water use of a 120-day maize between sowing and harvest in the Guinea Savanna has been reported to be 486 mm corresponding to crop water use efficiency of 253 g water per g total dry matter (Kowal and Kassam, 1973a). Eco-physiological aspects of growth and yield in maize have been reviewed by Duncan (1975).

CULTIVATION

Maize is grown as a rain-fed crop but in the *fadama* areas it may rely on residual soil moisture in the dry season. The local practice on the upland areas is to sow it as early as possible but after millet and sorghum have been sown. In the *fadama* areas it is generally sown after sugar cane either when the latter fails to establish or after it has been harvested. Maize is grown as a sole crop as well as in mixtures and the proportion of the area under each varies considerably. In village studies in the Northern Guinea Savanna about 27% of total area under maize was found to be grown sole while about 70% under 2-4 crop mixtures and about 3% under 5-6 crop mixtures (Norman, 1972). Maize is intercropped with a large variety of crops including cereals, legumes, vegetables, root crops, and cotton. In the *fadama* areas it is commonly intercropped with rice. It is sown on ridges particularly in the *fadama* areas or on the flat. When grown sole (Fig.1) it is sown at a spacing of about 0.45-0.80 x 0.90 m while the stand population varies between about 14,000 and 24,000 per ha. In mixtures it is sown at a variety of spacing depending on the crops involved and local practice. For example in the maize/rice intercrop (Fig.l) the crop is sown on the flat at spacings in the range 0.25-0.45 x 0.75-1.7 m (about 13,000-48,000 stands/ ha). Harvest time varies with area, sowing date and cultivar, and generally it is harvested after millet but before sorghum. The late sown crop in the *fadama* areas is harvested in the dry season. The grain to head weight ratio is about 75-80% while the harvest index is about 25-35%.

Improved maize cultivars are sown when the rains have established. Treated seeds are sown at a spacing of about 0.3 x 0.7-1 m, corresponding to plant densities of about 30-50,000 plants/ha. Responses to nutrients vary from area to area but for yields over 5 tonne/ha in the Guinea Savanna, experimental rates of 100-175 kg/ha of N and 60-150 kg/ha of P2O5 are applied. In the Sudan Savanna for yields over 3 tonne/ha, experimental rates of 60-120 kg/ha of N and 40-100 kg/ha of P_2O_5 are applied. Harvest index of improved cultivars is 40-50%.

Extra yield advantages have been shown to accrue in maize when intercropped under improved management and increases up to 40% have been recorded depending on the cultivar and crop combination (Baker, 1974).

DISEASES AND PESTS

Rust *(Puccinia sorghi)* is indigenous to West Africa but causes little damage. P. *polysora,* a rust of Central American origin caused considerable damage in the fifties (Cammack, 1953, 1956a, 1956b, 1958a, 1958b) but it is not a serious problem at present as improved cultivars have adequate resistance. Corn smut *(Ustilago maydis)* and head smut *(Sphacelotheca reiliana)* are not serious and generally localised. Leaf blight *(Helminthosporium maydis)* is widespread and has been known to cause considerable damage in the southern humid areas (Cammack, 1956a). Sources of genetic resistance to blight are available. Leaf spot *(Physoderma* spp.) is not serious but can become so under continuous cropping. Streak virus disease transmitted by leaf-hopper *(Cicadulina* spp.) has become more serious in recent years. The incidence varies from year to year and area to area but recently in northern Nigeria fields with 40-50% infected plants have been observed. Other diseases of maize in West Africa have been discussed by van Eijnattan (1965).

The most important pests of stored maize are the grain moth *(Sitotvoga cerealella),* the grain beetle *(Oryzaephilus surinamensis)* and the grain weevil *(Sitophilus oryzae).*

Maize is attacked by *Striga* and improved cultivars are *very* susceptible. Further, *Striga* can cause considerable damage in maize before it emerges above the soil surface.

RICE *(Oryza sativa)*

Rice of the species *O. glaberrima* has been cultivated for centuries in the West African Savanna. However, much of the present rice is derived from strains of *O. sativa* introduced from Asia. *O. glaberrima* and *O. sativa* closely resemble each other and are both considered to have a common ancestor. The consumption of rice is increasing in the Savanna areas and the total area under rice is probably greater than the area under maize. Rice is usually cooked by boiling in water while crop residues are used as feed. It has been reported (NAS, 1974) that non-paddy rice in West Africa accounts for at least two thirds of the total area under rice. Production and yield figures for non-paddy rice are not available. However, Norman (1972) reports average yields of about 500 kg/ha and 375 kg/ha for sole crop and mixed crop respectively for non-paddy rice in the *fadama* areas in the Guinea Savanna while Bourke (1965) reports yields between 700-1000 kg/ha for the flood plains of rivers in the Sudan and Sahel Savanna. Estimated total production of paddy rice in West Africa in 1971 was about 1.87 m tonnes from an area of about 1.55 m ha, corresponding to a yield of about 1,200 kg/ha. Yield figures from individual countries vary between 800 kg/ha in Cameroon and 1,700 kg/ha in Nigeria. If non-paddy rice is two thirds of the total area under rice then its area would appear to be just over 3 m ha. At a yield of 500 kg/ha, its production would be about 1.5 m tonnes which together with the similar average total production of paddy rice amount to more than that of maize. Yield potential of local strains of rice is low under improved practices (Porter, 1964). However, improved cultivars of paddy rice under proper management have produced over 8 tonne/ha in the dry season and 6-7 tonne/ha in the rainy season while upland cultivars 3-4 tonne/ha (de Geus, 1970; IITA, 1973a). Recently, at Kou Valley near Bobo-Dioulasso in the Northern Guinea Savanna in Upper Volta three crops of paddy rice per year grown on a large scale have produced yields of 12-14 tonne/ha. Similar yields have also been reported from Ghana (Kowal, 1962). General accounts on rice as a world crop are given by Grist (1965) and Purseglove (1975).

ECOLOGY

Rice in the Savanna areas is grown as a non-paddy crop in the upland areas and in the *fadama* areas with a high water table, as a paddy crop in the *fadama* areas and on the river banks which are seasonally flooded, and in paddies in which rainfall or irrigation water is impounded, while floating rice is grown on a restricted scale. Rice has a high degree of plasticity to the ecological conditions in the Savanna areas, but the chief limiting factor to its growth is the water supply which is the major factor influencing yields of upland rice during the wet season. Yields of paddy rice are higher in the dry season than in the wet season because of higher solar radiation and lesser pest problems. In the Sudan Savanna low temperatures during the dry season can lead to retarded seedling development and head sterility.

Successful paddy cultivation depends greatly on how well the water supply is controlled. Paddy crops relying on rainfall are greatly influenced by the variation in rainfall characteristics. Similarly, paddy crops on flood plains of rivers where water supply is largely uncontrolled are always vulnerable. High yields are only possible when the water supply is adequate and under controlled management. The ecophysiological basis of yield in paddy rice has been recently reviewed by Murata and Matsushima (1975). Rice breeding has led to the development of erect-leaved, short-strawed, heavy tillering cultivars (Tanaka *et al.*, 1968; Ito and Hayashi, 1969; Chandler, 1969). These make a more efficient use of solar radiation and nutrients with minimum lodging.

Rice is grown on many types of soil but heavy alluvial soils of river valleys are better suited than lighter soils. Heavier soils permit better puddling for paddy cultivation and greater return per unit of water and nutrients supplied as losses are relatively smaller compared to those on lighter soils. Optimum pH for paddy rice appears to be about 7 but upland rice will perform satisfactorily at 5-6 while on black soils where conditions are alkaline, paddy rice performs satisfactorily under pH of 8-9.

The soil conditions in paddy fields have been described by Grist (1965) and Russell (1973). Nitrogen fixation takes place by blue-green algae and the autotrophic bacteria in the soil and rhizosphere. Although the exact amounts are not known, it appears that in good paddy soils in Asia these sources of nitrogen are adequate to maintain yields of rice at low levels almost indefinitely. To what extent this is true for West Africa is not clear. However, for high yields adequate nutrition is essential. Improved photoinsensitive cultivars of paddy rice have been reported to remove N, 19 kg/ha; P2O5' *9.8* kg/ha; K2O, 56.4 kg/ha; Ca, 7.2 kg/ha; Mg, 5.3 kg/ha; Fe 2.6 kg/ha; Mn, 2.6 kg/ha; $Si0_2$, 379 kg/ha for each 1 tonne of yield (IRRI, 1963) while rain-fed rice crops in Senegal have been reported to remove, N, 24 kg/ha; P2O5, 12 kg/ha; K_20, 34 kg/ha; CaO, 10 kg/ha for each 1 tonne of yield (IRAT, 1972).

Some of the local cultivars of rice appear to be photoperiodic and flower under short days. Little is known about their adaptability to daylength in Savanna areas. High yielding improved cultivars are non-photoperiodic and allow sequential cropping when water is available.

DISEASES AND PESTS

Diseases of rice in West Africa have been reported by Williams and Abifarin (1973) and Williams (1973a),and Ou (1972) has presented a fuller account of rice diseases. Blast *(Pyviculavia ovyzae)* is one of the most serious diseases of rice. As it is both seed and air-borne, seed treatment provides only a partial control. Chemical control is effective but not economic at low levels of production. Recently tests conducted by IITA at the International Blast Nursery in Sierra Leone have produced a number of promising resistant types. However, it appears that new physiologic races are continually evolving and immunity based on the action of single genes is therefore likely to be short-lived. For example, of the 104 lines which were immune at IITA in 1970, only 15 remained immune in 1971 (Williams, 1973a). Cultivars with quite a high degree of what appears to be horizontal resistance have been developed but these have relatively low yield ceiling, with poor plant type and poor grain quality. The brown leaf spot *(Cochliobolus miyabeanus)* may cause considerable damage in cooler season or when there is a nutrient deficiency or in soils in a much reduced condition in which toxic substances accumulate (Ou, 1972). However, the disease is not serious at present and is not likely to be an important disease in adequately fertilized rice. Sources of resistance to brown leaf spot have been found but as the disease is seed-borne, seed treatment assists in control. Leaf scald *(Rhynchosporium ovyzae)* was first observed in Nigeria in 1969; and subsequently observed in Ivory Coast in 1970 and Ghana in 1971 (Lamey and Williams, 1972). Leaf scald has shown the potential to spread rapidly and be as destructive as the blast disease. The occurrence of leaf scald is not as widespread as the blast disease, however, and periods of rapid spread of leaf scald are frequently interrupted by periods of almost no spread. Narrow brown leaf spot *(Cerospora oryzae)* is common but not serious. Cultivars resistant to it exist. Other rice diseases encountered in West Africa are false smut *(Ustilaginoidea vivens)*, bakanae *(Gibbevella fujikuroi)*, stackburn disease *(Trichoconis padwickii)*, sheath blight *(Corticium sasakii)* and white tip *(Aphelenahoides beseeyi)*. These are not serious diseases.

Stem-borers *(Chilo zacconius, Sesamia Calamitis)*, white-borers *(Maliarpha sepavatella)* and stalk-eyed flies *(Diopeis thoraciaa, D. apioalis)* are serious insect pests of rice in West Africa. Recently at IITA sources of resistance have been isolated while chemical control under experimental conditions has been effective. Some cultivars with a high silica content in the stem have considerable resistance to borers. Other insect pests are considered minor and these include cotton stainers *(Dysderaus superstitiosus)*, coreid bugs *(Leptocorisa spp. Mirperus dentipes)*, **green shield bugs** *(Nezava viridula)*, spittle bugs *(Loaris maculata)*, mole crickets *(Gvyllotalpa afvicana)*, shield bugs *(Aspavia armigera)* **and stem beetles** *(Heteronychus ovyzae).*

The most serious damage in storage is caused by the rice weevil *(Sitophilus oryzae)*, the grain-borer *(Rhizopertha dominica)*, the grain beetle *(Oryzaephilus surinamensis)*, the grain moth *(Sitotroga cerealella)* and the khapra beetle *(Tvogoderma granarium)*.

Damage to rice by *Quelea quelea* is a major problem and damage by rodents can be serious.

The most serious weeds of paddy rice are the hydrophyte grasses and species of *Cyperus* but perennial grasses such as *Paspalum Echirochola pysamidalis* can become persistent. Cultural and chemical methods for control of these grasses have been described by Bullen (1971). In upland rice *Striga* has become a serious problem in some areas.

WHEAT *(Triticum aestivum)*

Wheat *(Triticum* sppJ has been traditionally cultivated in the Sahel and Sudan Savanna and around the shores of Lake Chad for unknown length of time, but certainly for centuries. Cultivars used under indigenous practice were introduced from North Africa and these have been grown on dry season irrigated gardens, usually on bunds between beds and on the edges of irrigation channels (Curtis, 1965; Andrews, 1968, 1969). Production of local wheat is very small, the grain being sold in the local market as a luxury product. The type of wheat which has been grown locally, known as 'Ble du Kanem', closely resembles a durum wheat *(T. durum)* but cytological investigation (Zaven, 1974) has shown it to be a hexaploid bread wheat *(T. aestivum).* The grain is used for making bread and during the last two decades there has been a rapid increase in the consumption of bread in the Savanna areas. Since 1960 locations have been developed in the northern Savanna areas to grow wheat under irrigation in the dry season.

Estimated total production of wheat in 1971 was about 19,000 tonnes from an area of about 12,000 ha, corresponding to a yield of about 1,600 kg/ha although yield figures from individual countries vary between 900 and 2,500 kg/ha. Some local wheat cultivars have the ability to produce good yields and over 4 tonne/ha have been recorded on a field scale (Andrews, 1968) but they are susceptible to stem and leaf rusts. Improved cultivars including the Mexican wheats from CIMMYT have a higher yield potential and some carry resistance to many sources of stem rust. Yields of over 5 tonne/ha have been obtained with improved cultivars in northern Nigeria (Andrews, 1972c, Andrews and Palmer, 1972).

ECOLOGY

Eco-physiological basis of growth and yield in wheat has been recently reviewed by Evans *et al.* (1975). Wheat requires cool weather during the tillering and early growth stages. These conditions are met during the months of November and December in the Sudan and Sahel Savanna. During this time humidity ranges 0-10%, day temperatures 32-38°C and night temperatures 8-15°C. Also, a constant wind (the Harmattanl) blows from the NE and this coupled with the very low humidity lowers the surface temperatures of the soil to about 4°C.

Time of sowing has a strong effect on yield and the best time to sow is early in the dry season - late October or November so that the crop matures in the coolest months - January and February. The reason for decrease in yield when sowing is delayed is partly eco-physiological (J.L. Palmer, personal communication 1974) and partly because of severe incidence of diseases particularly stem rust (Andrews, 1968).

Wheat can be grown on a variety of soils but prefers soils with reasonable drainage. However, in West Africa some of the areas selected for irrigated wheat production are near the rivers and on black soils with a high clay content and poor drainage. These areas are likely to create problems with alkalinity and salinity if drainage is not managed properly.

CULTIVATION

At the start of the dry season the ground is cultivated by hand hoeing. Beds for flood irrigation are formed and fertilizer is commonly broadcast just before sowing. The seed is commonly broadcast at rates between 90 and 135 kg/ha. Clumps of seeds in hills spaced 25-30 cm on the square may be sown on sites where weed problem is severe but clump sowing reduces the yield potential. A subsidised cultivation, sowing and fertilizing operation by tractor can be purchased by farmers in some areas in northern Nigeria. Irrigation (4-5 cm) are given once *every* week or 10 days. Harvesting and threshing are done by hand.

For yields over 4 tonne/ha, experimental rates of 60-125 kg/ha N and 40-90 kg/ha of P2O5 are applied. At these levels of fertility,

Harmattan is the dust laden wind which blows from the NE from the Sahara during the dry season.

local cultivars lodge badly.

Along the shores of Lake Chad in the Republic of Chad wheat is grown in the recesses in the shore line (D.J. Andrews, personal communication, 1976). Because of the undulating shore line, water flews into the lower areas forming recesses where *Papyrus* grows freely. After a few years of growth, the water is impounded. Surface water is lost through evaporation and the dead *Papyrus* provides a large amount of organic matter which may be up to 45%. Wheat is grown for a number of years until yields decline when the cycle is started again by letting water in.

DISEASES AND PESTS

The stem rust *(Puccinia graminis)* is one of the most destructive diseases of wheat and has appeared in West Africa particularly in 1962-64 causing up to 70% of crop losses in some areas. A large number of physiological races are found and new races appear to be continually evolving. Early sowing avoids much of the infection but where the infection comes from is not known. Wheat is not sown in the wet season and alternate hosts have not been found. The attacks do not occur annually and this suggests that the rust may be brought in by the prevailing northeasterly winds (Andrews, 1968). Brown leaf rust *(Puccinia recondita)* is frequently recorded, mostly on late sown crops but it does not cause serious losses.

At present there are no serious insect pest problems in wheat in the field while storage pests have not been studied in any detail.

PART II

LEGUMES

COWPEA *(Vigna sinensis)*

Cowpea, probably domesticated in Ethiopia (Steele, 1972), is the major grain legume crop in the West African Savanna, serving as both cash and food crop. It is exported from Savanna areas to the Forest areas in the south (Oyenuga, 1967; Gilbert, 1969). Estimated total production of cowpea in 1971 in Mauritania, Niger, Nigeria, Senegal and Upper Volta was about 1.1 m tonnes from an area of about 4.6 m ha, corresponding to a yield of about 240 kg/ha. Yield figures from individual countries vary between 220 kg/ha in Nigeria and 550 kq/ha in Niger. Good experimental yields of improved cultivars under improved management in the Savanna areas are between 1.5-2.5 tonne/ha of grain and yields *over* 3 tonne/ha have been obtained in the Guinea Savanna. Summerfield *et al.* (1974) have reviewed the current status of this crop.

ECOLOGY

Cowpea is considered to be either a short-day or day-neutral plant (Steele, 1964). The seed yield is largely dependent on the total number of nodes produced before the onset of flowering and the number of pods subsequently produced and retained at these nodes. The absolute size of plants at first flower and hence the number of nodes produced, is mainly dependent upon the extent to which cultivars are sensitive to night . temperature and/or daylength. According to Summerfield (1975a) higher night temperatures in photoperiodic and nonphotoperiodic cultivars and/or longer daylength in photoperiodic cultivars result in greater vegetative growth rates and larger plants at the time of first flower. Day temperatures experienced in the Savanna areas have little effect. Photoperiodic plants flower earlier in shorter days while high temperature can drastically hasten the onset of flowering in both photoperiodic and nonphotoperiodic plants. Consequently, the effects of longer days in delaying flowering in photoperiodic plants and the higher night temperatures in hastening can in some cases almost exactly offset one another. High day temperatures, despite having little effect on vegetative growth and time to first flower, after flowering has begun can reduce grain yield. Leaves senesce much faster in warmer days and the duration and efficiency of grain filling is considerably reduced. Under warmer day and night temperatures the abscission of young peduncles and flower buds is increased considerably.

Plants with effective nodules do not appear to show significant increase in seed yields from application of nitrogen. Under controlled conditions nodulated plants grown without nitrogen have produced yields only 10% less than non-nodulated plants supplied with nitrogen equivalent to 480 kg/ha (Summerfield, 1975b).

Cultivars vary in maturity between 80 and 160 days or more. Improved cultivars with erect and determinate growth habit do produce a high yield within 80-100 days. Local cultivars are generally late maturing with spreading and indeterminate growth habit, and therefore are more adapted to the lower light intensities in the intercrop canopies under local practice where crops in mixtures are largely superimposed on each other (Norman, 1972). With an early maturing cultivar of indeterminate growth habit two or more harvests are taken. Yields of cowpea are drastically reduced when intercropped with sorghum and millet, and the relative yield reduction compared to sole crop is greater in upright cultivars than in spreading cultivars. Yields may be reduced by as much as 75% of that obtained when grown sole but generally yield reductions are between 45-55% (Andrews, 1972a). However, cowpea as an intercrop in the indigenous practice is a bonus crop in a number of mixtures where it is undersown late and does not reduce yields of the standing crops. Further, without chemical control of pests sole crop cowpea generally fails to produce a yield whereas intercropped cowpea without chemical control produces about 25-50% of the yield.

Cowpea is grown under a wide range of soil and climate conditions in the Savanna areas, and can tolerate hot and relatively dry conditions in the Sudan Savanna. It prefers well drained soils and will perform satisfactorily on acid soils. A crop yielding 1.5 tonne/ha removes about N, 85 kg/ha, P2O5, 15 kg/ha; K_2O, 30 kg/ha.

CULTIVATION

Cowpea is rarely grown as a sole crop in the indigenous practice. It is generally grown in mixtures of 2-6 crop combinations involving sorghum, millet, maize, groundnut, cotton and root crops (Norman, 1972). Without chemical control of insects sole crop cowpea produces very low yields, but when grown in mixture with other crops, the incidence of pests is drastically reduced and a higher yield is obtained. The spacing varies greatly (Fig.1) depending on the crop mixture (Norman, 1972) and stand population varies between 6,000 and 7,500 per ha. Sowing time under local practice varies with region. In the Sudan and Northern Guinea Savanna it is undersown in July or August and harvested in November and December. In the Southern Guinea and Derived Savanna it is sown in April or May and harvested in August or it is sown in September and harvested in November and December. However, in the Sudan Savanna a dry season crop is grown in the *fadama* areas where it is sown in December and harvested in March or April. Pods are harvested and threshed by hand.

Sole cropping of cowpea with improved cultivars requires chemical control of pests for the high yield potential to be realized (Booker, 1965; Raheja and Hays, 1975). The crop is sown on ridges or on the flat at a spacing of about 0.15-0.3 x 0.75-1 m, (30,000-90,000 plants/ha). In the Sudan and Northern Guinea Savanna the crop is sown in June or July while in the Southern Guinea and Derived Savanna April or May for the early crop and August or September for the late crop. For yields over 1.5 tonne/ha, experimental rates of 35-70 kg/ha P2O5 are applied to the crop. A starter dose of 5-10 kg/ha N has been found useful for crop establishment prior to the development of effective nodules.

DISEASES AND PESTS

The fungal, bacterial and viral diseases of cowpea in Nigeria are described with information on their importance and control by Williams (1975a). In general, problems in cowpea are greater in the Derived and Southern Guinea Savanna than in the areas further north.

The major seedling pathogens are *Pythium aphantdermatum* and *Corticium solani.* Both pre- and post-emergence mortality occur. At the beginning of the rains when the soil has been hot and dry for several months and rainfall is sporadic the incidence is low; whereas during the cool wet overcast weather in the June to September period the incidence is high (Williams, 1975b). It appears unlikely that resistance can be found to these unspecialized soil-borne pathogens at the seedling stage. Seed treatment with fungicides provides effective control. Other principal fungal diseases are *Septoria* leaf spot *(Septoria vignae), Cercospora* **leaf spot** *(Ceraospora aanescens, C. cruenta),* **rust** *(Uromyces appendiculatus),* **stem rot** *(Pythium aphanidermatum)* **and** *Corynespora* **leaf** spot or target spot *(Corynespora aassiicola).* Sources of resistance to *Septoria* leaf spot, *Ceraospora* leaf spots and rust are known. Chemical control of these fungal diseases is effective. Pod and seed mould *(Aspergillus flavus)* can be serious in cowpea which matures in the wet season. Other fungal diseases of minor importance in the Savanna areas **are web blight** *(Corticum solani),* **powdery mildew** *(Erysiphe polygoni),* **stem rot** *(Corticium rolfsii),* **premature senescence** *(Rhizoctonia batatiaola),* **zonate leaf spot** *(Dactuliophora tarrii),* **and lambs-tail pod rot** *(Choanephora infundibulifera).*

Two most important bacterial diseases of cowpea in Nigeria (Williams, 1975a) are bacterial pustule *(Xanthomonas* spp.) and bacterial

GROUNDNUT *(Arachis hypogaea)*

Groundnut is of South American origin. It is the major cash crop in the West African Savanna and reaches its greatest concentration in the Sudan and Northern Guinea Savanna. It is also an important part of the diet and is consumed in stews, roasted meat preparations and as roasted or boiled kernels, while groundnut oil is used in cooking. Local oil pressing mills recently set up in the Savanna areas are increasingly absorbing a considerable proportion of the current production. Internal and export trade therefore involves kernels including confectionary types, oil and cake. Crop residues are used mainly as feed. Estimated total production of groundnut in shell in the West African Savanna was about 3.2 m tonnes from an area of about 4.5 m ha, corresponding to a yield of about 710 kg/ha or about 500 kg/ha of kernel at a shelling percentage of 70. Pod yields from individual countries vary from just over 1 tonne/ha (700 kg/ha of kernel) in Ghana and Cameroon to 400 kg/ha (280 kg/ha of kernel) in Togo. Good experimental yields of improved cultivars with proper management and pest control are about 3-3.5 tonne/ ha of kernel while 4 tonne/ha have been obtained in the Sudan Savanna and over 5 tonne/ha in the Northern Guinea Savanna (Rotimi, 1970; C. Harkness, personal communication, 1975; Kassam *et al.*, 1976). Crop culture and uses have been described by APREA (1973) while Sigafus (1973) has briefly reviewed the current worldwide status of the crop.

ECOLOGY

Groundnut is generally considered to be a day-neutral plant although some work suggests that sensitivity to daylength depends on temperature (Wynne *et al.*, 1973). However, daylength is not a critical factor influencing yields and in the Savanna areas days to first flower is largely independent of the daylength and depends on the cultivar. Two broad groups of groundnut cultivars are grown in West Africa. These are the alternately branched cultivars belonging to the Virginia and Castle Cary Group, and the sequentially branched cultivars belonging to the Spanish and Valencia Group (Bunting, 1955, 1958; Gibbons *et al.*, 1972). The alternately branched cultivars vary in maturity from 120-145 days while the sequentially branched cultivars from 90-105 days. Hybrids between these two types have produced promising cultivars with 115-120 days to maturity (C. Harkness, unpublished).

Detailed studies on the influence of temperature on groundnut have been conducted by de Beer (1963)who found that a temperature of 28°C may be considered as an optimum, whereas below 24°C or above 33°C growth and development is adversely affected. By altering the temperature from 24°C to 33°C and *viae versa* at various stages during the development of the plant, it was shown that vegetative growth and flowering were complements in development; in combination, however, they constitute an opposing factor to fruit development. The temperature during the vegetative phase of development has little or no influence on the later reproductive development, but the rate of flowering and some flower characteristics, e.g., length of hypanthium, pollen viability, is greatly influenced by temperature during the flowering stage. Groundnut plants flower abundantly at 38°C, but they produce very few pods, and de Beer (1963) found that at high temperatures smaller quantities of pollen are produced and set free and those produced have a low viability. Further, the hypanthia are longer and the distance the pollen tube has to travel in order to effect fertilization is therefore longer. However, pollen character was not seriously influenced by the temperature during the day of flowering, but by the temperature 36-96 hours before the opening of the flowers. Boron was found essential in production of active pollen.

The development of the groundnut fruit has been described by Schenk (1961). Pod yield per unit area depends on the number of pods per unit area and weight per pod. The number of pods depends on the proportion of total flowers which produce pegs and pods within the time available for filling, while the rate of pod growth and development to mature kernel depends on the supply of carbon. Therefore, although yield in a given cultivar depends on pod number and weight, these yield components in themselves do not determine yield *per se.* The eco-physiological factors which control the pattern and intensity of flower production, fertilization and survival on the one hand and the flow of carbon to support peg and pod growth on the other determine yield. High yields are obtained when a favourable balance is achieved between the early, concentrated, establishment by the plant of flowering nodes which can contribute to yield and the subsequent photosynthetic capacity to supply and develop them. In terms of supply of photosynthates yields in the Savanna areas are severely limited by *Ceraospova* leaf spot leading to premature loss of leaf areas. Large yield increases are obtained by spraying against the disease. The extra yield in a given cultivar is largely accounted for by more pods per stand and to a lesser extent by increased kernel weight. Sequentially branched cultivars have been found to produce higher yields with leaf spot control than do the alternately branched cultivars. Studies on high yielding cultivars in the Sudan and Guinea Savanna (C. Harkness, unpublished; 0. Rotimi, unpublished; A.H. Kassam and C. Harkness, unpublished) have indicated some of the differences in the flowering pattern and components of yield which are responsible for the present difference in yield between the sequentially and alternately branched cultivars (Table 1).

Groundnut crop is relatively more difficult to produce in the Derived and Southern Guinea Savanna than in the areas further north

TABLE 1. FLOWER PRODUCTION, YIELD AND YIELD COMPONENTS IN SEQUENTIALLY AND ALTERNATELY BRANCHED GROUNDNUT CULTIVARS IN 1973 AT SAMARU, NORTHERN NIGERIA (A. H. KASSAM AND C. HARKNESS, UNPUBLISHED).

Type	Sequentially branched		Alternately branched	
Cultivar	T47-56	Spanish 205	Samaru 61	Samaru 38
Days to first flower	27	27	34	34
Flowering period (days)	67	67	63	63
Total flowers produced/ stand	273	371	229	247
Pegs/stand	168	200	180	181
Pegs as % of total flowers	62	54	79	74
Pod bearing pegs/stand	93	146	98	95
Pod bearing pegs as % of total flowers	34	39	43	38
Pegs without pods	75	54	82	86
Pegs without pods as % of total flowers	28	15	36	35
% flowers not producing pegs	39	46	21	26
Days after sowing to produce 50% of total flowers	46	53	63	64
Days after start of flowering to produce 50% of total flowers	18	26	29	30

Contd....

Type	Sequentially branched		Alternately branched	
Cultivar	T47-56	Spanish 205	Samaru 61	Samaru 38
Days after sowing to produce flowers equal to total peg number	48	56	77	74
Days after start of flowering to produce flowers equal to total peg number	21	29	43	40
Days after sowing to produce flowers equal to total pod numbers	42	48	61	58
Days after start of flowering to produce flowers equal to total pod number	15	21	27	24
Pod yield (kg/ha)	5425	4961	4085	3775
Kernel yield (kg/ha)	3727	3397	2612	2497
Shelling %	69	69	64	66
Harvest index (%)	35.0	32.4	24.1	20.5
Kernel weight/stand (g)	78	71	55	52
Kernel number/stand	231	225	167	165
Weight/kernel (g)	0.337	0.315	0.328	0.316
Kernel number/pod	2.49	1.54	1.69	1.74

because of the greater incidence of pests and diseases particularly *Cevcospova* leaf spot, the aphid-borne rosette virus disease andaflatoxin produced by the *Aspergillus flavus* fungus. For the Savanna region as a whole good and clean crops are produced when the crops mature as the rains are ending. If the crop ripens too soon before the end of the rains, the wet harvest leads to problems with aflatoxin and drying of pods. If the crop ripens after the end of the rains, it experiences water stress at the critical stage in the last two or three weeks during pod filling (Kowal and Kassam, 1973b; C. Harkness, unpublished). Crop water use of a 120-day groundnut crop in the Northern Guinea Savanna has been reported to be about 440 mm corresponding to crop water use efficiency of about 520 g water per g total dry matter (Kassam *et al.*, 1975b).

A large number of trials on fertilizer including minor and trace elements have been conducted on groundnut in West Africa (Gillier and Prevot, 1960; Bockelee-Morvan, 1963, 1964, 1965, 1966, 1968; Goldsworthy and Heathcote, 1963; Evelyn and Thornton, 1964; Goldsworthy, 1964; Meredith, 1964; Gusten, 1965). Although response varies in different regions with cultivar, ridge or flat planting, spacing and population, adequate phosphorus, calcium and sulphur is essential for good yields and except for nitrogen, deficiencies of other elements are likely to become important under long-term intensive cultivation. Nutrient uptake has been studied by Gillier(1964, 1966) and Thornton, (1964), and mineral removal by the crop for each tonne of pod yield is generally N, 51-63 kg/ha; P_2O_5, 9-11; K_2O, 20-25 kg/ha; CaO, 11-15 kg/ha (FAO, 1965; IRAT, 1972) while a crop yielding 2.5 tonne/ha of pods and 5 tonne/ha of tops has been reported to remove N, 157 kg/ha; P2O5, 27 kg/ha; K2O, 115 kg/ha; CaO, 66 kg/ha; MgO, 34 kg/ha (Godin and Spensley, 1971).

The most suitable soils for groundnut are the well drained, light sandy loams. Soil which crust or cap easily can lead to difficulty with peg penetration. Groundnut tolerates a wide range of pH but prefers slightly acid soils. Groundnut does not tolerate waterlogging and in heavier soils harvesting is more difficult as the soil sticks to the pods.

CULTIVATION

Small farmers under indigenous practice sow much of the crop in mixture of 2-6 crop combinations involving millet, sorghum, cowpea, cotton, vegetables and even root crops. However, the most common mixtures involve millet, sorghum and cowpea. In village studies in the Northern Guinea Savanna about 16% of the total area under groundnut was in sole crop while about 70% was in 2-4 crop mixtures (Norman, 1972). On the other hand a much larger proportion of the groundnut crop in Senegal, where it occupies about 45% of the total cultivated area, is grown sole. Spacing under local practice varies greatly particularly in mixtures (Fig.1). The crop is largely sown on ridges. Under sole cropping the spacing is about 0.3-0.4 x 1 m while the stand population is about 28,000 per ha. In mixtures, ridges are about 1 m apart while the stand population is about 33,000 per ha. In the Northern Guinea and Sudan Savanna the crop is sown in June and harvested in September or

October. In the Southern Guinea and Derived Savanna two crops are often taken, the first crop being sown in April or May and harvested in August while the second crop is sown in August or September and harvested in November. Local cultivars and improved recommended cultivars grown under indigenous practice are the alternately branched types which have some tolerance to *Cereospora* disease.

Groundnut when grown in mixtures with sorghum, millet and maize produces lower yields per stand because of shading. The local practice is to keep the cereal population low, about 3,000-6,000 stands/ha, and raise the population of groundnut. In village studies stand populations of groundnut in sole crops were found to be about 28,000 per ha while those in mixture about 33,000 per ha. Respective yields per stand were about 21 g and 14 g while yields were 587 kg/ha and 438 kg/ha, a reduction of about 25% (Norman, 1972). However, an application of fertilizer to mixtures with groundnut in local practice has given yield increases of about 45% compared to groundnut in the unfertilized mixtures (Norman *et al.*, 1970). Despite the decrease in yield in groundnut, mixtures involving groundnut and cereals still produce a greater total yield/ha per season than one sole crop both in the indigenous practice and in experiments at higher levels of management. In intercropping experiments with improved cultivars at several population densities, groundnut grown with maize or sorghum has shown reduced yields but again total production in the mixtures were greater than those of the respective sole crops. With sorghum, reduction in yields were smaller with dwarf cultivars than tall cultivars (J.L. Palmer, unpublished results 1967-72).

Sole cropping of groundnut with improved cultivars, both sequentially and alternately branched types, requires chemical control of *Cereospora* for the high yield potential to be realized (McDonald, 1970a). However, yields of 1.5-2.5 tonne/ha are possible with the alternately branched cultivars without *Cercospora* control. This is not possible with the sequentially branched types which are highly susceptible to the disease. The crop is sown on ridges at a spacing of about 0.15-0.25 x 0.6-0.9 m (45,000-110,000 plants/ha). For alternately branched types 45,000-60,000 plants/ha are adequate to produce high yields but higher plant population is desirable for the sequentially branched types. With square sowing on the flat greater yields are possible with higher plant populations particularly with the sequentially branched types which have produced maximum yields at plant populations of 200,000 plants/ha or more with *Cercospora* control (Rotimi, 1970).

For yields over 2.5 tonne/ha, experimental rates of 40-80 kg/ha P_2O_5 are applied. Calcium deficiency can cause seriously low yields due to 'blind nuts'. A crop with effective nodules can supply all the nitrogen required for high yields.

DISEASES AND PESTS

Pest control in groundnut as a world cropis given in Feakin (1973). A wide range of soil inhabiting fungi are capable of causing disease in groundnut (McDonald, 1968, 1969, 1970b, 1970c, 1970d). Some are known as casual agents of wilt and stem and root rots (e.g., *Sclerotium rolfsii, Rhizoctonia bataticola, Pseudomonas solanacearum)* **while Others attack the** pod. Fungi which infect shells and kernels are of great importance as they reduce the quality of crop produce rendering it toxic and unacceptable for export and human consumption. Aflatoxin *(Aspergillus flavus)* and concealed damage *(Macrophomina phaseoli* and *Botryodiplodia theobromae)* are the most serious problems. Moisture content of the fruit and the environment is the most important factor in the development of these diseases. According to McDonald (1968) simple means of reducing the chance of fungal infection of fruits include cultural practices aimed at use of seed treatment and prevention of disease in the growing crop, timing of harvest to avoid inclusion of too many over mature fruits and rapid post-harvest drying of the pods and kernels. Investigations by McDonald and Harkness (1963) have shown that harvested pods are virtually free from aflatoxin toxicity except when pods are broken or damaged. Slow drying of moist pods and kernels is particularly conducive to fungal growth and Burrell *et al.* (1964) have shown that rapid and complete drying of pods **prevents their growth. Leaf spot** *(Ceraospora arachidicola, C. personata* and *C. canesaens)* is the major foliar disease of great economic importance. For example, in northern Nigeria losses up to 60% have been estimated from disease control trials (Fowler, 1970) and it is probable that no rain-fed crop or even plant remains free of these diseases. The alternately branched cultivars are more tolerant to leaf spot than the sequentially branched cultivars but genetic resistance does not seem promising. Chemical control of *Ceraospora* is effective and economical under improved practice (Fowler and McDonald, 1975). Resistance to *Ceraospora* has been found in wild groundnut species but its inclusion into adapted types has not yet been possible. Rosette virus is another serious disease particularly in the Derived and Southern Guinea Savanna (Hayes, 1932; Porteres and Legleu, 1937; Greenwood, 1951: Tourte and Fauche, 1954; Booker, 1963; A'Brook, 1964, 1968; Hull, 1969). The vector is *Aphis craccivora* and the principal host of the vector during the dry season is E*uphorbia hirta.* The infected plant is severely stunted and leaves are chlorotic and mottled (Storey and Ryland, 1955, 1957). The level of infection is less at higher plant populations and late sowing results in greater infection. High seed rate and early sowing have therefore been recommended in much of Africa as a standard control measure (Storey and Bottomley, 1928; Hayes, 1932; Soyer, 1939; Evans, 1954). Work conducted in East Africa has shown that chemical control of the vector is effective (Davies and Kasule, 1964; Davies, 1975a, 1975b). Studies conducted on the relationships between plant density and rosette disease incidence under sprayed and unsprayed conditions in Uganda

(Davies, 1970) have shown that during growth the number and percentage of plants showing symptoms of rosette disease was significantly greater at low plant densities under sprayed and unsprayed conditions. At harvest the numbers attacked in unsprayed plots were still greater at low plant densities but in sprayed plots the number of plants attacked was greater at high densities although the percentage of plants attacked was higher at low densities. Plant density did not affect quality of the groundnuts obtained, but yields were highest under both sprayed and unsprayed conditions at the highest plant densities. Resistance to rosette has been found in wild and cultivated species. In Senegal resistant cultivars have been developed subsequent to the discovery of the sources of resistance (Daniel and Berchoux, 1965).

Except for the *A. craccivora* which feeds on young leaves and stems, and spreads the rosette virus, no serious insect pests attacks the groundnut crop. However, fruit damage by millipede (*Peridontopyge* spp.) has been reported while termites have been known to cause premature death of plants (Perry, 1967).

Groundnut is seriously affected by pests in store. The groundnut bruchid *(Caryedon fuscus)* is important in that it causes severe damage to nuts in shell. Both the khapra beetle *(Tvogoderma granarium)* and the flour beetle *(Tribolium castaneum)* attack nuts which have been shelled.

SOYA BEAN *(Glycine max)*

The crop is thought to be of Asian origin. Attempts to introduce and extend the cultivation of the crop in the West African Savanna have met with limited success. However, there appears to be a good potential for soya bean in the Guinea and Derived Savanna. At present, the crop is grown to some extent largely in northern Nigeria where the total annual production is about 15,000 tonnes covering an area of about 53,000 ha. This corresponds to a yield of about 280 kg/ha. Experimental yields of 2.5-3 tonne/ha have been obtained with improved cultivars under proper management in the Derived and Guinea Savanna and over 3 tonne/ha have been obtained at IITA (IITA, 1973b). A recent account on improvement, production and uses of soya bean is given in Caldwell (1973).

ECOLOGV

Eco-physiological basis of yield in soya bean has been reviewed by

Shibles *et al.* (1975). Soya bean is considered to be either a short-day or day neutral plant. The seed yield is largely dependent on the total number of nodes produced before the onset of flowering and the number of pods subsequently produced and retained at these nodes. The effects of temperature and daylength on seed yield in soya bean are similar to those in cowpea (Summerfield, 1975a). Similarly, plants with effective nodules under adequate nutrition can meet the nitrogen requirement for high yields (Summerfield, 1975b) although often responses to nitrogen application have been obtained in different parts of the tropics. Recently, Kang (1975) in Nigeria found that inoculation alone was inadequate to supply the nitrogen need of the crop, 30 kg/ha of N being needed with inoculation, and 60 kg/ha of N without inoculation for maximum yield. However, the strain of *Rhizobium japonicum* is specific to soya bean, so that inoculation is essential when the crop is grown in a new area.

Cultivars vary in maturity between 80 and 180 days or more. However, high yields can be produced with improved, nonphotoperiodic, cultivars in 90-110 days. Cultivars presently grown are photoperiodic and late maturing. Work in Nigeria in the Guinea Savanna has shown that sowing date has a strong effect on yield. In the nonphotoperiodic cultivars, the effect of later sowing on yield is less marked unless the sowing is delayed to the extent that the crop has to mature partly or completely on the residual moisture in the soil at the end of the wet season. In the photoperiodic cultivars, delay in sowing results in a smaller plant at the time of first flower and fewer pod bearing nodes. Further, the crop matures under relatively more worse soil moisture conditions when sowing is delayed until July or August, in the Northern Guinea Savanna.

Soya bean can be grown on a wide range of soil types but sandy or clay loams with high calcium content are preferred. Optimum pH is in the range 5.7-6.2. Response to fertilizer depends on the cultivar and plant population but little work has been conducted on fertilizer requirements under intensive production in the West African Savanna. However, responses to phosphorus and sulphur have been reported (Goldsworthy and Heathcote, 1964) while nutrient removal for 1 tonne/ha of yield has been reported to be N, 60 kg/ha; P2O5, 35 kg/ha; K2O, 80 kg/ha (Godin and Spensley, 1971).

CULTIVATION

With improved cultivars of 90-110 days to maturity, high yields are obtained when the crop is sown at a population of 140,000-300,000 plants/ha or more and square planting produces slightly greater yields than rectangular planting. Yields in the range 2-3 tonne/ha have been obtained at spacings of 0.07-0.1 x 0.45-0.75 m. In the Northern Guinea Savanna, the crop should be sown in June, for harvesting in September. In the Southern Guinea and Derived Savanna two crops are possible with crops sown in April and May and again in August or September. For high yields experimental rates of 35-70 kg/ha of P2O5 are applied.

DISEASES AND PESTS

At present soya bean crops in the Savanna areas are relatively free from diseases and insects although damage by leafhoppers *(Empoasca spp.)* and pod borer *(Laspeyresia ptyahora)* has been reported but chemical control is effective.

PART III

ROOTS AND TUBERS

CASSAVA *(Manihot esculents)*

Cassava is of South American origin and was introduced into West Africa in the 16th century. Initially it was grown in the Forest areas but since the turn of this century it has been slowly moving into the Savanna areas. More recently it has become a common crop in the Northern Guinea and Sudan Savanna in areas of high population density. The cassava plant has many uses and it is grown as a source of carbohydrate and consumed in a variety of ways (Oyenuga, 1967; Irvine, 1974). Estimated total production of cassava in West Africa in 1971 was about 16 m tonnes from an area of about 1.93 m ha, corresponding to a yield of about 8.3 tonne/ha fresh tubers. Production figures for the Savanna areas are not available but in northern Nigeria the crop is estimated to occupy about 0.5% of the total cultivated area. Yields are larger in the High Forest areas, about 9.5-10 tonne/ha, while in the Savanna areas about 5-8 tonne/ha. Local cultivars have a low yield potential under improved practice, although improved local cultivars have produced experimental yields of 15-25 tonne/ha of fresh tubers or about 4.6-8.1 tonne/ha of dry yield in 12 month period (Ekandem, 1965; IITA, 1973c). Improved long-season cultivars can produce 40-50 tonne/ha of fresh tuber in 18-24 months. Recently, crop improvement research at CIAT and IITA has achieved a large measure of success and experimental yields of 25-30 tonne/ha in 7 months (Wholey and Cock, 1974) and 40-50 tonne/ha in 10-12 months have been obtained with improved cultivars. Kay (1973) has reviewed the status of cassava while Jennings (1970) and Coursey and Haynes (1970) have discussed the potential of cassava in Africa and the tropics.

ECOLOGY

The growth period of cassava is generally from 9-24 months depending on the cultivar and growing conditions. Normally, cassava is considered to be a long term root crop which can be harvested between 9 months and 2 years depending on whether the roots are to be consumed as a fresh vegetable or processed for flour or starch. A few quick growing cultivars can be harvested in 6-7 months, but good yields are normally obtained after 9-12 months. When utilized as a vegetable the tubers are harvested within 12 months, otherwise they become very fibrous. For processing they are left to reach full maturity, 18-24 months after planting.

Cassava appears to be a highly plastic plant and is grown in the

Savanna areas with rainfall of 500 mm and above. In the West African Savanna, cassava reaches its major concentration in the Northern Guinea Savanna and southern parts of the Sudan Savanna. Cassava is a hardy plant with a marked degree of drought endurance and can endure hot and dry conditions once it is established. Indeed, the crop under indigenous practice survives the dry season when it sheds all its leaves except the top few and resumes growth rapidly as the rains begin the following season. Optimum mean temperature conditions for cassava are in the range 25-29°C. Growth stops at mean temperatures below 10°C while yields are reduced at mean temperatures above 29°C. Cassava grows best on sandy or sandy loam soils but will perform satisfactorily on any soil with pH of 5-9 provided it is not saline, well drained and not water-logged. When grown on heavy clay soils, the plant produces stem and leaf growth at the expense of the roots and many cultivars give poor yields.

Cassava is a short-day plant and less productive of tuberous roots in daylengths greater than 10-12 hr. Both days to flower and height to branching decrease with decreasing daylength but there is a certain minimum vegetative growth requirement for flowering to be induced which varies with cultivars (IITA, 1973c). Flowering appears to be associated with yield and yields are lower in non-flowering plants. Short-days are required for tuberization (Bolhuis, 1966) and there is some evidence that tuberization is stimulated by low temperature (Arraudeau, 1967). Williams (1974) has discussed the process of tuberization in cassava. Tuberization is the result of a change in the nature of the differentiation of xylem cells in the secondarily thickened roots and involves the change from lignified xylem cells to parenchymatous xylem cells. This change is probably affected by the supply of assimilates and a hormonal factor which could suppress lignification and promote cell differentiation, the hormone (probably IAA) being transported from the tops under short-day conditions.

Studies on yield components, tuber weight and tuber number, in three high, medium and low yielding cultivars by Williams (1972, 1974) have indicated that tuber size contributes most to the differences in yield and the diameter of the tubers, rather than their length, is the main yield component. Wholey and Cock (1974) studying the onset and rate of root bulking found that the differences in the root yield in the cultivars studied were caused by the variations in rate of root bulking, and were not associated with differences in onset of root bulking, which occurred during the second month of growth. Root growth studies (Williams, 1974) have shown that bulking rate and canopy assimilation are strongly connected since differences in assimilation and bulking rate could not be accounted for by properties of the assimilation apparatus alone. Radial expansion of the storage cells, and the deposition of starch within them, appears to be the centre of sink activity which affects assimilation and bulking rate. Further, there is a strong internal competition for assimilates within the root system itself at the time of onset of bulking, since tuberization brings about a slowing down or cessation of growth in root length. However, tuberization does not reduce the growth of the stem, which forms an alternative sink for assimilates during tuber filling.

On the whole relatively little crop improvement research has been conducted on cassava until veryrecently. Local cultivars have a low yield potential under improved practice mainly because high fertility results in excessive vegetative growth. Improved local cultivars produce higher yields but again these have a low harvest index (20-30%) and long growing period. In the last 6-8 years research into changing the plant structure and developmental pattern has produced cultivars responsive to fertilizer at high plant densities. These cultivars produce a higher yield more rapidly and have a higher harvest index (40-60%). One of the major difficulties in achieving longer and higher rates of tuber filling has been the short duration of active life of leaves. For Savanna areas, short duration (6-10 months) cultivars with high root bulking rates are needed. These are likely to become available in the future and may have a good potential as a both food and cash crop because tubers and tops can be used for purposes other than for human consumption. The main advantage of cassava in the indigenous cropping is that the crop can be grown with little labour while the tubers can be kept in the ground until required. Cassava can tolerate soils of low fertility better than yams and other food crops, especially if the feeder roots can penetrate to depths of 40-60 cm or more. Further, cassava plays an important role in the local diet during periods of seasonal food shortage; and in year with poor and erratic rainfall or of severe attack from locust, cassava has proved to be the most valuable famine reserve crop. It is likely that cassava can be introduced into the northern areas of the Sudan Savanna and the southern areas of the Sahel Savanna as a famine reserve crop. However, there is an acute shortage of domestic water in these areas and cassava with very low HCN content, which require minimum washing, will be needed.

CULTIVATION

Cassava under local practice is grown both as a sole crop and in mixture of 2-6 crop combinations involving sorghum, maize, groundnut, cowpea, yam, sweet potato, vegetables and kenaf. In the village studies in the Northern Guinea Savanna about 65% of the cassava crop was found to be sole crop while about 30% in 2-3 crop mixtures (Norman, 1972). The common spacing of the sole crop is 0.45-0.7 x 0.9-1.1 m, equivalent to about 13,000-24,000 plants per ha at one plant/stand. In mixture the spacing is wider. Cassava is planted on ridges and on the flat but ridge planting is more common. Cuttings of about 20-30 cm long are inserted for about half their height often at an angle of 30-45 degrees. Cuttings sprout after 7-14 days after planting while root bulking begins during the second month after planting (Doku, 1969). The time of rapid bulking varies depending on the time of planting. Under local practice planting and harvest dates vary considerably. The crop is planted either in May to June and harvested the following September to December, or planted in late September to December and harvested the following October to December, although some is harvested before. Cassava is more popular than yam in the northern Savanna areas because it requires less labour and produces a greater yield in relatively poor soils.

For intensive production of short-season cassava, early planting at higher fertility will be required. Work elsewhere has shown that a yield of 40 tonne/ha at a harvest index of 50% removes about N, 285 kg/ha; $P_2 0 5$, 130 kg/ha; K20, 460 kg/ha; and CaO, 225 kg/ha. Cassava has a high requirement of potash, otherwise yields are very much reduced and the tubers have a low starch content and higher HCN content.

Harvesting is done by hand by digging up the tubers after detopping the plant. With large scale production they can be mechanically ploughed up but yields are often reduced because a higher percentage of tubers is left in the ground. The difficulty with machine harvesting is because tubers are spread 120 cm or more and their depth of penetration in the soil is 45-60 cm. Once harvested, the tubers deteriorate rapidly and begin to rot after 48 hours. Coating with a fungicidal wax has been found to extend the storage life to at least 16 days while cold storage at 0-2°C and 85-90% relative humidity has been reported to extend the storage-life for periods up to 6 1/2 months.

DISEASES AND PESTS

Leaf mosaic, a virus disease, is the most serious disease of cassava (Williams, 1973b). It can be spread by infected cuttings. It is transmitted by vectors of white flies *(Bemisia* sp.), probably *B. tabaci.* Genetic resistance appears promising at present. Bacterial blight, a new and potentially disastrous disease, was first identified in West Africa in 1972 (Williams *et al.,* 1973). It appears that resistance to cassava bacterial blight is associated with resistance to cassava mosaic disease (IITA, 1972-73). Root disease known as white thread *(Fomes lignosus)* has been reported to cause losses of 20% or more in Ghana. Other minor diseases are brown leaf spot *(Ceraospora hennigsii),* white leaf spot *(Ceraospora aaribaea)* and anthracnose *(Glomerella cingulata).*

The most serious insect pests are the white flies *(Bemisia tabaci).* **Other** common insect pests include the bugs *(Pseudothevaptus devastens, Anoplocnemis* spp., *Planococcus citri, Ferriseana virgata),* variegated grasshopper *(Zonocerus variegatus),* and scale insects *(Aonidonytilus albus).* Nematodes are also serious in West Africa, *Meloidogyne incognita* in the Ivory Coast and Nigeria, the lesion nematode *(Pratylenchus brachyurus)* and the spiral nematode *(Helicotylenohus erthrinae)* in Togo. Various species of termites have been known to cause damage to cassava while rodents and wild animals often attack cassava roots.

YAM *(Dio scorea* spp.)

Yams provide the staple carbohydrate food in the yam zone of West Africa. They are consumed in a variety of ways (Coursey, 1967a; Irvine, 1973; Purseglove, 1975). There are six main types of cultivated yams in West Africa and of these *V. rotundata* (white yam), *D. cayenensis* (yellow yam) and *P. alata* (greater yam) are the most important. Only these are considered here. *D. esculenla* (lesser yam), *D. bulbijera* (potato yam) and *D. dunotorum* (bitter yam) are in use but on a limited scale. Readers are referred to Coursey (1967a), Ayensu and Coursey (1972) and Kay (1973) for a detailed account on various cultivated yams. *D. rotudata* and *D. cayenensic* are of West African origin while *p. alata* of Asian origin. Yam production in West Africa is considered as declining because the crop requires a large input of manual labour for cultivation and food preparation, is attacked by several pests which limit yields and spoils easily in storage. These problems have tended to persist because little concentrated research has been conducted into yam improvement in the past. In the Savanna areas, particularly the Northern Guinea and Sudan Savanna cassava produces a better and higher return than yam. However, in the Derived and Southern Guinea Savanna the climate is more suitable for yam production and yields equal or surpass those from cassava under indigenous practice. The area under yam in the Savanna region is greater than under cassava, probably occupying about 2-4°' of the total cultivated area. Estimated production of yam in 1971 in West Africa was about 20 m tonnes from an area of about 2 m ha, corresponding to a yield of about 10 tonne/ha of fresh tubers. However, yields in the Savanna areas is probably about 7 tonne/ha in the Derived and Southern Guinea Savanna and about 3-5 tonne/ha in the Northern Guinea and Sudan Savanna. Crop improvement research conducted in West Africa in general and more recently at IITA has indicated that the yield potential of yam in favourable climate conditions is between 30-50 tonne/ha, and yields greater than 60 tonne/ha have been obtained (Gurnah, 1974). Yields greater than 50 tonne/ha under commercial production have been reported from elsewhere. However, in the Northern Guinea and Sudan Savanna the potential for yam cultivars presently available is low unless short-season cultivars of 5-7 months duration with early onset and rapid bulking rate become available. The past and future of the yams as crop plants has been discussed by Coursey and Martin (1970).

ECOLOGY

In West Africa the yam zone extends from about 4°N to about 10°N. Further north the dry season is too long. However, yam is grown in the Northern Guinea and Sudan Savanna but yields are low compared with those in the Derived and Southern Guinea Savanna. Optimum temperature for growth appears to be in the range 25-30°C. Growth is poor below 20°C while temperatures much above 30°C have an adverse effect, especially if accompanied by dry conditions. Yams require adequate moisture throughout their growing period and there is a positive correlation between moisture supply, vine growth and tuber yield. The critical period is during 14-20 weeks of growth when the food reserves of the sett are almost exhausted and the shoots are making rapid growth before new tubers have been formed. Later, they can endure periods of drought but yields are reduced. In West Africa yams reach their highest concentration in areas where there is a dry season of 2-4 months and a rainfall of 1,150 mm or more during the growing season. Good drainage is essential for high yields and quality. Yams perform best in deep well drained loams. In heavy soils tubers are susceptible to rotting while in very sandy soils favourable moisture conditions are difficult to maintain.

D. rotundata is better adapted to a long dry season and can complete its life cycle in 6-7 months, although about 8 months growing period is required for good yields. It can be grown farther north in the Savanna areas than most other yam species. For good yields, however, white yam requires a rainfall of 1,000-1,500 mm evenly distributed over 6-7 months. It grows best on heavy loams and can tolerate a higher clay content than most other yams. *D. cayenensis* can only withstand a short dry period, 2-3 months. It therefore performs best in the Forest areas. On average it requires about 10 months or more to complete its life cycle. When grown in the Savanna areas it is lifted prematurely. It is more tolerant of sandy soils than most other species. *D. alata* requires 9-10 months to reach full maturity and grows satisfactorily in the Derived and Southern Guinea Savanna. It will tolerate poorer soils better than most other cultivated yams.

Yams are influenced by photoperiod. However the relationships between daylength and vine and tuber growth have not been fully studied.

Long days (greater than 12 hours) favour the growth of the vine and short days (less than 10-11 hours) favour tuber development. Planting date has a strong effect on yield because the size of the vine at the time of onset of tuber development and the length of the bulking period are both affected by it. Delay in sowing reduces yields and generally earlier the planting the greater the yield. The time of planting varies considerably in different areas. In the Derived and Southern Guinea Savanna, yams are often planted in the dry season from November to March, so that they sprout with the early rain. In areas further north where the dry season is severe, this practice is not followed because yams tend to shrivel or decay or are attacked by termites. Yams are therefore planted just before or immediately after the rains have started. However, in general most of the yams in the Savanna areas are planted towards the end of the dry season and beginning of the rainy season. In the Northern Guinea and Sudan Savanna yams are often planted in June or July after the staple cereals have been sown.

Traditionally, yams are planted in hills or mounds which are between about 0.6-1.3 m high and 0.9-1.3 m apart. Hills are often made at the end of the rains when the soil is still soft. Various methods of mechanizing the crop have been tried and good results have been obtained from ridges about 0.45-0.6 m high and 0.6 m wide at the base. The average size of yam tends to be smaller than those grown in mounds but the total yield is greater. For propagations farmers use either seed yams or setts. Most yams produce one or two tubers larger than the rest and these are generally used as food. They are cut off near the top leaving the crown with the green stem attached. This is replanted and gradually grows again producing two *or* more small seed tubers. In the Northern Guinea and Sudan Savanna the growing season is not long enough to produce seed yams. Some farmers in the southern areas specialize in the production of seed yams but generally the available quantity of seed yam is insufficient. Large yams are therefore cut into pieces known as setts which are then used for planting. On average, seed yams or setts weigh between 170 and 400 g. Most farmers cut their yams into two or three pieces. The 'tops' are at the stem end, the centre part is the 'middle', and the other end the 'bottom'. Whole seed yams and tops generally sprout at the same time, but for equal weight seed yams produce slightly heavier yield than tops. Middles and bottoms generally sprout later but their yields are often lower than seed yams or tops. The weight of planting sett has a considerable effect on yield. For white yam Miege (1957) found that an increase in sett weight from 50 to 250 g linearly increased yield and decreased mean sprouting time. Baker (1964) also found similar relations between sett weights and yield that enabled him to deduce a mathematical relation between yield per plant, sett weight and plant population. Recently, Gurnah (1974) found that in white yam sett weight in the range 203-608 g had a large effect on yield, heavier setts producing the greatest weights of tubers. Further, increasing sett weight increased the average number of tubers produced per plant, possibly because the heavier setts had more buds from which new tubers could be initiated. However, sett weight did not appear to affect average tuber weight in this study, although Coursey (1967a) has observed that heavier setts are used when extra large tubers are required for festivals and shows.

The plant population used by farmers is about 7,000-10,000 plants/ha. However, studies in West Africa and elsewhere have shown that higher yields are possible at much higher plant populations with adequate fertility. Thus, Gurnah (1974) in Ghana found that the relation between plant population and yield in white yam was linear up to the highest population tested, 35,000 plants/ha. However, spacing has a considerable effect on yield of tubers, and Gurnah (1974) found that the best yields over the four square spacings tested (0.31, 0.61, 0.91 and 1.22 m) were produced with the narrowest spacing (highest plant population). The number of tubers per plant was not affected but the average tuber weight was, the heaviest being in the widest spacing (lowest plant population). However, a higher plant population entails the use of more setts. Cheaper methods of propagation are likely to contribute greatly towards growing yams at higher populations economically as husbandry practices improve. It has demonstrated with several yam species that it is possible to propagate yams from vine cuttings. Recently seed propagation of white yam at IITA has met with some considerable success although the method needs much more research (IITA, 1973c). One of the major advantages of denser planting is that the small yams produced could be more easily lifted mechanically specially as the local consumers do not appear to object to smaller tubers.

Most yams are grown as the first crop in the rotation or on land after it has been cleared from bush or fallow because yams under local practice unlike cassava perform poorly on soils which has already been cropped in the previous seasons. Little or no fertilizer is used on yams and there is a wide response to treatment, particularly to the application of phosphorus and potassium. In their review on the response of yams to fertilizers and manures, Ferguson and Haynes (1970) noted that there were generally low but positive responses to nitrogen and organic matter. In some cases low levels of potassium gave small increases, but phosphorus did not affect yield. The growth, development and nutrient uptake in white yam in Nigeria was studied by Sobulo (1972a, 1972b). It was estimated that a yam crop of 29 tonne/ha removed 133, 10 and 85 kg/ha of nitrogen, phosphorus and potassium respectively. This pattern of nutrient usage may explain why yams often respond to nitrogen and sometimes to potassium but not to phosphorus. For example, trials conducted in West Africa under Freedom from Hunger Campaign (FFHC, 1965) showed that in the Forest areas compound fertilizer containing about 45 kg/ha each of N, P_2O_5 and K_2O increased yields whereas in the Savanna regions nitrogen was the only element which gave a response. Sobulo (1972b) obtained similar results in the Savanna areas of Nigeria while

Gurnah (1974) in the Forest area of Ghana.

Seed yams or setts are planted in the middle of the hills in holes 15 cm deep. In some areas yams are planted 5-10 cm deep while some farmers plant them almost at ground level. However, it appears that it is better to plant too deeply than too near the surface. Shallow planting may dry out the sett before sprouting. After planting the hills are capped by a layer of dried grass or weeds about 30 cm in diameter on the top of the hill and kept in position by a thin layer of soil. Experiments have shown that the percentage of sprouting and the final yield from capped hills are double those from uncapped hills. In the Savanna areas failure to cap hills can result in almost complete loss of the crop and in drier areas capping preserves the tubers throughout the dry season by preserving the moisture. In general protected yams sprout more quickly than unprotected yams as they do not dry out. However, if left too long the caps and even the tubers may be eaten by termites. Capping is thought to create steady temperature conditions and also protects the tubers from the sudden spells of dry weather and scorching sun, and also from the heavy rain and wind during the wet season.

As young shoots appear, long yam poles from hard wood trees are put in 1-2 m deep on the windward side of the hills. Soft wood poles rot or are attacked by termites at the ground level, or at the end of the season may break under the weight of the foliage. Living poles are also used. In the drier Savanna areas where trees are scarce, yam poles are sometimes only 1 m high, although experiments have shown that yams grown on 2 m poles yield almost double those on 1 m poles. Further increase in pole length does not increase yields appreciably. In the Derived and Southern Guinea Savanna, yams are planted after late maize and sorghum and when these crops have been harvested the dried stalks are bent over 1 m above the ground in rows. As the yam vines grow they are trained along the dried stalks thus avoiding the use of poles in areas where wood is scarce. In Forest areas yams are grown around trees left when the bush is cleared and strings are attached to the outer branches and to short stakes. Sometimes three or four mounds may have strings leading to one tree. An experiment conducted to study the effect of staking and changing plant canopy structure by pruning yam stems to 50 cm and 100 cm heights (IITA, 1973c) showed that pruning in white yam resulted in bushy plants with sturdy main stems minimizing the requirement for staking specially when the plants were pruned to 50 cm. Staking, pruning and their interactions had no significant effect on the number of tubers per hills but significantly affected tuber size and yield. Staking improved tuber size and yield when the stems were not pruned. When the stems were pruned, staking made little difference while yield reduction was proportional to the severity of pruning.

Aspects related to storage problems and losses, storage practices and post-harvest technology and processing have been discussed by

Coursey (1967a, 1967b).

CULTIVATION

White, yellow and greater yams are grown as rain-fed crops. The indigenous practice is to grow them on hills and mounds which are prepared at the end of or early in the wet season. They are planted sole mixture with other crops in 2-4 crop combinations involving millet, sorghum, maize, rice, cowpea, groundnut, sweet potato and cassava. In village studies in the Northern Guinea Savanna about 30% of the total area under yams was found to be sole crop while about 48% in two crop mixtures (Norman, 1972). The crop is sown during the dry season or at the beginning of the rains depending on the region. Seed yams or setts are planted in the mounds which are 0.6 m high or more. When setts are used the cut part always points upwards while the buds or eyes downwards. After sowing the hills are protected by capping. A wide range of planting distances is used depending on the species, growing conditions and whether grown sole or in mixture. Common spacings used are about 0.6-1.2 x 1.2-1.8 m at one plant per stand (about 9,000-14,000 plants/ha) and corresponds to about 1.5-2.5 tonne/ha of setts. During the growing season cultivation operations include weeding, hilling and setting poles. Harvesting is done in the dry season but often yams planted in October or November in the southern areas are lifted in July or August. Fertilizer is not commonly used on yams but organic manure is often used. Lifting is done by hand.

For high yields whether on hills or ridges, good fertility at much higher plant population is necessary. Mechanical harvesting is possible on ridges but lifting is difficult at low plant densities because of the large size of tubers which can vary in weight up to 20 kg or more. Staking is necessary for high yields but adds to the cost of production.

DISEASES AND PESTS

Of the various diseases which can affect yams shoe-string and die back *(Glomerella cingulata)*, an anthracnose type of disease, are of major importance. Recently sources of resistance to these diseases have been found (IITA, 1973c). Witches' broom *(Phylleutypa dioscorea)* has been known to cause damage to yams in West Africa. Several leaf spot diseases have been reported and those caused by *Cercospora* spp. are the commonest. A virus disease of the mosaic type has been recorded while susceptibility appears to vary with species and cultivars. It is believed that both leaf spot and virus diseases cause relatively little yield losses.

Storage losses from various fungal rot diseases are generally severe, particularly when the tubers are damaged. The commonest and most important is *Botryodiplodia theobromae* which also causes a rot in the field. It has been shown to be responsible for wet rot, soft rot and brown rot. Other fungal rot diseases in storage causing considerable damage are *Rosellinia bunodes*, *Penicillium* spp. and *Fusarium* spp. Chemical control of these diseases is effective to some extent.

Yam tuber beetles *(Heteroligus meles, E. appius, Prionoryctes rufopiceus, P. caniculus)* are by far the most serious pests in West Africa but *H. meles*, the greater yam beetle, is the most common and widespread species and is found in the Savanna areas. These beetles do not breed in the yam fields but in swampy areas. The eggs are deposited in moist soil during November and December. The 3 larval instars and the pupal stage are completed by March or April when the beetles emerge. Beetles fly to the yam fields with the advent of rains and remain until the end of the rain. In November and December the beetles return to the breeding areas completing the one generation a year cycle (Libby, 1968). Chemical control is effective. A beetle *(Crioceris livida)* is known to cause damage. Both larvae and the beetle attack the leaves soon after the rains begin, but can be controlled chemically or by hand-picking. Scale insects *(Aspidella hartii* and *A. destructor)* are common pests of which *A. hartii* is the worst. *A. hartii* mainly attacks stored yams but when large colonies are built up on the tubers, sprouting is prevented. *A. destructor* builds up large colonies and feeds on the underside of leaves causing the leaves to become distorted and wilted. Chemical control of scale insects is effective. In parts of Nigeria considerable damage is occasionally caused by the cricket *(Gymnoryllus lucens)* and, in association with ants of the genus *Camponotus*, the citrus mealy bug *(Planococcus citri)*. Chemical control of these is effective. The variegated grasshopper *(Zonocerus variegatus)* has been reported to cause loss of stand or reduced yield. Nymphs and adults defoliate the plants and may kill young plants. Yam tubers are also subject to attack by several species of termites both when growing and during storage, while rats and other large animals can also cause damage. Nematodes can cause considerable damage, seriously reducing yields, increasing storage losses and affecting tuber sprouting. The most important is the yam nematode *(Scutellonema bradys)* while root-knot nematode *(Meloidogyne* spp.) and root-lesion nematodes are of importance. Little work has been done on the control of nematodes but chemical control is partially effective.

SWEET POTATO *(Ipomoea batatas)*

Sweet potato is of South American origin and was introduced into

West Africa by the Portuguese. Although it is considered a minor root crop in West Africa, it is widely grown in the Savanna areas. Total estimated production of sweet potato in 1971 in West Africa was about 0.9 m tonnes from an areas of about 0.22 m ha, corresponding to a yield of about 4 tonne/ha of fresh tubers. Yields between countries vary widely from about 0.5 tonne/ha in Mauritania to about 9 tonne/ha in Mali. Although figures are not available, it appears that a large proportion of the crop is grown in the Savanna areas, particularly in the Derived and Guinea Savanna. The popularity of the crop under indigenous practice seems to rest on its dependability of producing some yield regardless of the season and thereby providing valuable reserves during the dry season and in times of famine. There are three recognized West African types, white, red and yellow. The crop is grown as a source of carbohydrate and tubers are consumed boiled or baked while young terminal shoots and leaves are used as spinach. In West Africa, flour, starch, syrup and spirit are made from sweet potato tubers while crop residues are used as stock feed. However, the crop can be processed in a variety of other ways (Kay, 1973). Crop improvement research conducted in West Africa and more recently at IITA has shown that the yield potential of sweet potato under favourable conditions is between 20-30 tonne/ha, and experimental yields greater than 40 tonne/ha have been obtained (IITA, 1973c). The highest experimental yields obtained elsewhere are of the order of 50-70 kg/ha (Chadha and Dakshinamurthy, 1965; Lowe and Wilson, 1975a) and yields of 20 tonne/ha or more under commercial production have been reported.

ECOLOGY

Sweet potato, although a perennial, is normally cultivated as an annual crop. The crop under indigenous practice is harvested from 3-8 months after planting, depending upon the cultivar and climatic conditions. It can be successfully grown under irrigation in the dry season and experimental yields of 30-40 kg/ha have been obtained at IITA. Because the crop can be harvested in 3-4 months, sweet potato is grown in the northern areas, in the Sudan Savanna, where rainfall is only 500 mm. However, for good yields an annual rainfall of 750-1,250 mm is necessary, with dry weather as the crop reaches maturity. The best area for sweet potato in West Africa is therefore the Guinea Savanna and southern areas of the Sudan Savanna. Sweet potato can tolerate dry periods of considerable length once it is established. However, yields are drastically reduced if severe water stress occurs at the time when tuber initiation has begun, 40-60 days after planting. Sweet potato thrives best under temperatures around 24°C or more with abundant sunshine. Growth is poor in cool weather and temperatures below 10°C damages the plant.

Sweet potato is a short-day plant and short days promote both flowering and root development. A photoperiod of 11 hours or less hastens flowering while at 13 1/2 hours flowering ceases, but tuber yields do not appear to be affected. Little work has been done on the effect of planting date on the physiology of yield of the rain-fed crop. However, early planting results in higher yields mainly because the plant size at the time of onset of tuber development and the length of the bulking period are greater. Consequently, both the mean number of tubers per plant and mean weight per tuber decrease with delay in planting. Under adequate moisture and temperature conditions, however, dry season yields are often greater than wet season. The crop takes longer to mature in the wet season and has fewer tubers per plant. During the dry season solar radiation receipts are considerably greater than in the wet season and may partly contribute to the difference in the yield.

Studies on the eco-physiological basis of yield conducted elsewhere in the tropics have shown the importance of aspects related to dry matter accumulation such as crop growth rate, net assimilation rate and leaf area index (Haynes *et al.*, 1967) as well as the distribution of assimilates (Fujise and Tsuno, 1967; Austin and Aung, 1973). However, the terminal components of yield in sweet potato and other tuber crops are the number and mean weights of tubers per plant. Consistent production of both high tuber number and mean tuber weights is therefore a major characteristic of a high yielding cultivar. Further, reciprocal graft experiments with high and low yielding cultivars (Wilson, 1967; Hozyo, 1970; Hozyo *et al.*, 1971) have shown that the capacity of tuber development in root stocks was an important determinant of yield, emphasizing the importance of the process of tuberization relative to dry matter production in the development of tuber yield. Studies on contribution of yield components to tuber yield in six cultivars (Wholey and Haynes, 1969; Wilson and Lowe, 1973; Lowe and Wilson, 1974, 1975a) showed that there were significant negative correlations between tuber number and mean tuber weight in five of the six cultivars, and positive correlation between these yield components and yield. Lowe and Wilson (1975a) have suggested that these cultivars may be grouped into 'tuber number - tuber weight' and 'tuber weight' types, as well as a 'random type' in which yield is related to neither component because of the existence of a strong compensatory relation between yield components. In general, sweet potato crops show a high degree of variability in tuber yield, both total and marketable (Haynes and Wholey, 1971). This has been found to be related to either or both yield components; and the sources of variation in yield components, and hence yield, have been attributed to planting material (i.e. number of nodes on terminal cuttings used for planting since tubers are produced on root developed from subterranean nodes), tuber development (i.e., time of onset, and rate and period of bulking), and season (Wilson, 1970; Wilson and Lowe, 1973; Lowe and Wilson, 1974, 1975b).

Considerable variation in CO? compensation point has been found in sweet potato, a C3 plant (Sadik, 1973). However, growth analysis experiments on cultivars with low and high compensation points under field conditions have not revealed any consistent difference in total biological yield and components of the biological and economic yield between the two categories, suggesting that in addition to compensation point, other yield determining physiological factors are involved (IITA, 1973c).

Response to application of fertilizer depends on the cultivar and growing conditions. However, a crop yielding 15 tonne/ha of fresh tubers has been reported to remove about N, 70 kg/ha; P_2O_5, 20 kg/ha; K_2O, 110 kg/ha (Samuels, 1967; Yong, 1970; Kay, 1973). For good growth and yield sweet potato has a high requirement for other nutrients particularly calcium, boron and magnesium. Good drainage is essential for high yields although the crop can be grown in a wide range of soils. A sandy loam of pH 5.6-6.6 with a permeable clay sub-soil is considered best for the crop. As the crop does not tolerate waterlogging, it is commonly grown on ridges or mounds. It is sensitive to saline and alkaline conditions.

CULTIVATION

Sweet potato is grown largely as a rain-fed crop in the Savanna areas although some is grown in the low-lying *fadama* areas on residual moisture. The indigenous practice is to grow the crop on ridges or some time on the flat but in areas which are liable to flood it is grown on mounds. It is mainly grown in mixture in two to six crop combinations involving sorghum, millet, maize, rice, cowpea, groundnut, yam, cassava, potato, vegetables, cotton and tobacco. About 16% of the total area under sweet potato was found to be in sole crop in village studies in the Northern Guinea Savanna while about 85% in 2-3 crop mixtures (Norman, 1972). The crop is generally sown in May and June in the Derived and Southern Guinea Savanna and in June and July in the Northern Guinea and Sudan Savanna. The plant may be propagated either by tubers (whole or part of a tuber), slips or vine cuttings, the last method being the one in common use. In slip propagation tubers are planted in a nursery bed. The new plants which sprout from the various buds of the tubers are known as slips. They are separated and planted as such. Vine cuttings are preferred as they are relatively cheaper, the plants are free from soil-borne diseases and the tubers produced are of a more uniform shape and size. Apical cuttings are generally used as they produce better growth and yield than basal or middle cuttings. Vine cuttings 20-45 cm long with 7 or more nodes are planted half to two-thirds of their length in the soil. In some areas the crop is grown in large flat-topped mounds varying in area from 3 to 5 m^2 with several cuttings planted on mounds. In other parts mounds are small, round-topped, and 30 to 60 cm apart, with one plant on each mound. When planted on ridges or rows, the spacing varies considerably depending on whether grown sole or in mixture (Fig.l). Common spacing in sole crop is about 0.25 x 0.9 m at one plant per stand (about 48,000 plants/ha). In two to three crop mixtures, the common spacing is about 2-3 x 0.9 m (about 3,700-5,500 plants/ha). Roots sprout from the subterranean nodes within 5-14 days depending on the quality of the planting material and moisture conditions. Once the crop is established, it requires minor weeding if the land has been properly prepared initially and is not over infested with weeds, since the creeping stems spread quickly covering the soil. At maturity the stems turn from green to brown while the growing period generally varies between 4 to 6 months depending on the cultivar although often tubers are harvested as required from 3 months after planting, the crop being finally harvested in the dry season in November or December. The crop responds well to manures while results from fertilizer trials are conflicting for reasons explained earlier with yam. Jacob and Uexkull (1963) have discussed the fertilizer application rates for the crop.

For yields of over 20 tonne/ha at adequate fertility common spacings appear to be between 0.25-0.4 m apart in rows or ridges 0.6-1.1 m apart (24,000-72,000 plants/ha) depending on the cultivar, days to maturity, fertility and purpose for which the crop is grown. Mechanical harvesting of the crop is possible but losses can be high. Sweet potato tubers are very perishable and methods used to harvest the crop have a *very* considerable effect upon the market quality and storage life of tubers. Aspects related to harvesting, storage and processing have been discussed by Gooding and Campbell (1964), Keleny (1965), Kushman and Wright (1969), Austin (1970), Austin and Bell (1970), Austin and Graves (1970) and Francois and Law (1971).

DISEASES AND PESTS

In general diseases in the field are of minor importance at present. **Black rot** *(Ceratocystis fimbriala)* **and soft and dry rot** *(Rhizopus* spp..) which affects the growing crop can be controlled by planting healthy tubers and by crop rotation. Leaf spot *(Colletotrichum capsici)* has been reported but little work has been conducted on this disease.

Storage or black rot *(Botryodiplodia theobromae)* can be a serious disease in stored tubers which have been damaged during harvesting. A soft rot *(Rhizopus* spp.) is also known to attack the tubers in storage while the black rot *(Ceratooystis fimbriate)* can also develop in stored tubers. Under indigenous practice of harvesting, storage losses are considered small at present.

The sweet potato weevil *(Cylas puncticollis)* is the major insect pest, the larva feeding on the roots and tubers. The crop is not usually severely attacked before July or August so that early harvest may avoid infestation. It is particularly serious on the late planted or dry season crop. Proper crop rotation helps in its control while sources of resistance have been isolated recently (IITA, 1973c). Chemical control is effective. Leaf feeding caterpillar of hawk moth *(Herse convolvuli)* and tortoise beetle *(Aspidomorpha spp.)* have been reported on the wet season crop but they appear to be sporadic pests. Variegated grasshopper *(Zonocerus variegatus)* and flee beetle *(Haltious tibialis)* have been reported to attack the crop, damaging the leaves.

COCOYAM *(Colocasia esculenta* and *Xanthosoma sagittifolium)*

There is a considerable confusion in the taxonomy of the cultivated edible species of *Colocasia* and *Xanthosoma.* Here the various reported species are grouped into one polymorphic species each as suggested by Purseglove (1975), namely, *C. esculenta* and *X. sagittifolium,* although Dalziel (1955) considers that *X. mafaffa* is the species currently cultivated in West Africa. *C. esculenta* is of Asian origin but has been grown in West Africa for centuries. It is known as the old cocoyam distinguishing it from *X. sagittifolium,* the new cocoyam of tropical American origin, introduced into West Africa in the middle of the 19th century. Cocoyam is the third most important cultivated root crop in West Africa following yam and cassava, although in the Savanna areas the production is less than of sweet potato. Since it was introduced, *X. sagittifolium* has been gradually displacing *C. esculenta* and in Ghana and Cameroon its cultivation is greater. Some of the reasons for increasing preference for the new cocoyam are that it is resistant to *Phytophthora* blight, easier to prepare and cook, more tolerant to lower rainfall conditions, and less of a health hazard. Cocoyams are mainly consumed baked, boiled, pounded or mashed, and as flour in stews and soups. Young leaves and shoots are used as spinach. Accurate production figures are difficult to find but cocoyam is a major root crop in the Forest areas where probably 75-85% of the total crop is grown. Much of the remaining crop is grown in the Derived and Southern Guinea Savanna although some is grown in the *fadama* areas in the Northern Guinea and Sudan Savanna. Separate production figures for new and old cocoyam *are* not readily available but combined annual production from Nigeria, Ghana, Cameroon and Ivory Coast during the period 1966-70 was about 0.31 m tonnes (Kay, 1973). Yields under indigenous practice in the High Forest areas appear to be in the range 3-5 tonne/ha while in the Savanna areas 1.5-2.5 tonne/ha. In general little crop improvement research has been done on cocoyam although experimental yields of 15-30 tonne/ha of fresh tubers have been obtained in the High Forest and Derived Savanna areas. Elsewhere in the tropics, experimental yields of 20-40 tonne/ha in the upland areas and 35-55 tonne/ha in the lowland areas with adequate moisture have been obtained from crops of 9-12 months in duration, and yields up to 75 tonne/ha have been reported for 12-15 months crop at high fertility. The crop is only briefly considered here because it is a very minor crop in the Savanna areas. Readers are referred to Kay (1973) for a fuller account.

ECOLOGY

The old cocoyam is perennial but its life cycle in the field varies from 6 to 18 months according to the cultivar and growing conditions. In the High Forest areas the crop is often in the ground for 12 months or more while in the Savanna areas about 5-9 months. With the new cocoyam the tubers are considered to be mature in 10 to 12 months but the crop will continue to grow for 18 months or more if moisture permits. In the Savanna areas the crop is harvested in 5-9 months after planting depending on the region. Highest yields are obtained when the crop is grown for 12-15 months and generally the earlier the crop is harvested the lower the yield. Also, because of the fact that cocoyams thrive under warm and humid conditions with long and moist growing season, the region best suited for intensive production in Savanna areas is the Derived and Southern Guinea Savanna although its natural potential lies in the High Forest areas. *Colocasia* is adapted to moist environments but will grow well under irrigation in upland areas provided temperature does not limit growth. *Xanthosoma* is also adapted to high rainfall conditions but can be grown satisfactorily in areas with rainfall of 1,000-1,200 mm if it is evenly distributed or under irrigation. In general yield improvement in the Savanna areas will depend on the availability of high yielding, quick maturing cultivars. For good growth mean temperatures in the range 20-30°C is required.

Cocoyams can be grown on a wide variety of soils but deep, well drained, loams with pH of 5.5-6.6 are considered best. Yields are low in very sandy or hard clay soils. The new cocoyam unlike the old cocoyam is very sensitive to waterlogging and saline conditions. Indeed, the old cocoyam has been used elsewhere in the tropics as a first crop in the reclamation of saline, sandy, soils. Little is known about the nutritional requirements of cocoyams. In the tropics, good responses to nitrogen have been obtained but responses to K and P have been variable. Recommended rates for 9-12 month crop is in the range N, 40-110 kg/ha; P2O5, 35-90 kg/ha; K2O, 60-130 kg/ha but higher rates are used for longer duration crops. The old cocoyam has a high calcium requirement and liming has been found to be beneficial.

CULTIVATION

Cocoyam is grown as a rain-fed crop. Small corms, or cormels, or pieces of corms, or the top of the main root stock with part of the original corm with cormels attached are used for propagation. These are planted at 0.6-0.9 x 0.6-0.9 m (12,000-28,000 plants/ha) but spacing varies widely. The crop is grown sole or in mixture with maize, rice and vegetables (Norman, 1972). Planting usually takes place during the rainy season in May to July on ridges or mounds. Sprouting occurs 7-15 days after planting and the crop is harvested at the end of the rains when the leaves turn yellow.

Higher yields of cocoyams in the Derived and Southern Guinea Savanna are possible if soil fertility can be improved. Successful, mechanized, commercial production under irrigation and rain-fed conditions exist elsewhere in the tropics.

DISEASES AND PESTS

In general the new cocoyam is relatively free from severe attacks **by pests. Leaf spot** *(Clasdosporium tenuissimum, Ceraospora xanthosomatis)* **have been reported on** *Xanthosoma.* **Leaf blight** *(Phytophthora aoloaasiae)* **is prevalent on** *Coloaasia* **in the lowland. Wilt** *(Salerotium rolfsii)* has been reported to attack the roots and collar in very moist conditions. Root rot in *Xanthosoma* although not so severe now is still common but the casual agent is not known.

Root-knot nematodes *(Meloidogyne* spp.) can cause damage in upland areas if the soil is heavily infested.

POTATO ***(Solatium tuberosum)***

Potato originated in South America and although in the tropics it is grown in highland areas, and at low altitudes during the cool season, it is not a tropical crop because of its very specific temperature requiremerits. In the West African Savanna it is grown in areas of high altitude but during the dry season when temperature conditions are moderate it is grown in the lowland and *fadama* areas, although some farmers grow it as a rain-fed crop. The potato was introduced at the beginning of the century to the Cameroons and the Jos plateau in northern Nigeria but production remained small until the outbreak of World War II when there arose the need to feed troops stationed in West Africa (Williams, 1962). Although production declined immediately after the War, the crop remained of some importance and there has been a considerable expansion in recent years particularly in the Cameroons, Nigeria, Senegal and Mauritania. Estimated combined production from these countries in 1971 was about 0.1 m tonne from an area of about 13,000 ha, corresponding to a fresh yield of about 7.7 tonne/ha. However, experimental yields of 15-30 tonnes in the highland areas of West Africa have been obtained. The potato is growing in importance in West Africa and a potato growing industry is developing around several metropolitan centres in the Savanna areas. It has been reported that the potential for growing the potato in climates warmer than those in which it thrives are considerable (NAS, 1974). Crop improvement research at the International Potato Centre (CIP) at Peru is attempting to increase the tolerance of the crop to high temperatures, and if successful it is likely that large areas of West Africa will be open to production. Since it is a short-season crop of 3-4 months duration, the potato can compete well with other root and tuber crops that require much longer growing season. However, in the highland areas of West Africa the potential of the potato crop has been well established. Full account of this crop is not given here as detailed accounts are available in Ivins and Milthorpe (1963), Burton (1966), Deanon and Cadiz (1967), Smith (1968), Hawkes and Hjerting (1969), Simmonds (1971), Booth and Proctor (1972), Meijers (1972) and Kay (1973).

ECOLOGY

Eco-physiological basis of yield in potato has been reviewed by Moorby and Milthorpe (1975). High yields of temperate potato cultivars are obtained in areas where the average temperature during the growing season ranges 15°-18°C and these conditions in the Savanna areas of West Africa prevail in the highlands at elevation above 1,300-1,500 m, and are approached in the lowlands during the dry season in the Sudan and Northern Guinea Savanna. In temperate cultivars day temperatures above 21°C have an adverse effect upon yields while cool nights with an average temperature of 10°-14°C are essential. Tuber formation is retarded when the soil temperature rises above 20°C and above 29°C little or no tuberization occurs. Although young potato plants are very susceptible to frost, most cultivars once established will tolerate light frosts. In West Africa potatoes produce tubers satisfactorily in seasons with mean temperatures below 24°C and cultivars suited for the tropics have a much wider temperature tolerance than temperate cultivars. However, day temperatures in the highlands or during the dry season at lower altitudes are still too high while night temperatures not low enough to allow the present tropical cultivars to produce yields approaching those in the temperate areas. Generally, therefore, average yields in the tropics are about half of those obtained in the temperate areas where commercial yields of 20-30 tonne/ha are commonplace.

Potatoes originated in the Andes in tropical areas of high altitude, a region characterized by short daylengths (12-13 hours). Early cultivars bred in temperate conditions require a daylength of 15-16 hours while the late cultivars produce reasonable yields under long- or short-day conditions. For the tropics therefore cultivars which tolerate short-days at high temperatures are required and crop improvement research is directed towards developing cultivars that will widen the climatic adaptation of the crop (Upadhya *et at.*, 1972). Some of the present late maturing temperate cultivars are best suited to elevations above 1,500 m where temperature conditions are adequate for good growth and tuber development. At lower elevations these cultivars are acceptable in the dry season when mean temperatures drop to 24°C or below. One of the reasons why satisfactory tuberization does occur at higher temperatures in the tropics is that the effect of daylength and temperature is modified by radiation intensity. Radiation receipts are higher in the high altitude areas and during the dry season and it appears that higher the radiation intensity, the higher the maximum temperature permitting tuberization. Recently, potato cultivars adapted to a range of tropical conditions have been developed and better adapted cultivars are likely to become available in the future.

Potatoes require a continuing supply of moisture. Dry periods, even of short duration, can drastically reduce tuber yields while seriously affecting the quality of the crop when moisture supply becomes limiting or irregular toward the final stages of bulking. Generally, it is considered that a short duration crop required 500-700 mm or evenly distributed moisture supply either from rainfall or irrigation and a long duration crop about 750-900 mm.

The crop can be grown on all types of soils, except heavy waterlogged clays. A deep, well drained, loam or sandy loam with a pH of 5.5-6 is considered best. pH in the range 4.8-5.5 is tolerated but above 6 m, tubers are liable to suffer from scab.

Potatoes respond well to manures and fertilizers, and good yields can be obtained only with adequate fertility. Fertilizer requirements vary greatly depending on the cultivar and growing conditions but a crop yielding 25 tonne/ha removes N, 115-120 kg/ha; P_20_5, 45 kg/ha; K_20, 200 kg/ha and CaO, 100 kg/ha. In the tropics good yields are generally in **the range 10-18** tonne/ha **and the nutrient** removal **is about** N, 50-80 **kg/ha;** P_2O_5, 20-30 **kg/ha;** K_2O, 80-140 kg/ha.

CULTIVATION

The crop is grown sole or in mixture with sorghum, millet, maize, cowpea, groundnut, sweet potato, vegetables and tobacco. In village studies in the Northern Guinea Savanna about 22% of the crop was found to be grown sole while the remaining in mixture of 2-5 crop combinations (Norman, 1972). Propagation is done using tuber, either whole or cut, although whole tubers are less liable to develop rots in the soil. Tubers have a dormancy period of at least 8-12 weeks after being harvested depending on the cultivar and environmental conditions. Dormancy can be broken artificially but naturally broken dormancy produces a more uniform crop and better growth. Non-dormant planting material weighing about 40-60 g of regular shape is considered best. It is essential that the planting material is free from diseases, pests and damage and certified 'seed' free from virus disease should be used when possible. When cut pieces are planted immediately, it is recommended that they are chemically treated to prevent disease, or else stored for a period of 7-10 days for the cut surface to heal *or* suberize before planting. Potatoes may be planted by hand or mechanically and the crop is usually planted on ridges at a depth of 5-15 cm. As the crop is shallow rooted, a seed-bed cultivated to a depth of about 25-30 cm to produce fine deep tilth is necessary for good yields. Common plant spacing is 0.2-0.3 m in rows 0.75-1.2 m apart but optimum spacing depends on the cultivar, fertility and growing conditions, and spacing between rows of 0.4-0.6 m may be required for a short duration crop at high fertility. For fertilizers to be most effective, these should be placed in bands somewhat below the 'seed' pieces and separated by a 5-8 cm layer of soil. This avoids the hazards of chemical 'burning' and minimizes the inactivation of phosphate by interaction with soil, and ensures that the fertilizer will be promptly available to the young plant as well as the growing crop Potatoes compete weakly with weeds and timely, efficient, weeding by pulling, hoeing *or* tillage is essential. In temperate areas the crop is often repeatedly hoed, up to 5 times during the season, to control weeds while ridges are earthed up to avoid greening of the tubers. Normally the crop is mature for harvest in 3-4 months. Harvesting should be done on a dry day and when the tubers are mature. The crop is lifted by hand but mechanical harvesting is possible. It is recommended that the tubers are harvested when the three-quarters of the crop leaves have turned yellow or brown. The **tubers** should be stored temporarily in a shaded, dry well ventilated place for 7-10 days to allow time for the skin to become well suberized before they are prepared for market or long term storage.

DISEASES AND PESTS

Potato crop is subject to a number of diseases some of which are of great economic importance in West Africa. Brown rot or bacterial wilt *(Pseudomonas solanacearum)* is the most serious disease of potato in West Africa (Robinson, 1967, 1968). Cultivars bred and selected in temperate regions are extremely susceptible as bacterial wilt does not occur there. The disease is carried by seed tubers. There is considerable evidence that the ability of the bacteria to survive the dry season as saprophytes in the soil is very limited and the bacteria survive the dry season in alternative hosts in the weed flora. In recent years sources of resistance to bacterial wilt have been discovered. Other bacterial diseases **include soft rot** *(Erivinia carotovova)* **and ring rot** *(Corynebacterium sepedonicum).* In the early sixties the potato industry in West Africa suffered a severe setback because of severe losses due to late blight *(Phytophthora infestans).* All parts of the plant are affected and infested tubers develop dry or wet rots either before or after harvest. There is no cultivar completely resistant to late blight, although some have a high degree of resistance for several years. In addition, there are other diseases of considerable importance and potential threat to the crop. Early blight or target spot *(Alternaria solani)* can be of considerable economic importance, although it is easier to control than late blight. Scab *(Streptomyces scabies)* often affects potatoes grown in soils of pH above 6, causing raised corky areas, on the tubers. Black scurf or stem canker *(Rhizoctonia solani)* has the potential of causing serious damage, attacking the stems and tubers at or below the soil level. The fungus has a wide host range and can survive as a saprophyte in the soil, which can make its control difficult. *Verticillium* wilt *(Vevticillium albo-atrum)* is another potentially serious disease with a wide host range. Several types of tuber rots are caused by *Fusarium* spp. which also cause wilting of plants.

There are several virus diseases which can cause severe crop losses and virus-free planting stock is essential since there are no effective treatments for these diseases. Some of these viruses are transmitted by aphids and the only effective control method is to grow virus-free 'seeds produced from special aphid-free areas in the highlands in West Africa. Locally grown seed tubers are heavily contaminated with viruses.

Potatoes are attacked by aphids which are widespread and spread **virus diseases. Flee beetles** *(Podagrica sjostedti, P. uniforma)* **and** mole crickets *(Gryllotalpa africana)* have been known to attack the crop and can cause considerable losses when young plants are attacked by a large number of these insects. A number of nematodes are capable of causing serious losses. These include the root-knot nematodes *(Meloidogyne* spp.) the reniform nematode *(Rotylenahulus reniformis)* and root-lesion nematodes *(Protylenahus* spp.). Root eating ants *(Dorylus orientalis)* can be troublesome.

PART IV

VEGETABLES

TOMATO *(Lycopersicon esculentum)*

Tomato plant is of South American origin (Rick, 1956) and it appears that little was cultivated in Africa until the end of the 19th century. At present it is one of the most important vegetable crops in West Africa. Its use raw as a salad is rare in the traditional patterns of consumption and much of the tomato produced locally is eaten cooked in local dishes. Further, it has never been available in large quantities and because of its low keeping quality, it is used more as a condiment. To cater for extensive dispersion and reduce the seasonality of supply, it has been ground, usually together with other similar components such as onions and peppers (Quinn and McLean, 1974). Recently, the consumption of canned tomato paste has increased considerably to meet the growing demand. In rural areas, it is readily accepted and used when supplies of fresh and dried fruits are unavailable. However, much of the tomato used in the paste industry is imported. For example Senegal, Ivory Coast, Ghana and Nigeria together import nearly 20,000 tonnes of concentrated paste (28-30%) annually while the figure for West Africa as a whole probably may be over 30,000 tonnes. Estimated production of fresh tomato in West Africa in 1971 was about 332,000 tonnes from an area of about 44,000 ha, corresponding to a yield of about 7,500 kg/ha. Yield figures vary greatly between countries from about 670 kg/ha in Togo to about 10 tonne/ha in Ivory Coast and Nigeria. The market and scope for processing of local tomatoes in the West African Savanna is very large and recently commercial production for making canned tomato paste is being encouraged. Crop improvement research has shown that improved cultivars can produce fresh marketable yields of 50-80 tonne/ha (Quinn, 1974) while experimental yields of over 90 tonne/ha have been recorded in the Northern Guinea Savanna (J.G. Quinn, unpublished). Indeed, in commercial plantings yields of 40-50 tonne/ha have been obtained (Quinn, 1973a).

ECOLOGY

Tomato is grown throughout the Savanna areas in both the upland areas and *fadama* areas where it often receives supplementary irrigation. In general experimental yields of rain-fed and irrigated dry season crops are greater in the Northern Guinea and Sudan Savanna than in the Southern Guinea and Derived Savanna. Detailed research into field problems resulting from variations in climatic conditions and pest environment in the Savanna areas have confirmed that if a tomato industry was to be established, it would have to be in the drier areas of the West African Savanna (Quinn, 1971). The lower yields of rain-fed crops in the Southern Guinea and Derived Savanna can be largely attributed to the greater incidence of foliage and stem diseases and to some extent to the relatively lower solar radiation and higher night temperatures (Kassam and Kowal, 1973) leading to excessive vegetative growth at the expense of fruiting. Observations have shown that the build-up of root-knot nematodes, bacterial wilt and virus diseases is more severe where the dry season is short. Indeed, where there is a long desiccating dry season, these problems are greatly reduced in subsequent wet season cropping on the upland areas.

Tomato is a day-neutral plant. However, planting date investigations at Samaru (Quinn, 1971; Quinn, 1974; Quinn and McLean, 1974) have revealed a strong effect of temperature on yield. Tomatoes transplanted at 3-4 week intervals year round have produced average yields of about 35 tonne/ha from crops established during the June to December period, while yields from crops established during the January to May period averaged about 8 tonne/ha. This difference is largely attributed to temperature extremes. Night temperatures often decrease below 15°C during December and January and, from late February to May day temperatures frequently exceed 33°C, while night temperature above 21°C are common. Such extremes cause an imbalance in the relationship between vegetative and reproductive growth processes while high day and night temperatures accompanied by relatively greater energy load leads to decrease in photosynthesis, increase in plant water deficit and early leaf senescence (Went, 1944, 1949; Calvert, 1965; Evans, 1969). Evaporation demands in March and April at Samaru often exceed 7-8 mm/day, with much greater day-time values which leads to plant water deficits high enough to cause plants to wilt under irrigated conditions.

During the wet season high relative humidity conditions favour heavy attacks of leaf and stem diseases, although in the Northern Guinea and Sudan Savanna where rainfall is lower these diseases are easier to control with chemical means. Marketable yields can be doubled or trebled as compared with an unsprayed crop (Quinn, 1971). However, rains frequently occur in torrential storms of short duration accompanied by violent winds. Unprotected crop under such conditions suffer considerably and plants are beaten to the ground, often breaking lateral branches heavy with fruits. Further, the resulting contact with the soil causes rotting to both fruit and foliage, while soil splash extends rotting further up the plant. Experiments at Samaru (Quinn, 1973b) using either stakes or a heavy mulch of grass or groundnut shells, have shown average increases of over 90% in marketable yields. Successful wet season production may therefore need disease control by spraying and mulching while crops planted late in the wet season may need supplementary irrigation to finish them to maturity. However, the dry season crop needs full irrigation and insect control against fruit worm but no disease control, mulching or support (Quinn and McLean, 1974).

Tomatoes can be grown on a variety of soils but a well drained, light loam with a pH of 5-7 is preferred.

CULTIVATION

Most of the tomato under indigenous practice is grown in mixture of 2-6 combinations involving other vegetables, sweet potato, maize, cowpea and sorghum. In the village studies in the Northern Guinea Savanna about 18% of the crop was found to be grown sole while about 80% was in 2-4 crop mixture (Norman, 1972).

For efficient production, Quinn (1973a) recommends that seeds should be sown in nurseries and later transplanted. The recommended practice is for seeds to be sown in rows approximately 10 cm apart and 0.5 cm deep in well prepared nursery beds. These beds are about 2 m wide to facilitate hand-sowing, weeding and thinning (Schneider and Quinn, 1972). A seed bed area of about 80 sq m is required to supply one hectare of transplants. For the first planting during the wet season, seed-bed nurseries should be on raised bed about 15-25 cm high. Later seed-beds established in the dry season should be arranged so that the margins are surrounded by an irrigation channel. Seedlings should be planted on the water line along each side of the 90 cm ridge to give a population of about 41,000 plants/ha. Phosphate, about 25 kg/ha P_2O_5 should be applied during cultivation before transplanting while three and six weeks after transplanting an equally split side dressing, of 65 kg/ha of N has been found to produce optimum yields. For high yields during the wet season the crop must be sprayed to control diseases and it is necessary to stake or mulch the crop. Disease control is not necessary during the dry season but one or two applications of insecticides are required to control fruit worm. Time to maturity varies between 10 and 14 weeks after transplanting depending on the cultivar.

DISEASES AND PESTS

Bacterial wilt *(Pseudomonas solanacearum)* is one of the most serious diseases of tomatoes, particularly in the Southern Guinea and Derived Savanna and when strict rotation is not followed. Genetic resistance so far has not been promising. Early blight *(Alternaria solani),* leaf spot *(Septoria lycopersici)* **and leaf mould** *(Cladosporium fulvum)* **are the most** serious diseases of the wet season crop. Fungicide spraying is effective. During the dry season only early blight is the major disease but is not of economic importance at present. Tomatoes can be seriously attacked by various virus diseases particularly in the southern areas.

A number of insects attack tomatoes but at present they are of minor importance and can be controlled effectively by spraying. These include the fruit worm *(Heliothis armigera)*, mites *(Hemitarsonemus latus)*, **the flower midge** *(Contarina lycopersici)* **and the leaf miner** *(Liriomyza stricata)*. Root-knot nematodes *(Meloidogyne* spp.) are very common particularly when strict rotation is not practised.

ONION *(Allium cepa)*

Onion is believed to have originated in the near East in an area which includes Iran, Afghanistan and West Pakistan. It has been grown in the West African Savanna for a *very* long time for both food and cash. Its use as a salad is rare and much of it is consumed cooked in local dishes and fried bean cakes. Although it is commonly eaten, it has never been available in large quantities. Availability is at its lowest in July-August and highest in March-April. However, onions are traditionally a *very* important vegetable in the Savanna areas and would probably constitute an ingredient of one meal per day if supplies were available (Green, 1971). Although no figures are available, average yields quoted are about 40-50 tonne/ha or more under improved husbandry (Green, 1972a, 1972c, 1973).

ECOLOGY

Observations suggest that most of the onion production in the West African Savanna is located in the Northern Guinea and Sudan Savanna. The main commercial crop is grown during the dry season because of disease problems associated with conditions of high relative humidity during the wet season. Thus, the main sites of onion production are the *fadama* areas where the irrigation is possible.

The common onion under normal conditions forms a food storage organ in the first season of growth and flowers in the second season. The production of bulbs is controlled by photoperiod. The critical daylength varies from 11-16 hours, depending on the cultivar. Long-day cultivars developed in temperate countries will not form bulbs in the shorter days of the tropics, for which short-day cultivars are required. Bulbing is influenced by temperature and plant size before the bulbing stage is reached. Bulbing takes place more quickly at warm than at cool temperatures provided the photoperiodic requirements have been met. Good vegetative growth is necessary before bulbing is initiated to produce good yields, although excessive vegetative growth particularly due to excess nitrogen can slow down the bulbing process.

The conditions required to initiate flowering are low temperatures (below 14°C) and a certain minimum size of bulb since small bulbs show almost no tendency to flower when exposed to low temperatures (Jones and Mann, 1963). If plants have attained a certain size and are subject to low temperatures, they may flower in the first season. This is commonly referred to as bolting which is not influenced by photoperiod. Environmental conditions which will induce bolting occur in the Northern Guinea and Sudan Savanna during the dry season (October-April) when the main commercial bulb crop is grown. Surveys conducted in northern Nigeria have shown that bolting is a serious problem and the percentage of bolters is generally high (Green, 1970). Part of the season for this is probably due to the undesirable practice of saving seed from the previous years bolters. Cultivars vary in their susceptibility to bolt and a high percentage of bolters can be expected from imported cultivars not adapted to local conditions. However, assessment of indigenous strains of onion at Samaru and observations in other areas have shown that the numbers of bolters generally exceed 50 per cent. According to Green (1970) it appears that many farmers are not aware of the detrimental effect bolting has on yield and quality of the ware crop. The farmers seem to feel that if they can harvest seed and bulbs from the same crop, then it may be more profitable than growing separate crops.

Seed for both wet and dry season plantings is produced by farmers in the previous dry season. The traditional method is to select a mother bulb of good quality that was grown in the previous wet season or dry season. A transverse cut is made 1/3-1/2 way from the neck of the bulb and the lower portion of the bulb is then planted in a nursery bed. Axillary buds, formed during the growth of the mother bulb, sprout and they are separated from the cluster when 10-15 cm in height and transplanted as individuals to produce seed during the dry season. Some 15-20 plants are obtained from one bulb of 8-10 cm diameter. This method is used by many farmers and produces seed which will produce a good quality bulb crop with a low percentage of bolters (Green, 1970). However, Green (1972a) studying the influence of bulb cutting and separation of axillary shoot on seed production found no evidence to suggest that the local method of onion seed production was superior in any way to the method commonly employed elsewhere in the world using uncut bulb. In Niger, where bulb cutting is practised, Nabos (1971) reported that cutting and shoot separation was decidedly disadvantageous, the seed yield per unit area being depressed by 35-62%. The reduced seed yields are due to loss of food reserve for growth when mother bulb tissue is removed, because larger bulbs produce more inflorescence, more seed per inflorescence and a greater weight of seed per original mother bulb (Jones and Emsweller, 1939; Woodbury and Dictz, 1942; Green, 1972a).

Planting date has a strong effect on yield and crop maturity. Highest yields are obtained from crops transplanted during October-November. Yields decrease sharply and maturity is delayed in later planted crops which produce green bunching onions from August onwards.

A large proportion of the main crop bulbs harvested during March-April is stored to fetch a higher price during the wet season. During storage there is frequently a loss of over 50 per cent of bulb within 12 weeks, and this is thoughtto be partly due to storing bulbs which have bolted (Green, 1970). The necks of such bulbs do not cure properly because of the wide hole left by the emerging scape, allowing ease of access to pathogens. Storage of bolted bulbs is not recommended (Jones and Mann, 1963). Storage losses depend on a number of factors including the cultivar, storage conditions, bulb quality at harvest and how properly the bulbs were cured. In northern Nigeria, Green (1972b) has made suggestions to achieve improved storage.

Onions can be grown under a wide range of climatic conditions but they are not suited to regions with heavy rainfall. Cool conditions, with an adequate moisture supply, *are* most suitable for early growth, followed by warm, drier conditions for maturation, harvesting and curing. These conditions prevail between October and April in the Northern Guinea and Sudan Savanna in the *fadama* areas. Onions grow best in well drained soils, a good fertile loam of pH 6-7 being the best.

CULTIVATION

Of the three main types, white, red and purple skinned, the red is most common and has a longer storage life. The wet season onion crop under indigenous practice is largely intercropped in 3-6 crop combinations involving cowpea, potato, sweet potato, peppers, okra, tomato, millet, sorghum and groundnut (Norman, 1972). In the village studies in the Northern Guinea Savanna about 13% of the crop was found to be grown sole while about 73% in 2-4 crop mixtures (Norman, 1972). The wet season crop is planted in June and harvested in August about 90 days. The dry season crop is grown sole or in mixtures with other vegetables. The normal spacing under improved practice is about 0.07-0.1 x 0.3-0.4 m when planted either from seed, dry sets or transplants. For yields of 25-35 tonne/ha, 70-100 kg/ha N and 30-50 kg/ha P_2O_5 are applied to the crop. Nitrogen in split application, 2/3 applied after transplanting and 1/3 when bulbing commences, reduces excessive leaf growth. The crop matures 90-150 days after planting, depending on the cultivar. After harvesting the bulbs are cured which takes 5-10 days, and well cured bulbs are hard with firm necks. For longer storage life, dry conditions with good air circulation are necessary.

DISEASES AND PESTS

A wide variety of diseases attack the crop, particularly in the wet season. These include purple blotch *(Alternaria porri),* powdery mildew *(Peronospora destructor),* pink rot *(Pyrenochaeta terrestrial* and white rot *(Sclerotium cepivorum).* Yellow dwarf virus disease is also common.

The most serious pests of onion are thrips *(Thrips tabaci, Podothripa* spp.) which can cause serious losses of the dry season crop. A heavily infested crop can lose 50 per cent of its yield. In general, thrips do not thrive in conditions of heavy rain, and the damage caused by them in the wet season is small. Work at Samaru (Raheja, 1973b) has shown that thrips in the dry season crop appear soon after transplanting. The population gradually builds up and reaches a peak about 50 days after transplanting when thrips per plant can be about 40.

PEPPER *(Capsicum* spp.)

Pepper is of South and Central American origin. It is widely grown in the West African Savanna. The two species of pepper grown are *C. annum* and *C. frutescens,* the former is also grown for export, as in northern Nigeria, the latter for local consumption. *c. annum* are the chilli and sweet peppers, but most of cultivars grown are the chilli type which are very pungent. *C. frutescens* are the birdseye peppers which are very hot. Accurate production figures do not exist but average yields under local practice are probably around 400 kg/ha of fresh fruits because most of the crop is grown in mixture. Yields of sole crop or in two crop mixture may be about 700-900 kg/ha. Improved cultivars under good management can produce yields of 2-3 tonne/ha of fresh fruit.

ECOLOGY

Pepper grow well in most areas and under a variety of soils. They are usually grown as a rain-fed crop but heavy rainfall and wet conditions is detrimental, as it leads to poor seed set and rotting of the fruit. Peppers are very sensitive to waterlogging and perform best in light loamy soils which are well drained. It is best to sow the crop appropriately late in the wet season so that the fruits mature as the weather becomes dry, but not so dry or hot that they shrivel before they *are* ripe. Days to first picking vary between cultivars but generally flowering begins 1-2 months after planting and it takes another month to the first picking of green fruits. Then on ripe fruits are picked at intervals of 1-2 weeks and harvesting continues over a period of 3 to 5 months depending on the region. Heavy rain during flowering results in flower shedding and poor fruit set. Flowers remain open for about 2-3 days while the percentage of fruit set is 40-50. *C. annum* usually grows more quickly than C. *fructescens* and is more suitable for areas in the Northern Guinea and Sudan Savanna. *C. fruatesaens* is usually grown in the Derived and Southern Guinea Savanna where some cultivars survive the dry season and bear fruits in the following season.

CULTIVATION

Under indigenous practice the wet season crop is grown mainly in mixture of 2-6 crop combinations involving other vegetables, cowpea, groundnut, millet, sorghum, maize, kenaf and root crops. In the village studies in the Northern Guinea Savanna about 19% of the crop was found to be grown sole while about 62% in 2-3 crop mixtures and the rest in 4-6 crop mixtures (Norman, 1972). The crop is planted during May to July and finally harvested in November or December, 130-180 days after planting. Seedlings are transplanted at 4-5 weeks when they are about 10-15 cm high. The crop is grown on ridges or on the flat at a variety of spacings (Fig.l) at 1 plant/stand. The stand population varies from about 38,000 plants/ha when grown sole to about 29,000 plants/ha when grown in 2-3 crop mixtures. Fruits are picked over several months after the first picking, 2-3 months after planting. Harvested fruits, if not consumed fresh, are spread out thinly and dried in the sun for 1-2 weeks. Crop grown for export is not stored for too long as it loses colour. The main harvest is during October to December, and fruits are picked with their stalks to reduce fruit rotting. Dried fruits store well for long periods.

For high yields, improved cultivars require good fertility at spacings of about 0.65 m on the square or on rows 0.75-0.9 m apart and

0.45-0.75 m between plants.

DISEASES AND PESTS

Leaf curl and mosaic, both virus diseases, cause serious damage to the crop. It is probable that they are transmitted by the thrip *(Scirtothrips dorsalis).* **Powdery mildew** *(Leveillula taurica)* **and bacterial wilt** *(Pseudomonas solanacearum)* **are known to attack the crop while** the damping off disease can be serious in the southern areas. Other serious diseases are fruit-rot *(Colletotrichum capsici)* and anthracnose.

Eelworm can reduce yields if there is a heavy infestation. Strict rotation helps in its control. Stored peppers are liable to infestation by the grain moth *(Cadra eautella)* and the grain beetle *(Oryzaephilus mercator).* Chemical control is effective.

OKRA *(Hibiscus esculentus)*

Okra is of African origin and is grown as a vegetable on almost all West African farms. The fruits are consumed dry, ground with other vegetables, or fresh, in soups and stews. Young shoots and leaves are used as spinach while leaves and stems as fodder for sheep and goats. Stem fibre can be used for domestic purpose. Production figures are not available but average yields under local practice are probably around 200 kg/ha of fresh pods because most of the crop is grown in mixture. Yields of sole crop or in two crop mixture may be about 1 tonne/ha. Improved cultivars under good management can produce yields of 4.5-5.5 tonne/ha of fresh pods.

ECOLOGY

Okra is tolerant to wide range of soil and rainfall conditions and grows well during both wet and dry seasons. Some cultivars are sensitive to excessive soil moisture. Days to maturity varies considerably depending on the cultivar and whether young or mature pods are required. The first batch of pods are ready for picking in 2-3 months after sowing while the plant continues to bear fruit for several months afterwards until the dry season, when they become fibrous and set seed.

CULTIVATION

Under indigenous practice the wet season crop is grown mainly in mixture of 2-6 crop combinations involving other vegetables, cowpea, groundnut, maize, millet, sorghum, kenaf and root crops. In the village studies in the Northern Guinea Savanna about 3% of the crop was found to be grown sole while about 78% in 2-4 crop combinations (Norman, 1972). The crop is sown during April to June depending on the onset of rains and finally harvested in October or November, 130-180 days after sowing. The crop is grown on ridges or in the furrow or on the flat at a variety of spacings (Fig.l). The stand population varies from about 11,000 per ha and 7,600 per ha in 2 and 3 crop mixtures respectively to about 6,275 per ha in 5 crop mixtures. Pods are picked over several months after the first picking, 2-3 months after sowing. Harvested pods, if not consumed fresh, are dried and stored. For production of seeds for the next planting, selected pods are allowed to ripen and these are dried and seeds extracted from them.

Improved cultivars grown for high yields are sown at a spacing of 0.30 x 0.3 - 0.9 m under good fertility.

DISEASES AND PESTS

Leaf curl and mosaic, both virus diseases, often attacks okra. Strict rotation, use of disease free seed and proper sanitation helps in controlling these diseases. Powdery mildew and black leaf mould have been reported to cause damage to okra. There appears to be no known control for either.

Leaf eating beetles and sucking insects including the cotton stainer are often found on the leaves and can cause serious damage. Eelworm or root-knot nematodes may cause a serious reduction in yields where the crop is grown continuously without rotation.

PART V

FIBRES

COTTON *(Gossypium hirsutum)*

The origin of cotton is still uncertain (Purseglove, 1974). However, several species of short staple, diploid, cotton were grown in the West African Savanna for many centuries. These were almost completely displaced in the 16th century by the medium staple, tetraploid, American cotton of the species *G. hirsutum.* Cotton is second only to groundnuts in importance as a cash crop. Until recently it was a major export crop but large textile industries developed within the countries in the West African Savanna are increasingly absorbing a considerable proportion of the current production. Virtually all surplus seed is exported, but crushing mills now being established locally will produce edible oil, and seed cake for the livestock industry and export. Cotton reaches its major concentration in the Northern Guinea and Sudan Savanna and only a small amount is produced in the areas further south. Estimated total production of seed cotton in the West African Savanna in 1971 was about 0.54 m tonnes from an area of about 1.06 m ha, corresponding to a yield of about 510 kg/ha (180 kg/ha of lint at ginning percentage of 35). Experimental yields of 1.5-2 tonne/ha seed cotton are generally obtained under proper management while yields of 2.5-3.0 tonne/ha of seed cotton have been obtained in the Northern Guinea Savanna on long term maximum yield plots. A full account on cotton as a world crop is given by Prentice (1972).

ECOLOGY

The eco-physiological basis of yield in cotton has been reviewed by McArthur *et al.* (1975). The crop is grown under a wide range of climatic conditions and on various soil types. In the West African Savanna the crop is entirely rain-fed, except for a small amount in the extreme north of the Sudan Savanna where cotton is grown in riverain alluvial soils. Most of the cotton crop is produced in the Northern Guinea and Sudan Savanna with rainfall of 700-1,100 mm and the rainy season of 120-180 days. Only a small amount (about 5%) of cotton is grown in the Derived and Southern Guinea Savanna where rainfall is 1,100-1,500 mm and the rainy season is 190-250 days. The rainfall distribution is bimodal so the choice of an optimum sowing date is more difficult than in the unimodal rainfall regime further north. Insect pest attack, boll rotting and the risk of rain damage at harvest are far greater in the Derived and Southern Guinea Savanna than in the northern areas. Although good yields have been obtained in the southern areas by the use of fertilizers and efficient pest control, the cost of production is higher and quality of the crop lower than elsewhere. Another minor area of production is situated in the extreme north of the Sudan Savanna where cotton is grown on riverain alluvial soils. Here the annual rainfall is only 500-600 mm in a rainy season of 90-100 days, but some supplementary irrigation is provided and the cotton produced is of good quality.

Under indigenous practice the farmer gives priority to the production of food crops and the sowing of cotton is delayed until labour can be spared. For example, in the Northern Guinea Savanna the rainy season begins in May but most of the cotton crop is not sown until late July or early August (Norman, 197Z; Norman *et al.*, 1974). Flowering does not start until the end of the rains in late September or early October, and continues in the dry season. Very little fertilizer or insecticide is used on the crop at present. It has been generally recognized that the late sowing is the main factor limiting the yields of the farmers' crop and that the application of fertilizers or pesticides under these conditions is not worthwhile. High yields are only possible when sowing is early together with the use of fertilizers and insecticides (Lawes, 1968; Lyon, 1970; Palmer and Goldsworthy, 1972). Further, it appears that use of nitrogen on the crop without adequate pest protection may lead to greater losses and uneconomic returns (Hayward, 1972). Indeed, Palmer and Heathcote (1970) reviewing cotton agronomy work in northern Nigeria pointed out that results from trials conducted in many areas suggest that farmers should not be encouraged to fertilize unsprayed cotton.

As cotton has an undeterminate habit of growth the length of its growth cycle in the West African Savanna is controlled primarily by the availability of water. The amount of water available at the end of the rainy season has been shown to have a considerable effect on late sown cotton. Thus King (1957), examining the production statistics in the main cotton growing areas in Nigeria, found a positive correlation between the amount of October rainfall and yield. However, King (1957) found a poor relation between the yield of early sown cotton and the date when the rains ended, while King and Lawes (1959, 1960) found that supplementary irrigation after the end of the rains increased the yield of late sown cotton but not of early sown cotton.

Studies on flower production, crop phenology and crop water relations (Kowal, 1971; Kowal and Faulkner, 1975; Smithson and Hayward, 1976) have shown that the period between the time to first flower and when evapotranspiration exceeds rainfall controls the number of bolls which are eventually retained and harvested. The length of the period is strongly dependent on sowing date and the later the sowing the shorter it becomes. For example, when the crop in the Northern Guinea Savanna is sown early, in June, the days to first flower (Phase I) is about 60 days after sowing, the duration of the flowering period before the onset of the rainfall deficit period (Phase II) about 40-50 days, and the maturation period (Phase III) about 55-60 days. When the crop is sown late Phase II is reduced. This results in a reduction in flowers and bolls produced and retained, and a" reduction in plant size and root system which further leads to less efficient use of water stored in the soil after the rains and shortening of Phase III (Kowal and Faulkner, 1975). An extension of Phase II therefore improves yield, provided that plant nutrition and pest control are adequate, by lengthening the flowering period before the onset of water stress and by improving the use of water in Phase III. Work elsewhere has drawn similar conclusions and in Uganda, Farbrother and Munro (1970) showed that the yield was strongly correlated with the length of time from sowing to the end of Phase II. Other indirect evidence to support this hypothesis is provided by work in Nigeria where increase in yields resulting from earlier sowing, or from supplementary irrigation at the end of the rains can be interpreted as due to an extension of Phase II. Similarly, the greater productivity of the farmers' late sown crops in years when the rains continue beyond the end of September can also be attributed to a delay in the onset of water stress and a lengthening of Phase II.

It is clear that in absence of irrigation the principal method of extending growth Phase II must be early sowing. Sowing at the beginning of the rainy season would give the longest possible duration of Phase II, but there are practical considerations limiting the extent to which the sowing date can be advanced. In order to avoid reducing the quality of the crop, it is desirable that boll opening should not begin until near the end of the rainy season. For the improved cotton cultivars currently in use in the West African Savanna, the period from sowing to the start of flowering is about 60 days and the boll maturation period is about 55-60 days. It therefore follows that the optimum length of Phase II, consistant with maintaining lint quality, would be achieved by sowing crops about 120 days before the start of the rainfall deficit period. By applying these arguments to the different regions where cotton is grown, some tentative conclusions may be drawn. In the Derived and Southern Guinea Savanna where the rainy season is about 200 days, optimum sowing date would be in early July and trials have indicated that further delay leads to a reduction in yield (Faulkner and Smithson, 1972). In the Northern Guinea Savanna where the rainy season is about 150-180 days, optimum sowing date would be early to mid-June. In all these regions there is a lengthy period of rainfall before the optimum sowing date, which gives adequate time for land preparation and, in some cases, the possibility of growing a preceding crop. In the Sudan Savanna, however, the rainy season is no longer than the optimum growing period (Phase I + II), 120 days. Here, the cotton crop requires the whole rainy season for maximum production, and should be sown as soon as possible after the beginning of the rains in May. In the extreme north the rainy season of less than 100 days is inadequate for good cotton production, which justifies the local practice of sowing the crop in the river valleys at the beginning of the rains and extending the growing period by supplementary irrigation at the end of the season.

Thus, earlier sowing of cotton becomes increasingly important from south to north. In the Northern Guinea Savanna in Nigeria, the main area of production, the sowing date currently recommended is mid-June. However, the rainy season of 150-180 days suggests that a sowing date earlier (i.e., beginning of June) than now recommended (i.e., mid-June) would lengthen the growth Phase II and allow the crop to develop its full potential (Brown, 1971). However, Kowal and Faulkner (1975) have pointed out that many of the difficulties that now prevent farmers from adopting the present recommendation would apply even more strongly to very early sowing when the cotton crop would compete directly with food crops. Furthermore, the period in which the crop is exposed to pest attack would be lengthened, and the additional protection required would increase the cost of production.

Another approach to the problem of lengthening Phase II of growth would be to produce earlier varieties, which start flowering earlier. Such cultivars would be most valuable in the more northerly areas of production, but might have little or no advantage in southern areas, although it could be argued that longer term cultivars would make better use of the extended rainy season. Recent work in Nigeria on okra-leaf cotton (Smithson and Hayward, 1976) indicate that further improvement in yield may be possible. Okra-leaf cotton, an unadapted recent introduction, flowers and matures earlier than normal-leaf cotton. Further, because its smaller size, more synchronized vegetative and reproductive growth, higher harvest index, better ability to accept closer spacing and canopy structure, better suited to efficient pest control with chemical spray, okra-leaf cotton may prove more advantageous than normal-leaf cotton in the future as farmers become more serious of the need for improved practice. The optimum population of normal-leaf cotton is about 100,000 plants/ha while of okra-leaf cotton about 200,000 to 300,000 plants/ha.

Cotton can be grown on a variety of soils from light sandy to heavy alluvium. However, good drainage and aeration are important, and as the crop matures on residual moisture, loam soils are preferred as they allow a greater proportion of the available water to be used by the crop. For well drained soils in the Savanna area estimated available water between field capacity and -15 bar soil water potential in the 120 cm soil profile is about 140-200 mm, and deficits of 160-180 mm at harvest have been reported (Kowal, 1971; Kowal and Faulkner, 1975). At Samaru, in the Northern Guinea Savanna, an early sown crop was shown to remove 87% of the available water while a late sown crop 74% (Kowal and Faulkner, 1975). The amounts withdrawn from the upper half of the profile by the two crops were similar,the main difference occurring below 75 cm indicating that cotton was efficient in using available soil moisture, but the late sown crop was less efficient than early sown crop in using water from the lower parts of the soil profile. The crop water use of cotton sown at the end of June at Samaru has been reported to be about 480 mm (Kowal and Faulkner, 1975) while mineral removed by a crop producing 1 tonne/ha seed cotton in Senegal has been reported to be N, 48 kg/ha; P_20_5, 17 kg/ha; K_20, 32 kg/ha; CaO, 12 kg/ha (IRAT, 1972).

CULTIVATION

Small farmers under indigenous practice sow most of the crop in mixture of 2-5 crop combinations involving groundnut, cowpea, sweet potato, millet and sorghum. However, the most common mixtures involve cowpea, groundnut and sweet potato. In village studies in the Northern Guinea Savanna about 20% of the total area under cotton was found to be grown sole while about 45% was in 2-4 crop mixtures (Norman, 1972). Generally, except for cotton grown in settlement schemes where support facilities for spraying and extension exist, unsprayed cotton is grown in mixtures (Norman *et al.*, 1974). Spacing under local practice varies greatly particularly in mixtures (Fig.1). The crop is largely sown on ridges. Under sole cropping the spacing is about 0.5 x 1 m while the stand population is about 20,500 per ha. In mixtures ridges are about 1 m apart while the stand population varies from about 19,000 per ha in two crop mixtures to 24,000 per ha in five crop mixtures (Norman, 1972). The crop is sown in July or August and harvested in December. Much of the crop is cultivated by hand but few farmers do use ox-drawn implements on schemes which are government assisted where farmers are encouraged to spray the crop and follow recommended practice. Harvesting is done by hand.

Sole cropping with improved cultivars requires early sowing at adequate population and crop nutrition and efficient spraying regime to control pests for the high yield potential to be realized. For intermediate levels of fertility and pest control spacing is generally about 0.4 x 0.9 m at two plants/stand (55,500 plants/ha) while at high fertility and efficient pest control, optimum plant population is about 100,000 plants/ha either on square planting at about 0.32 x 0.32 m at one plant/stand or on rectangular planting at about 0.03 x 0.6 m at two plants/stand.

For yields over 1.5 tonne/ha, experimental rates of 40-80 kg/ha N and 30-50 kg/ha P_20_5 are applied to the crop. Recently widespread boron deficiency has been reported in farmers' fields while large responses to applications of boron have been reported (Smithson, 1972; Heathcote and Smithson, 1974; Smithson and Heathcote, 1974).

age of dry ribbon is about 61-67% (Abdullahi, 1970). Mechanical decortication with retting is effective while recently, decortication of dry stems without retting has given good results at Samaru in Nigeria.

DISEASES AND PESTS

The most common diseases are dry rot *(Macrophomina phaseolina)*, **anthracnose** *(Collelotrichum hibisci)*, **leaf burn** *(Corticum solani)* **and stem and root rot or wilt** *(Phytopthora nicotianae).*

The most common insect pests are flea beetles *(Podagrica* spp.*)* which attack the leaves particularly of late sown crops, stem girdler *(Alcidodec brevirosties)* **and cotton Stainers** *(Dysdereus* spp.).

ROSELLE *(Hibiscus sabdariffa)*

Roselle is probably indigenous to West Africa. It is grown in much of the West African Savanna on a very small scale to provide fibre while the succulent calyces and young leaves and stems are used as pot-herbs. No reliable statistics exist for the crop. However, limited research in Nigeria has suggested that considerable potential exists for roselle in the Savanna areas. A brief account of the crop is given by Kirby (1963).

In preliminary trials in the Guinea Savanna yields of about 2 tonne/ha of dry fibre have been obtained with the crop growing on 90 cm ridges, although potential yields at closer spacings on the flat appear to be considerably greater, about 3 tonne/ha.

ECOLOGY

The climate in the Guinea Savanna is suitable for intensive production of roselle. It is a short-day plant and early sowing therefore produces greater and longer stem growth before flowering begins. Fibre stands of 3-5 m require about 5-7 month growth period. It prefers well drained, neutral, sandy loams and does not tolerate waterlogging.

CULTIVATION

Under indigenous practice much of the crop is grown in mixture with vegetables. The crop is grown at a very low plant population for fruit production and is harvested 3-5 months after sowing.

For fibre and seed production under improved practice, the husbandry and retting is similar to that in kenaf. However, dry fibre as percentage of dry ribbon is generally lower than in kenaf, about 49-63.

DISEASES AND PESTS

Pests which attack kenaf have been reported to also attack roselle but little research work has been conducted to date.

PART VI

OTHER CROPS

SESAME (*Sesamum indicum*)

Sesame or benniseed is believed to have originated in Africa, probably Ethiopia. It is a well established crop in parts of the African Savanna, grown for its edible seed which are a rich source of sesame oil. A large proportion of the crop is exported for industrial and domestic use elsewhere while locally ground or cooked seeds are eaten in soups and sweetmeat. Young leaves are used as pot-herb and stems are burnt as fuel. There *are* a number of other uses for sesame products (Weiss,1971; van Rheenen, 1973; Purseglove, 1974). Estimated total production of sesame in 1971 in West Africa was about 88,000 tonnes from an area of about 0.3 m ha, corresponding to a yield of about 290 kg/ha. About 70% of the total production is in Nigeria where most of the crop is grown in the Southern Guinea Savanna. Although the crop is grown largely for export, there are no large scale commercial growers. The yield reflects the low standard of crop husbandry because under proper management in parts of America yields of about 2 tonne/ha are obtained under commercial production of rain-fed crops; and yields in the range of 0.7-1.2 tonne/ha have been reported for other areas in Africa (Litzenberger, 1974). In general, little crop improvement research has been done on sesame and high yielding cultivars adapted to the conditions in the West African Savanna have yet to be bred and introduced. However, work conducted by van Rheenen (1973) in Nigeria has shown that yields of up to 0.8 tonne/ha are possible with local improved cultivars under improved practice. Further improvements in the yield potential will depend largely on breeding plant types whose structure and developmental physiology is adapted to local environmental conditions but responsive to high fertility at high plant densities.

ECOLOGY

Sesame is adapted to growing in hot and dry conditions but in West Africa it is grown in areas where rainfall ranges from 500 mm, in the Sudan Savanna, to 1,100-1,500 mm in the Southern Guinea and Derived Savanna. Once established, it has a marked degree of endurance to drought of short periods. About 80"' of the crop in West Africa is grown in the Southern Guinea and Derived Savanna, although environmental conditions are suitable for production in the Northern Guinea and Sudan Savanna where the remaining crop is grown. The crop is sown early in the wet season but in the Southern Guinea Savanna a late crop sown two or three months before the end of the wet season is common.

Sesame is basically a short-day plant but long-day types exist while some appear to be less sensitive to photoperiod. Yield is greatly influenced by photoperiod and temperature can have a considerable modifying effect. Effect of photoperiod and temperature interactions have not been fully studied although Weiss (1971) has summarized the work conducted in various areas of the world. It appears that in short-day cultivars such as those grown in West Africa flowering is delayed and vegetative growth increases with longer photoperiods, while capsule and seed produced may be positively or negatively affected depending on the cultivar (Ghosh, 1955; Matsuoka, 1959, 1960; Smilde,1960). Sesame normally requires fairly hot conditions during growth to produce maximum yields and the total heat units required during the critical three to four months' growth period are reported to be about 2,700°C (Kostrinsky, 1959). A temperature of 25°-27°C encourages rapid germination, initial growth and flower formation while temperatures below 18°-20°C inhibits germination and growth. Low temperatures at flowering can cause pollen sterility and flower drop while temperatures above 40°C reduces fertilization and capsule set. In some African cultivars studies (Matsuoka, 1959, 1960) have shown that the number of days from sowing to flowering, the height to the first capsule and number of branches per plant is greater under temperature higher than those occurring normally, although the number of capsules per plant is less. Under controlled conditions Smilde (1960) found that the optimum germination temperature ranged 32°-35°C while vegetative growth increased as the average temperature was raised from 24°C to 33°C. A constant temperature of 24°- 27°C induced early flower initiation, whereas high (33°C) and low (15"C) night temperature caused a delay. However, the retarding effect of low and high night temperature was more or less counteracted by high and low day temperature respectively. Further, the delay in flowering due to long photoperiod is offset by high temperatures. In non-African cultivars different kinds of sensitivity and responses to temperature and photoperiod have been reported (Weiss, 1971).

Cultivars grown in West Africa have a growth cycle of about 120-160 days but cultivars of 180 days to maturity are also grown. Date of sowing has a great influence on yield. Delay in sowing causes decreases in yields in all areas (Stonebridge, 1963; van Rheenen, 1973). Highest yields are obtained when the crops are sown in March and April in the Southern Guinea Savanna and May and June in the Northern Guinea and Sudan Savanna. Each week's delay after the optimum sowing time has been found to decrease yield by about 15%. In the Southern Guinea Savanna where a late crop is sown, August sowing was found to produce the best yield with about 8% decrease in yield per week's delay in sowing subsequently. Effects of sowing date on growth, development and yield of sesame in Nigeria have been discussed by van Rheenen (1973). Factors thought to affect yields in different sowing dates were daylength, temperature, soil moisture stress, leaching of nitrogen, soil capping by rainfall, waterlogging, solar radiation and disease and pest incidence.

The optimum plant population varies with cultivar, fertility and growing conditions. Although sowing on 0.90 m ridges is recommended in West Africa, maximum yields at adequate fertility have been obtained at a spacing of about 0.13 x 0.22 m (about 350,000 plants/ha). Generally, local cultivars at low fertility produce their best yields at wider spacings while improved cultivars, at a closer spacing (van Rheenen, 1973).

Most of the local cultivars are characterized by open or dehiscent capsules. This character has the advantage that it simplifies threshing, but the disadvantage that it increases seed loss. The discovery of 1943 of the indehiscent character led to the possibility of complete mechanized production. Recently, a somewhat similar mutant (paper capsule) appears to be more promising. Losses due to seed shattering can be high under local practice if harvesting is delayed. However, experiments (van Rheenen, 1973) have shown that seed loss need not exceed 2% if a good harvesting method is applied.

Recommended cultivars in West Africa respond only to a low level of fertilizer application but for high yields of 1-2 tonne/ha cultivars responsive to fertilizer must be used. Estimated removal of nutrients by a crop yielding 0.5 tonne/ha is N, 25 kg/ha; P2O5, 7 kg/ha; K2O, 30 kg/ha. However, a crop yielding 2.2 tonne/ha removes about N, 120 kg/ha; P2O5, 70 kg/ha; K2O, 160 kg/ha (Bascones and Lopes Ritas, 1961a, 1961b). Aspects related to crop nutrition have been discussed by Weiss (1971).

Sesame prefers sandy loam soils and it is grown in well drained soils of pH 6.0-6.5. It is very sensitive to waterlogging although it will grow reasonably on poor soil under indigenous practice. In West Africa sesame is grown as the third or fourth and last crop in the rotation, frequently after sorghum and yams, but also following maize, groundnut, cotton, millet or beans. Exceptionally it takes the first or second place in the rotation.

CULTIVATION

The crop is grown during rainy season. The local practice is to grow the crop without fertilizer at a wide range of spacings and plant densities. Sowing is done on widely spaced ridges about 4 m apart and about 1.5 m between stands (1,650 stands/ha) with about 16 plants per stand (27,500 plants/ha) or by broadcasting the seed either over the whole flat field or on the low, fairly wide ridges. In the latter the average amount of seed used is 4.5-9 kg/ha. No thinning is done after sowing, and the plant population varies from 460,000 to 900,000 plants/ha (Steele, 1960; van Rheenen, 1973). Interplanting of melons which creep in the furrows is not uncommon. When leaves begin to drop off and the remaining have turned yellow, and when the lowest capsules on the stem *are* about to split open, sesame is ready for harvest. Plants are uprooted or cut and either left in the windrow for one or two days or immediately bundled and tied. The plant bundles are placed in shocks or put to racks until sufficiently dry for threshing which is done by beating gently with sticks.

If yields in the order of 1-2 tonne/ha are to be obtained, cultivars responsive to fertilizer must be grown at adequate fertility. Deficiency of one major nutrient has been shown to reduce uptake of other nutrients and phosphate deficiency in particular can reduce uptake of nitrogen, potassium, calcium, sulphur and magnesium (Pal and Bangarayy, 1958; Sen and Lahiri, 1959). Spacing and plant density can vary from 0.5-0.10 x 0.6-0.90 m to 0.15-0.45 x 0.15-0.45 m depending on the cultivar and harvesting method. Sesame crop does not compete well with weeds and timely weed control is essential for good yields.

DISEASES AND PESTS

Sesame is attacked by a number of diseases during the wet season. It appears that foliage diseases in West Africa occur as a complex and not as individual diseases. Identification work in Nigeria has isolated a number of organisms from leaves of diseased plants (i.e., *Alternaria sesami*, *Cercospora sesami*, *Curvularia lunata*, *Cylindrosporium sesami*, *Fusarium semitectum*, *Helminthosporium halodes*, *Macrophomina phaseoli*, *Oidium* spp., *Pestalotiopsis mayumbensis* and *Pseudomonas sesami*). However, it appears that the pathogens *Cylindrosporium sesami*, *Cercospora sesami*, *Alternaria sesami* and *Pseudomonas sesami* are possibly the main members of the disease complex and cause leaf spot symptoms described by van Rheenen (1973). Root rot *(Corticium solani)* has been reported on crops grown continuously or too often on the same place. Virus diseases reported for sesame are mycoplasma and leaf curl. Damage caused by mycoplasma is negligible at present but can become of some importance in the dry season crop under irrigation. Leaf curl *(Nicotiana virus* 10 or *Tobacco leaf-curl virus)* transmitted by the white fly *(Bemisia tabaci)* can do much damage to sesame and it has become a disease of major importance since 1964 in Nigeria (Bailey, 1966). It was not reported before that (Robertson, 1963).

Main insect pests are the leaf roller or webber *(Antigastra catalaunalis)* and the gall midge *(Asphonydylia sesami)*. Larvae of the former eat the young flower buds, flowers and young fruits but can be controlled effectively with insecticides, while the effect of climatic factors on the pest incidence has been reported (Chadha, 1974). The gall midge lays eggs in the ovaries and gall develop before the flowers open. The maggots feed on the surrounding tissue and pupate inside the gall. Capsules may be partly or totally affected and in extreme cases all or nearly all capsules of all plants in the field show galls. Chemical control is difficult but resistance against the gall fly has been found recently (S.S. Chadha, unpublished, 1970-73). Resistance to the gall midge has also been observed in the species Ceratotheca *sesomoides*, which is indigenous to Africa, and crosses with Sesamum *indicum* (van Rheenen, 1970). Other insects which are known to attack sesame are grasshoppers, *Agonoscelis versicolor*, and the seed bug *(Rhyparochromus)*. .

TOBACCO *(Nicotiana tabacum)*

Tobacco is believed to have originated in South America. V. babacum is the source of commercial tobacco and it is one of the very few crops whose trade is on a leaf basis. Tobacco is an important cash crop in West Africa where most of it is used in cigarettes and some in snuff, chewing and pipe smoking. Although figures are not available, a large proportion of the crop is grown in the Savanna areas. Estimated total production of cured tobacco leaves in 1971 in West Africa was about 33,000 tonnes from an area of about 66,000 ha, corresponding to a yield of about 500 kg/ha. Average yield vary widely from 300 kg/ha in Ivory Coast to about 1,700 kg/ha in Mali, depending on the level of husbandry, growing conditions, fertility and area under cultivation. About 55°' of the total production in West Africa is in Nigeria where average yields are about 460 kg/ha. Recently, there has been quite a rapid expansion of commercial tobacco in many of the West African countries. Although quantities grown are small by world standards, increasing proportion of the commercial crop is being grown under conditions of improved management, and pesticides and low to medium levels of fertilizers are applied. Here, yields of 0.3-1.0 tonne/ha *are* obtained but at a more higher level of management yields of 1.5-2.0 tonne/ha *are* possible and have been obtained under experimental conditions. Elsewhere in the tropics commercial yields under high level of management *are* in the range 2.2-2.6 tonne/ha. A full account of growing and processing of tobacco as a world crop has been given by Akehurst (1971).

ECOLOGY

Most of the crop in West Africa is grown in the Derived, Guinea after

Sudan Savanna where the tobacco types grown are principally the flue-cured Virginia and the air-cured Burley. Cigar and oriental types have been reported to be minor. The optimum growing temperatures *are* between 20° and 30°C, but tobacco will tolerate temperature up to 35°C. The crop requires about 90-120 days from transplanting to final harvesting and for good yields about 500-750 mm well distributed rainfall and the length of the rainy season are adequate for two crops. In the Sudan and Northern Guinea Savanna the rainy season is long enough for one crop but during the dry season a sizable proportion of the total crop (about 30-40:") is grown in the f*adama* areas and a small amount under irrigation (Coppock, 1965; Irvine, 1974). There are considerable season to season variation in yields of rain-fed crops and differences in weather, especially in duration, frequency and intensity of the rains, are the principal causes. Also, disease, especially leaf curl, has an important influence. Dry weather is required for ripening and harvesting. Continual rains towards the end of the crop's life leads to diseases and thin, light-weight leaves. A prolonged dry period when the crop is nearing maturity causes premature ripening while heavy rains after a long dry period during ripening leads to secondary growth. In both cases the leaves are difficult to cure. Further, after harvest too dry a weather during air-curing may cause leaves to dry out too rapidly and remain green; too high a humidity may cause leaf rot.

Cultivated tobacco is day-neutral although short-day types, the 'Mammoth' cultivars, only flower when exposed to short days. Because leaf expansion is greatly influenced by temperature, leaf thickness under a given temperature regime depends on the solar radiation intensity. High temperature and low radiation intensity can lead to production of thin leaves which may be difficult to cure.

Both yield and quality *are very* sensitive to soil conditions and they determine the type and use of the leaf produced. Collectively, all tobaccos cover a wide range of soil conditions; but for a specific tobacco type, the requirements *are* somewhat exacting for production of high quality cured leaf. Different types of tobacco make effective use of a wide range of soils. A light sandy loam is essential for flue-cured bright tobacco; air-cured brown tobacco grows best on heavier silt or clay loam soils; air-cured bright tobacco is grown on soils intermediate between the two. In general, the crop requires adequate drainage, soil moisture retention and aeration. Tobacco is very sensitive to waterlogging while strongly acid or strongly alkaline soils do not produce good crops. Soils with a pH of 5.0-6.5 are considered satisfactory.

The three principal cured tobaccos at present produced in West Africa vary in accordance with the method of curing which also varies with climatic conditions in the area in which the crop is grown. The air-cured tobacco is produced by allowing the leaves to dry in natural air. However, since the humidity in the Derived and Southern Guinea

Savanna is high, the curing period is extended and results in a change of leaf colour from green to yellow and finally to dark brown. This is in contrast to the bright colour produced from the air-cured crop in the Sudan and Northern Guinea Savanna where drier conditions result in rapid drying and curing of the leaf. Air-curing is done by either hanging the leaves outside in the open (i.e., sun-cured tobacco) or in barns (i.e., shade-cured tobacco) which are simple open sided or drop sided sheds with thatched *or* tin roofs. Drop sided barns are necessary in the humid areas as the sides can be lowered at night. Curing in the humid areas takes 5-6 weeks or more while in the drier areas as short as 3-7 days. The rain-fed crop in the Northern Guinea and Sudan Savanna is harvested in October and November and leaves *are* hung-up to dry until the rising humidity of the first rains makes it possible to handle the leaves again in June or July. Much of the crop grown in the areas during the dry season is planted from mid-September to mid-November depending on the area and recession of the floods. Some may be continued to be planted until February, but its contribution is very small. The crop is harvested in January to March and the harvested leaves are cured but not handled until June or July when the leaves *are* moist enough. However, for the production of high quality bright tobacco in the dry season in the fadma areas or under irrigation, it is advisable to plant as early in September as possible to take advantage of the very dry conditions which are essential to produce a bright yellow, air-cured leaf. Because of low temperatures during the first half of the dry season crop growth both in the nursery stage and in the field is slow and a late planted dry season crop may reach maturity when the *very* dry conditions are on the wane, leading to slower curing and less bright tobacco (Winter, 1965). In the flue-cured tobacco, artificial heat is applied during curing and the whole process is completed in 5-7 days. Curing, particularly flue-curing, requires considerable skill and experience and it must be done with great care because imperfect curing can destroy the potential good qualities in the leaf. The various methods of curing have been described by Akehurst (1971) and Purseglove (1974). The process basically involves starving the leaves slowly. During the yellowing process circulation of the sap is necessary, followed by killing and drying the leaf. If water is lost too quickly the leaf remains green, if lost too slowly the leaf becomes sponged and may rot. In West Africa some tobacco is sun-cured for home consumption.

Good yields are only obtained under adequate fertility and an air-cured crop yielding about 1.9 tonne/ha removes N, 101 kg/ha; P2O5, 25 kg/ha; KgO, 145 kg/ha. The fertilizer type and amount must be adjusted to the kind of tobacco grown, soil type and the yield level being aimed at. Flue-cured bright tobacco should be grown under fertility conditions relatively low in nitrogen but high in phosphate and potash. For air-cured tobacco the fertilizer should be more balanced as to the nutrients. In the tropics for medium to high yields of 1.5-2.0 tonne/ha under commercial planting, nitrogen is usually applied at the rate of 20-45 kg/ha to flue-cured, and 50-110 kg/ha to air-cured. Phosphate and potash are applied at the rate of P_2O_5, 55-110 kg/ha and K_2O, 110-170 kg/ha after transplanting.

CULTIVATION

Commercial tobacco growing in West Africa is an example of integrated management (Hunter and Bottrall, 1974) where commercial firms provide full control of the complete process. In Nigeria, for example, this includes research, extension service, inputs including seed, credit and graded marketing and processing of the crop (Norman, 1974). Mechanization is becoming increasingly important in many areas in the preparation and cultivation of the land, and tractors and implements can be hired in some regions at a fixed price per unit area. Commercial crop is usually grown sole while for home consumption tobacco is often grown in mixture. In the village studies in the Northern Guinea Savanna, about *12%* of the crop was found to be grown sole while the remaining in 2-3 crop combinations involving sorghum, maize, sweet potato, okra and onion (Norman, 1972). Nursery seed beds are prepared either before the rains or during the early part of the wet season for the rain-fed crop and towards the end of the rains for the dry season crop. In the southern areas nursery beds are prepared during the middle of the rainy season for the second crop. Seed beds are shaded and mulched, and 12: 24:7 compound fertilizer at the rate of 540 kg/ha with pesticides is recommended. After about 40-50 days the seedlings are transplanted to the field, usually on ridges or, when the land is suitable, to the flat. Ridges are more satisfactory because of good drainage and better root growth. When large areas are planted, crops are often successively planted to spread out the work of harvesting and drying. In commercial plantings, 10:13:10 compound fertilizer at the rate of 112 kg/ha is recommended at present and this is applied at the time of transplanting, placed inside the ridge about 20 cm deep, or side-placed few days after transplanting. Spacing is usually 0.6-0.75 x 0.9-1.2 m (about 11,000-18,500 plants/ha) but seedlings may be planted at closer spacings 0.3-0.6 x 0.5-0.9 m (18,000-66,500 plants/ha) depending on the cultivar and soil fertility. Weeds can influence both yield and quality and the field is generally cultivated two to three times to control them. When flower buds are formed, about 50-70 days after transplanting, the inflorescences and the top most leaves are broken off by hand, an operation which improves the yield and quality. The time and height of topping depends on the type of tobacco grown and soil, the level of fertility and the spacing. Topping therefore requires considerable skill and judgement for achieving best results. Soon after topping suckers are produced in the axils of the leaves and are removed weekly until harvest otherwise the advantages of topping are lost. About 15-25 days after topping or 65-95 days after transplanting, lowest leaves begin to ripen and these are picked singly from the bottom. Two or three leaves are taken at each picking, which is continued at weekly intervals. The leaves are strung back to back in alternate pairs on each side of sticks and hung in the barn for curing. The sequential picking of leaves for the flue-cured tobacco is essential but for the air-cured tobacco whole plants may be harvested by cutting the stem near the ground when the greatest number of the best leaves are at the proper stage of ripeness, which is usually 90-125 days after transplanting. This method is used elsewhere in the tropics and the leaves may be cured on the stems, which are tied to the poles and the leaves are wilted before transfer to the curing barn. Complete stalk-curing is not done in West Africa. Occasionally, when half the leaves have been taken from the plant and if the remaining leaves show a uniform ripening, plants are cut and the remaining leaves are then stalk-cured, thus saving labour. Usually, however, the remaining leaves do not ripen simultaneously.

In West Africa at present there are five grades of flue-cured tobacco, and three grades of air-cured, with graded prices (G.A.F. Rand, personal communication 1976). The grades of flue-cured tobacco are: (1) Clean yellow leaves without blemish; (2) Yellow/orange leaves with spots and some degree of blemish or sponging; (3) Yellow leaves with under-ripe greenish centres; (4) Burnt leaves; (5) Green leaves. The grades of dark air-cured tobacco are: (1) Clear light to dark brown leaves without blemish, usually from the middle of the plant; (2) Clear light to dark brown leaves but with a degree of blemish and coarseness and darker colour; (3) Short tip leaves with medium to dark brown colour, and those leaves not fitting into grades (1) and (2). The grades of bright air-cured tobacco, from the fadama areas in the northern Savanna regions, are: (1) Clear bright leaves without blemish, usually from the middle of the plant; (2) Clear bright leaves but with a degree of blemish and coarseness and duller colour; (3) Short tip leaves with medium to bright colour and those leaves not fitting into grades (1) and (2). Quality of tobacco is determined by the genetic make-up, environment, cultural practice, curing and aging. In countries where tobacco growing is advanced, cured leaves are sorted into many different grades and in assessing leaf quality all the following elements are taken into account: size and shape of leaf, mid-rib, leaf venation, thickness, density of structure and texture, weight per unit area, elasticity, aroma, taste and hygroscopic properties. In West Africa in general, however, quality does not yet seem to be a major agronomic objective, but it is likely to become more important as the tobacco industry advances and the volume of production increases, necessitating finer grading. When this stage is reached more attention will have to be paid to a number of aspects of cultural practice in particular the nitrogen-potash balance in the nutrition of the crop.

DISEASES AND PESTS

Tobacco suffers from many diseases of the leaf, stem and root, and is attacked by several insect pests. Damping-off disease *(Pythium* spp., R*hizoctonia* spp.J is a condition of young seedlings in which the stem at soil level becomes soft and rotten, killing the seedling. The fungus is present in the soil, entering and softening the tissues which are then invaded by a large number of soil organisms, especially bacteria (Keay and Quinn, 1967). Chemical control is effective while good drainage, avoidance of over watering or over crowding, and seed-bed sterilization also help in its control. Black shank *(Phytophthora parasitica)* is primarily a disease of the roots and the basal part of the stem, but the pathogen is capable of attacking any part of the plant at any stage of growth (Amile, 1972). Symptoms vary according to the age of the plant and organ affected, weather conditions and the degree of host resistance. On young seedlings early attack results in damping-off. Environmental conditions greatly influence the severity of this disease. Black shank is a warm weather disease and soil temperature below 20°C drastically reduces field infection. Excessively wet soil conditions favours the disease. There is some evidence that the severity of the disease is increased in the presence of nematodes, especially the root-knot nematodes; and most black-shank resistant cultivars appear to lose some of their resistance in the presence of this nematode. Previously it was thought that tobacco was the only natural host for the black shank fungus. However, Allen (1971) reported that the fungus causes Zebra disease on *Agave* spp. Tomato, egg plant, sweet potato, castor bean and peppers have been infected with the disease by means of artificial inoculation. However, these crops when grown on heavily infested soil in field do not show any evidence of disease attack, although these crops can play a role in the perpetuation of the fungus. There is no adequate chemical treatment for control. Resistant cultivars are available while soil sterilization, rotation and strict sanitation helps considerably in its control. Black root rot (T*hielaviopsie basicola)* has been reported on tobacco and the fungus can live in the soil for a long time. It attacks other plants such as groundnut and cowpea. Soil sterilization helps in its control but resistant cultivars exist. Southern stem rot *(Selerotium rolfsii.)* has been reported (Irvine, 1973) attacking the plant in its later stages of growth. The fungus appears to have a wide host range so that crop rotation does not lead to its control. Frog-eye leaf spot *(Cercospora nicotianae)* can be a serious disease under wet and humid conditions. It is mainly found on the older leaves in the field but can cause spotting during the early stages of curing.

Tobacco mosaic virus disease is very common but recently sources of genetic resistance have been found. Several mosaic virus strains appear to be involved and these are transmitted mechanically in handling plants and the use of infected tobacco. Other major virus disease is leaf curl transmitted by white flies *(Bemisia tabaci).*

Several insect pests in addition to white flies have been reported (Libby, 1968). These include green shield bugs (Nezara *viridula),* mealy bugs *(Planococcus citri),* budworms *(Heliothis umbrosus),* leaf worms *(Spodoptera littoralis)* and mole crickets *(Gryllotalpa africana).*

Nematodes, particularly the root-knot nematode *(Meloidogyne* spp.) and the reniform nematode *(Rotylenchulus reniformis),* have the potential of causing serious losses. Other crops such as vegetables, sweet potato, potato, cowpea, wheat, cotton, melon are also affected by these nematodes. Tobacco should not therefore be grown near these crops while land infected through these crops should be avoided. Control of nematodes is effective through the use of nematicides while high fertility, fallow, flooding and soil sterilization do help in their control.

SUGAR CANE *(Saccharum* spp .)

Sugar cane originated in Asia and the original cane *(S. officinarum)* probably evolved in New Guinea from *S. robustum,* and introgression from *Erianthus maximum* may have been involved. *S. robustum* is believed to have evolved from strains of wild species *S. spontaneum,* which, although indigenous to India, is thought to have become isolated in New Guinea, and introgression also may have occurred from *Miscanthus floridulus* (Grassl, 1969; Purseglove, 1975). Cultivars of *S. officinarum* are known as the 'noble' canes, because of their fine thick stems, to differentiate them from the thin canes of *S. barberi* and *S. sinense* which have long been cultivated in India and Asia and thought to be hybrids between *S. spontaneum* and *S. officinarum.* Up to the end of the nineteenth century, only a few clones of the noble canes had been used to establish the major portion of the world sugar cane industry. With the rediscovery of seed and seedlings in sugar cane in 1898 genetic variability was increased to some extent by using new cultivars and breeding within *S. officinarum.* Many of these noble canes were high yielding but their resistance to pests and pathogens was low. These continued as the main commercial cultivars until higher yielding interspecific hybrids with greater and wider resistance to pests and pathogens were produced from crosses with *S. spontaneum* and back-crossing to the noble canes, the process known as nobilization. Almost all the commercial cultivars grown today are interspecific hybrids of *Saccharum* spp., specially bred during the present century and these have a complex ancestry (Purseglove, 1975). It has been recorded that sugar cane was introduced into West

Africa by the Portuguese during the early fifteenth century. Whether the spread to the deep interior took place from the coast or from the Mediterranean is not known. Sugar is a popular item in the diets of the people in West Africa, and consumption far exceeds the supply from local production. Sugar imports into West Africa are currently estimated at about 0.3 m tonnes annually, equivalent to about 2.3 m tonnes of cane. Estimated total production of cane in West Africa in 1971 was about 1.3 m tonnes (about 0.17 m tonnes of sugar) from an area of about 51,000 ha, corresponding to a yield of about 25 tonne/ha. In other words, about two-thirds of the sugar consumed in West Africa is imported. Sugar cane is therefore an important crop commodity in West Africa not only because of its present demand on the foreign exchange but also for its domestic and industrial potential within West Africa and for export, both of sugar and various by-products. Although sugar cane is widely distributed in West Africa, in the past it has nowhere been grown on a large scale, being mainly grown in small patches for chewing, and production during the dry season of 'jaggery' and alcohol by local methods. Recently, however, large plantations *are* being established for commercial production. The setting up of the commercial sugar industry in Nigeria has been discussed by Barnes (1974). About 50% of the total sugar in West Africa is produced in Nigeria where cane yields under local practice over about 8-12 months growing period average about 20-25 tonne/ha. Large scale experimental yields in the range 130-170 tonne/ha have been obtained in 12 months (Kowal, 1962; Kowal and Hill, 1965); and fields from commercial production over about 11-14 months growing period are likely to be about 90-120 tonne/ha or more which compares favourably with other areas in the tropics where production is advanced. Detail accounts on growing and processing of commercial sugar cane are available (King *et al.*, 1965; Humbert, 1967; Barnes, 1974; Purseglove, 1975), and only a brief presentation is given here.

ECOLOGY

Sugar cane thrives under conditions of high temperature and solar radiation. For a crop of 12-14 months duration about 1,500-1,700 mm of water is needed and for good yields, high fertility and good drainage are essential. The ideal climate is one with a long warm growing season (24°-27°C or more) and a fairly dry, sunny and cool ripening and harvesting season. These conditions prevail in the Savanna region in the *fadama* areas and flood plains, and on the upland under supplementary irrigation. Elsewhere in the tropics the duration of the crop ranges from about 9 months to 2 years, but most sugar cane is grown for 14-18 months for the plant crop and 12 months for the ratoon crop.

The crop is propagated from stem cuttings called setts. Each node has an axillary bud and a band of root primordia and is capable of producing a new plant. The germinating bud is initially dependent on the sett and sett roots for nutrients and water, but develops its own root system after about 2-3 weeks in favourable conditions. The optimum temperature for the sprouting of stem cuttings is 32-38°C. Below 20°C growth is slow and fails at lower temperatures. The short roots arise from underground nodes, and the axillary buds at these nodes give rise to tillers. As many as 144 stalks have been recorded in a stool arising from a one bud sett. The development of the cane plant from germinating sett has been reviewed in detail by van Dillewijn (1952).

Various eco-physiological aspects related to crop growth, development and yield have been reviewed by Bull and Glaszion (1975). A 12-month crop has a quadratic growth curve while a 20 to 24 month crop a cubic growth curve because after the bloom stage in the first year growth slows down as the cane stalks approach maturity. However, the exact shape of both the 12 and 24 month crop depends greatly on cultivar, temperature, solar radiation, availability of nutrients and moisture. On average, total dry matter production of a 12-month crop is about 50 tonne/ha while a 24-month crop about 75 tonne/ha, equivalent to about 100 tonne/ha and 150 tonne/ha of cane respectively. Experiments in Hawaii and Queensland have shown that the linear relationship between total dry matter production and water use (about 125 g water per *a* dry matter) is not greatly affected by temperature or the stage of growth of the plant (Mongelard and Mimura, 1971, 1972; Bull and Glazion, 1975). Provided prolonged periods of water stress do not occur during the wet season the potential cane yield is roughly 2-4 tonne/ha per 2.5 cm of evapotranspiration. It may be thus possible to use evaporation and water budget figures to estimate the potential yields in different regions.

Most Suecharum cultivars will not flower under daylengths longer than about 13 hours or shorter than about 12 hours, nor if given light in the middle of the dark period. There are exceptions, some of the *spontaneum* cultivars behaving as long-day plant while some cultivars flower regardless of the nature of the photoperiod. Coleman (1968) has discussed the physiology of flowering in sugar cane. Generally, a daylength of 12.5 hours and night temperatures between 20°C and 25"C will induce floral initiation if enough inductive cycles are given once the plant has reached a certain stage in its development. However, there is a great variation in the sensitivity to photoperiod depending on the cultivar, and the response is modified by the age of the plant, temperature, water stress, nutrition and weed infestation prior to full cover. Flowering has a considerable negative effect on growth and yield and several methods with varying degrees of success have been used to prevent flowering during the first season. In West Africa, sugar cane flowers in the dry season, October to December. The sugar in the stalk is capable of being mobilized and transported elsewhere in the plant to support growth requirements in excess of that provided by current photosynthesis. Conditions which favour sugar storage in stalks include maturity of the plant, a check to internode elongation rates in the stalk by cold, nutritional, or water stress, provided canopy photosynthesis is maintained at a sufficient rate.

Sugar cane can be grown on a wide variety of soil types, but heavy soils are usually preferred. The crop is a gross feeder and exhausting to the soil. The nutrient requirements and fertilizer practices vary widely between countries depending on local climate, soil and economic conditions (Davies and Viltos, 1969) and whether or not the crop is irrigated and ratooned. Sugar cane removes large quantities of nutrients from the soil. A crop yielding about 28 tonne/ha, of cane is reported to remove N, 30 kg/ha; P_2O_5, 20 kg/ha; K_2O, 60 kg/ha while a crop yielding about 74 tonne/ha about N, 107 kg/ha; P_2O_5, 60 kg/ha; K_2O, 300 kg/ha. Aspects related to crop nutrition have been reviewed by Purseglove (1975).

In the West African Savanna sugar cane under indigenous practice is grown in the *fadama* areas and the flood plains of streams and rivers which flow strongly in the rains and shrink or dry up during the dry season. These lands are subject to annual flooding and waterlogging and in the dry season the water table is high. There is considerable variation in texture, and 60-70°'. of clay is frequently present in the upper soil overlying silty or sandy clay below. These soils are usually acid, and often rich in nitrogen.

CULTIVATION

Under indigenous practice the land is prepared for planting by deep hoeing soon after the end of the rains, and un-arrowed tops or stem segments are planted during the period October to March. The predominant cultivars are the noble cane Bourbon *(s. officinarum)* and thinner Creole cane (s. *barberi).* The planting material is often sprouted before being planted, by making bundles which are placed with their cut ends in shallow water. Cuttings are put into the soil at an angle. Sugar cane is usually planted on the flat but where the land is liable to flood they are grown on ridges and sometimes on hills. About 3-4 tonne/ha of setts are planted. Spacing varies considerably (Norman, 1972) and spacings of 0.7 x 0.8 - 0.9 m (16,000-19,000 stands/ha), 0.55 x 0.55 m (34,000 stands/ha) and 0.4 x 0.45 m (57,000 stands/ha) have been reported. The crop is largely grown sole but a tiny amount (2-3%) has been reported to be grown in mixture of 2-3 crop combinations involving cowpea, rice, cassava, sweet potato and vegetables (Norman, 1972). In favourable weather setts root in about two weeks and new growth appears soon after. The crop is harvested from October to

February, 8-14 months after planting depending on the region. In the Northern Guinea and Sudan Savanna the crop duration is often about 8-10 months while in areas further south about 12-14 months. Ratoon crops are rarely taken. The cane is harvested by pulling the ripe stalks from the stool using a twisting action which causes the break to occur below the ground level or by cutting at the ground level. Yields in terms of sucrose are unknown but the yield of 'jaggery' or crude sugar is about 8-10% of the weight of cane crushed.

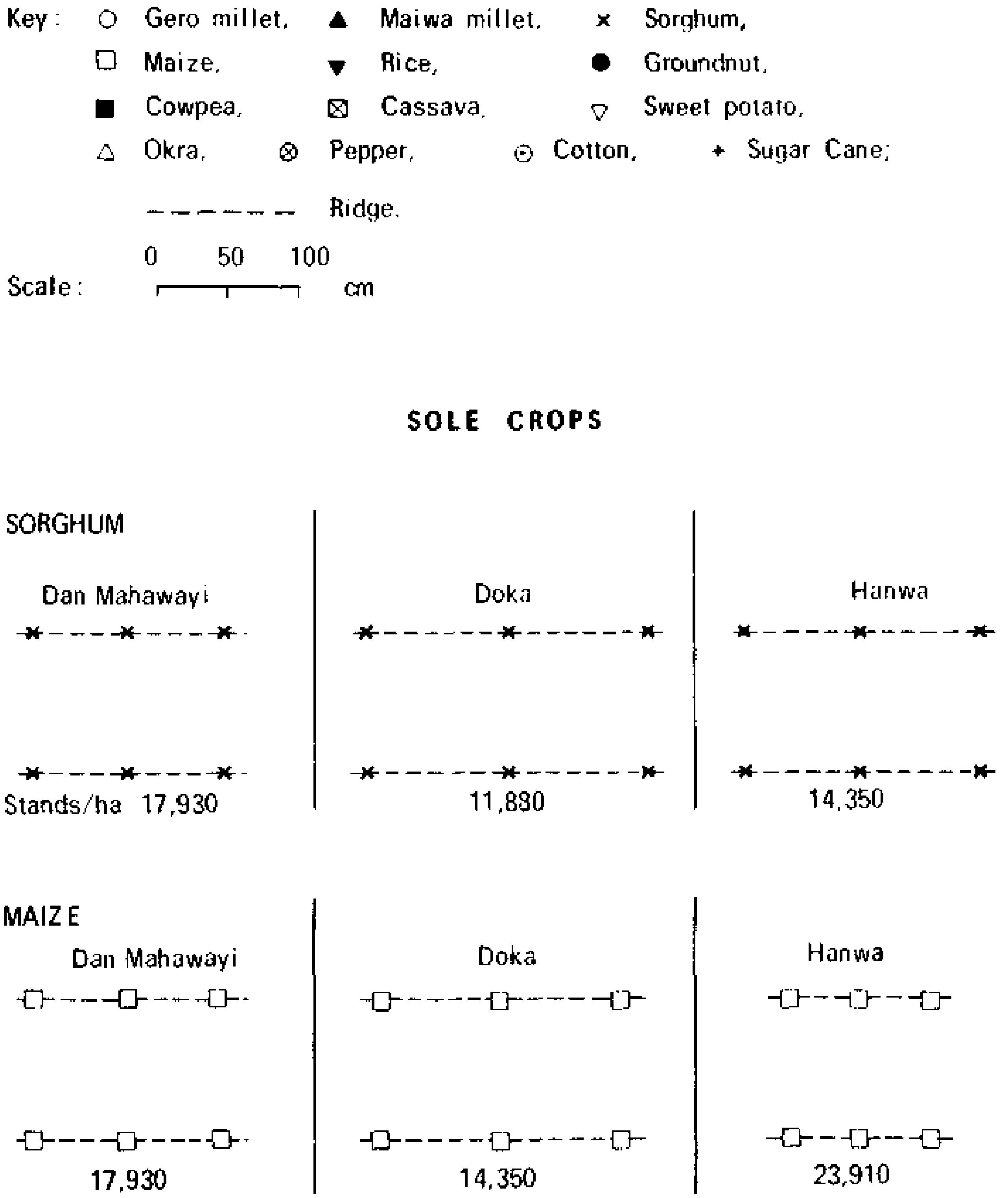
Commercial crops in West Africa are generally planted directly in the field, either in setts on ridges or cuttings laid horizontally in the base of a shallow furrow which is earthed up as the plants grow. The planting material is chemically treated before planting. With mechanized cultivation and irrigation, spacing is about 0.30-0.60 m in the rows 1.30-1.60 m. Commercial planting is done in October to February and harvested by hand using cutlasses the following December to February, after 12-14 months. The cut cane soon begins to deteriorate and it is transported to the factory within 48 hours. Ratoon crops are taken but as elsewhere in Africa their yields are lower than the planted crop. Fertilizers are applied but amounts generally vary in the range N, 50-220 kg/ha; P2O5, 25-90 kg/ha; K2O, 35-205 kg/ha.

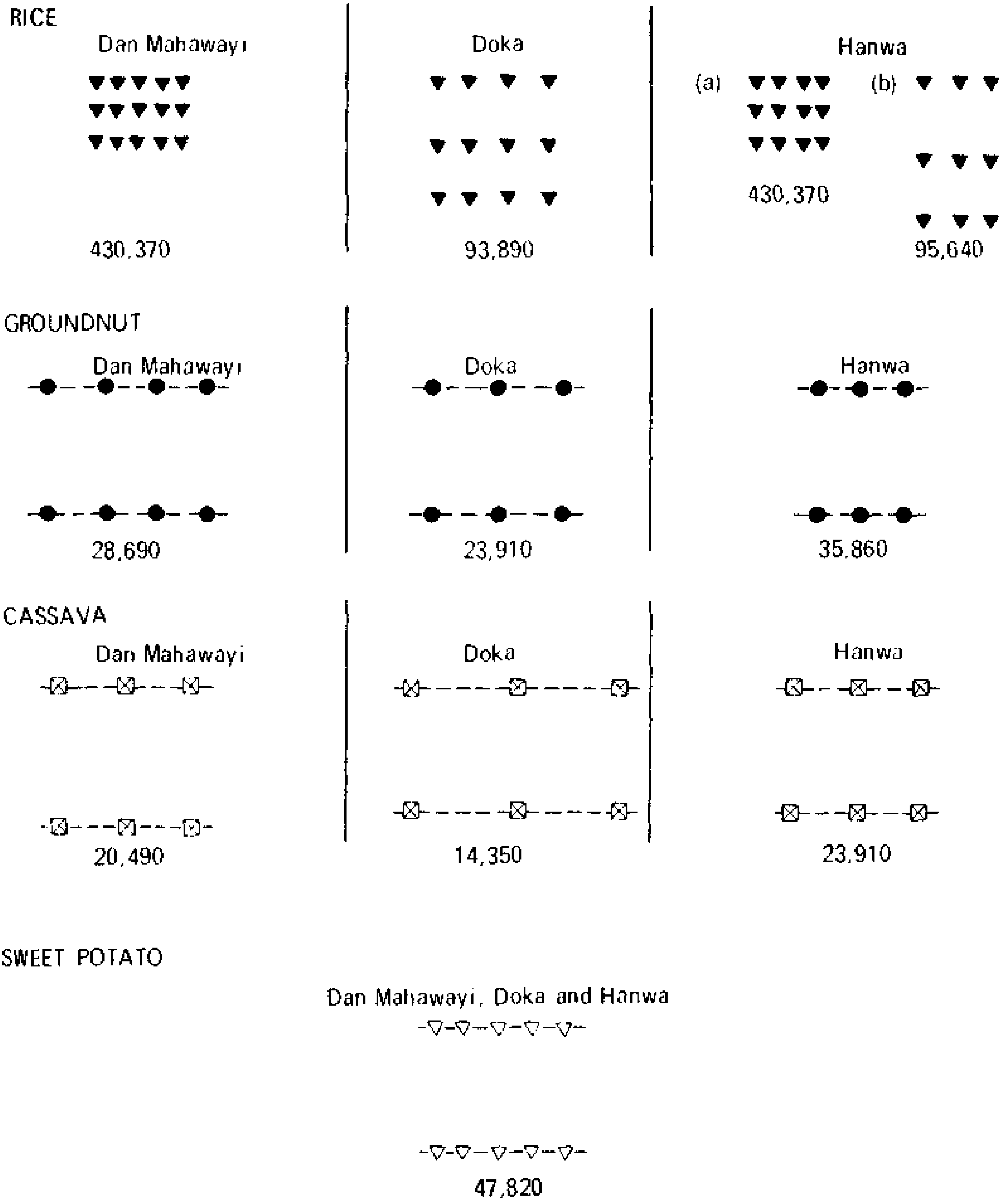
DISEASES AND PESTS

Commercial crops grown on large scale elsewhere in the tropics are attacked by a number of pests. In West Africa because of the recent commercial nature of the crop and areas involved are small, disease problems are relatively mild. However, a severe outbreak of red rot *(Colletotrichum falcatum)*, of which the perfect stage is *Physalospora tucumanensis*, occurred in Nigeria in 1952. This was the first record of the disease in epidemic proportion, though it had possibly been present for a long time previously in a mild form. Dark red lesions occur on the midrib, reddish discolouration occurs near the base of the stem in one or more internodes, interspersed with whitish spots. The conidial stage of the fungus can sometime cause the whole plant to die. Most noble canes are very susceptible, but sources of resistance exist in some clones of *S. spontaneum*. Other diseases include ring spot *(Leptosphaeria sacchari)* and eye spot *(Helminthosporium* spp.). These fungus diseases are of little importance at present. The ratoon stunting disease (RSD) has been observed in local cultivars and in ratoon of some of those recently introduced, but not in the plants of the latter. Infected canes show depressed growth, particularly in ratoon crops, resulting in thin canes. Diseased plants have orange-red vascular bundles at the nodes, and pink discolouration of the growing point. The disease is spread by diseased setts and infected cutting knives. Hot-water treatment of setts is effective in its control, together with sterilization of knives used for cutting setts.

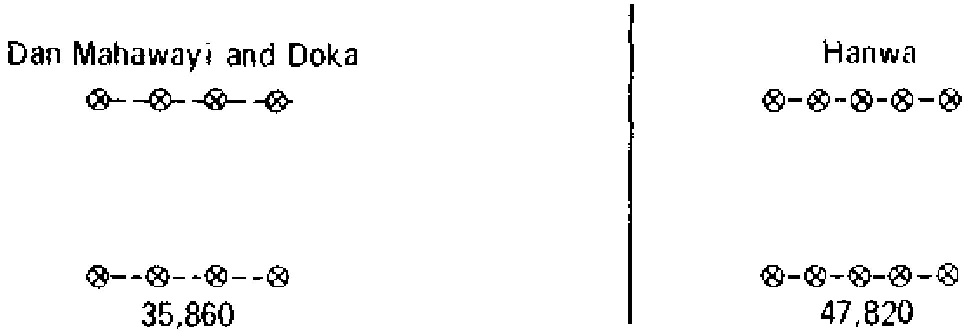
Of the several insect pests recorded on sugar cane in West Africa, cane borers, *(Busseola fusca, Sesamia* spp., *Eldana saccharina, Coniesta (ignefusalis)* are the most numerous and can become of economic importance. These borers are found on other crops such as sorghum, millet, maize and rice. The eggs are usually deposited by the moths on the young leaves and the larvae burrow into the stem, subsequently emerging as adults. This results in a loss of sucrose, stem strength and young tillers. The tunnel provides an entrance for other diseases such as red rot. Various species of termites have been known to cause serious damage to the crop, particularly in the dry season, and small fields are often completely destroyed. Irrigated crops appear less liable to be attacked. Chemical control on the newly planted cane is effective. Other insect pests reported include cotton stainers *(Dysdercus superstitiosus)*, spittle bugs *(Locris maculata, Poophilus adustus)*, stem beetles *(Heteronychus oryzae)*, sap beetles *(Carpophilus* spp.*)* and maize beetles *(Heteronychus licas)*. The beetle attack is often followed by secondary attacks from other beetles and rot organisms (Libby, 1968).

FIGURE 1. SPATIAL ARRANGEMENT OF SOME COMMON SOLE CROPS AND CROP MIXTURES IN SURVEY VILLAGES, DAN MAHAWAYI, DOKA AND HANWA, NEAR ZARIA (NORMAN, 1972).

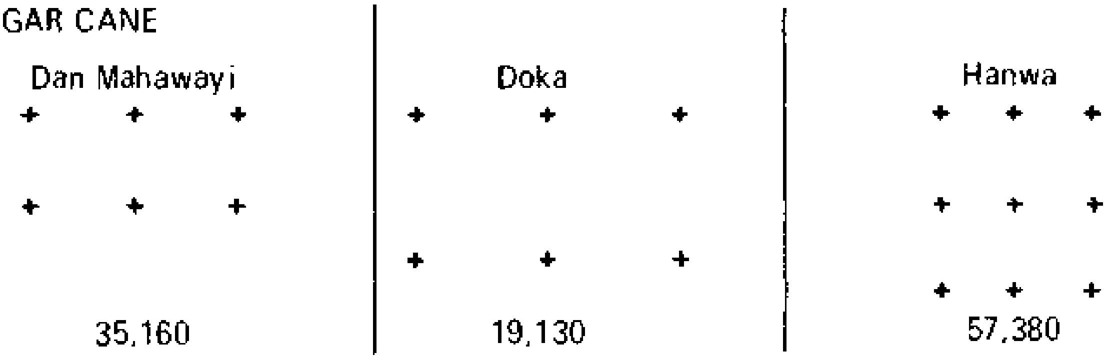



RICE
Dan Mahawayi
430,370
Doka
93,890
Hanwa
(a)
430,370
(b)
95,640
GROUNDNUT
Dan Mahawayi
28,690
Doka
23,910
Hanwa
35,860
CASSAVA
Dan Mahawayi
20,490
Doka
14,350
Hanwa
23,910
SWEET POTATO
Dan Mahawayi, Doka and Hanwa
47,820

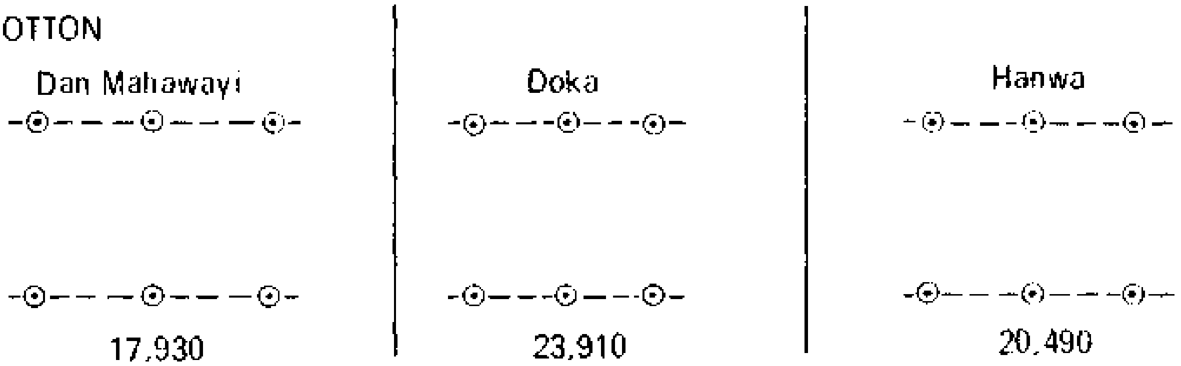
PEPPER



SUGAR CANE

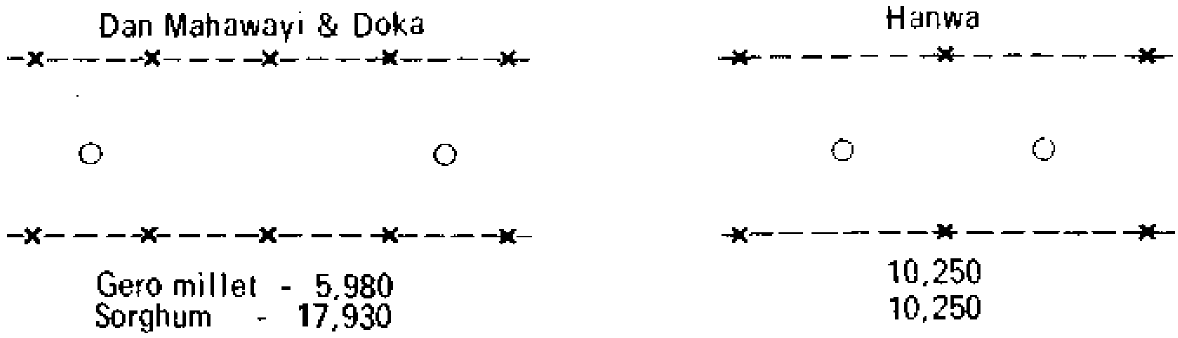


COTTON

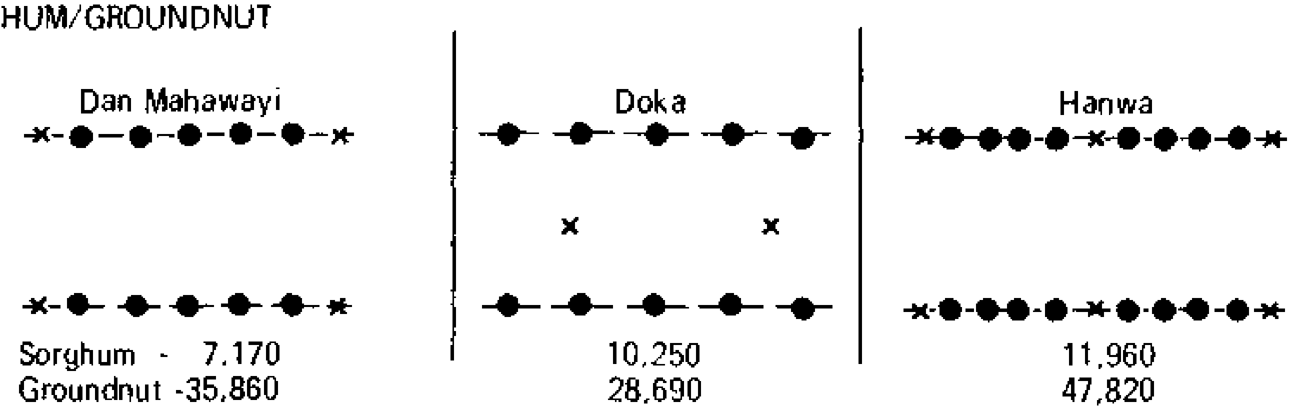


TWO CROP MIXTURES

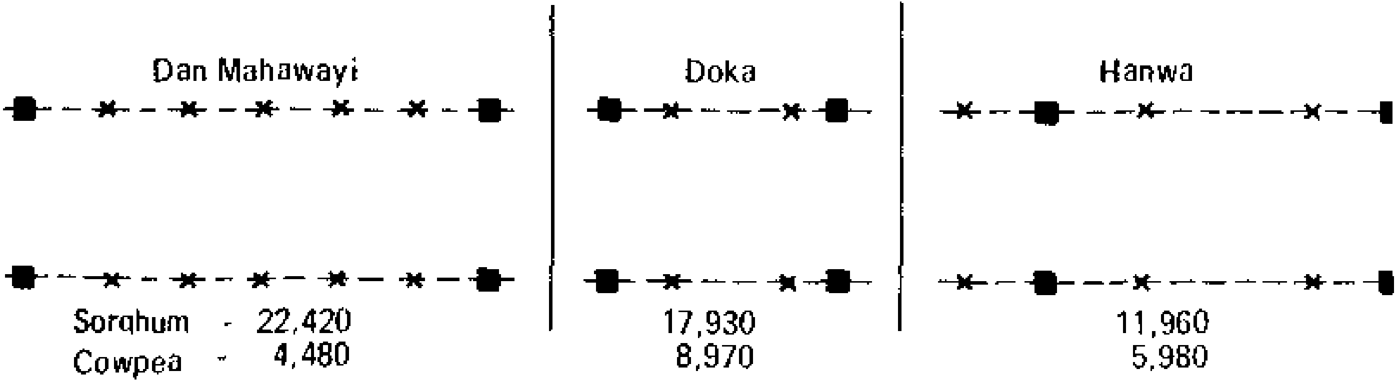
GERO MILLET/SORGHUM



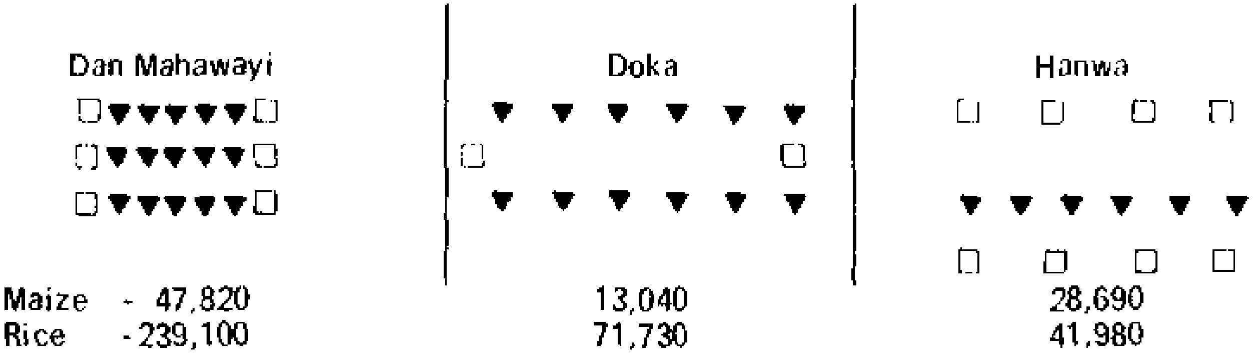
SORGHUM/GROUNDNUT



SORGHUM/COWPEA



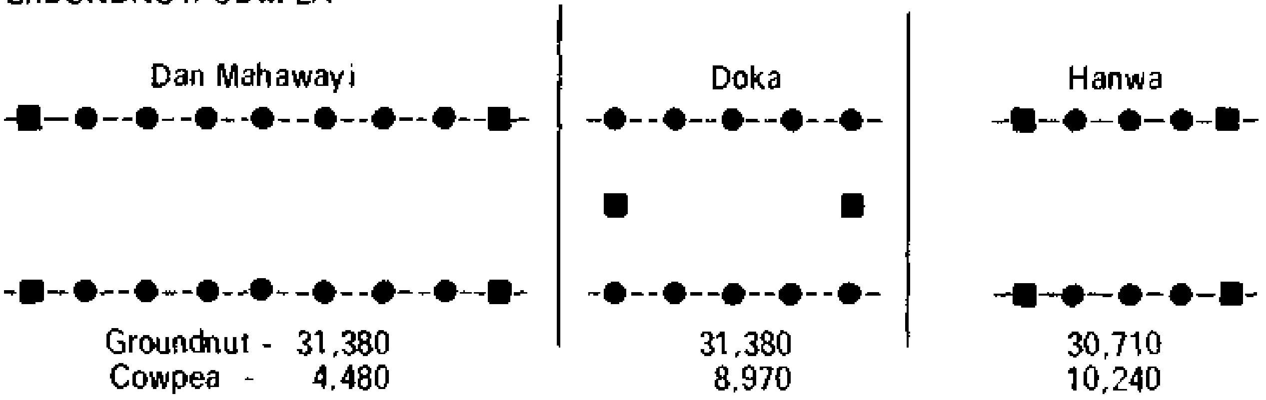
MAIZE/RICE



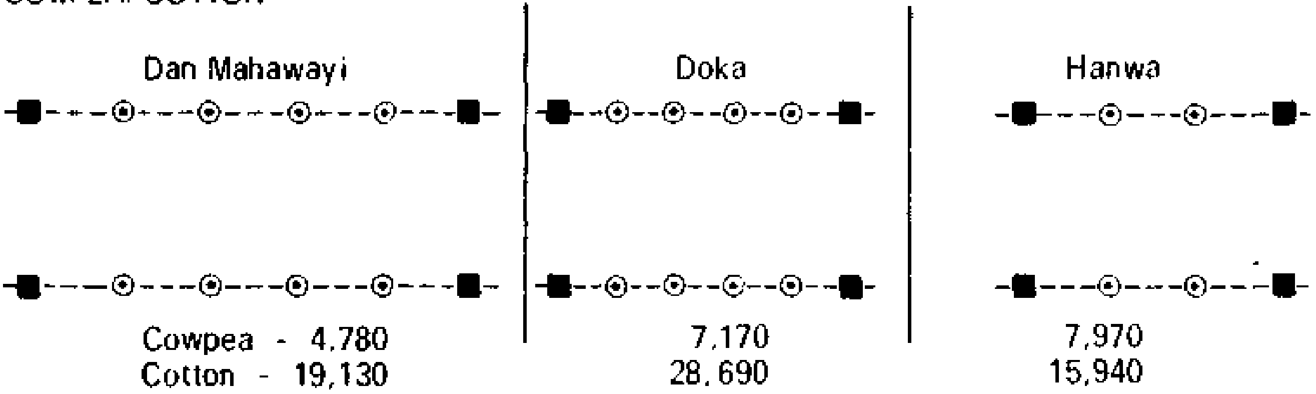
MAIZE/SUGARCANE

Not grown as mixture. Maize planted if sugar cane fails or after sugar cane is harvested

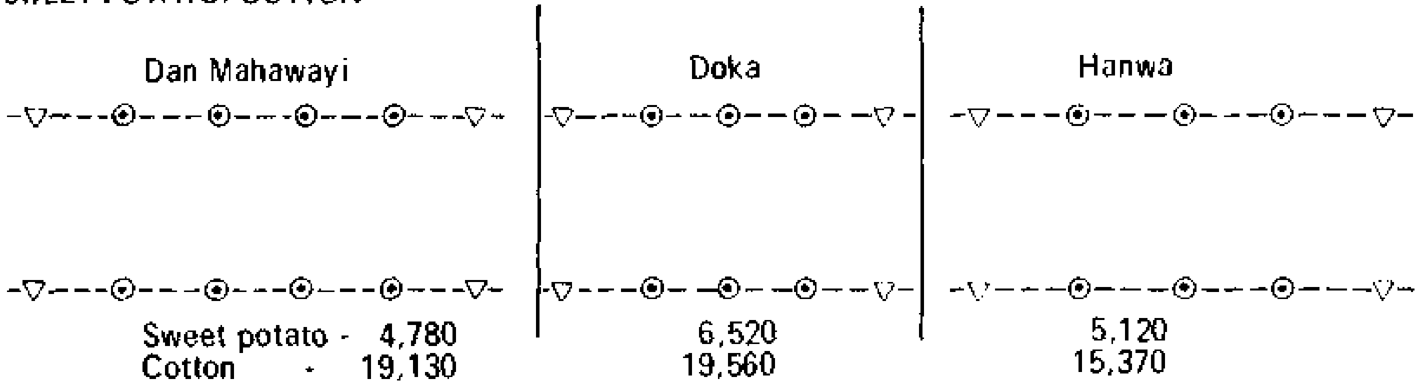
GROUNDNUT/COWPEA



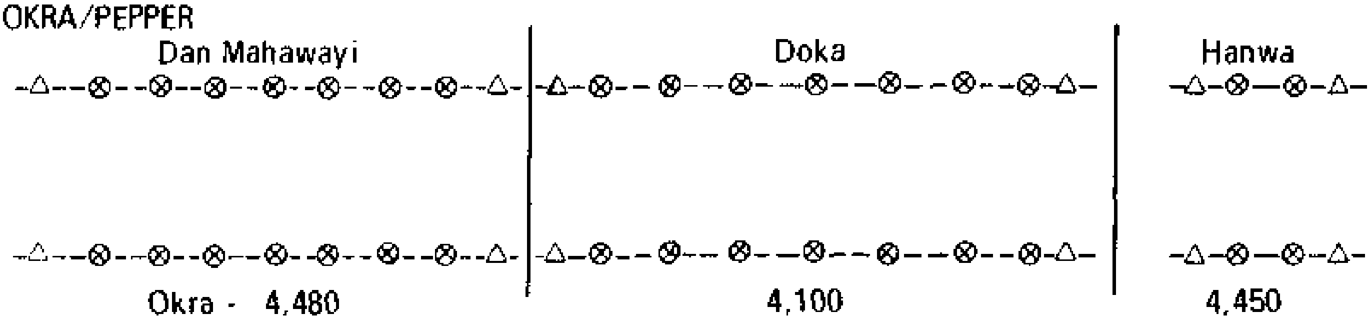
COWPEA/COTTON



SWEET POTATO/COTTON



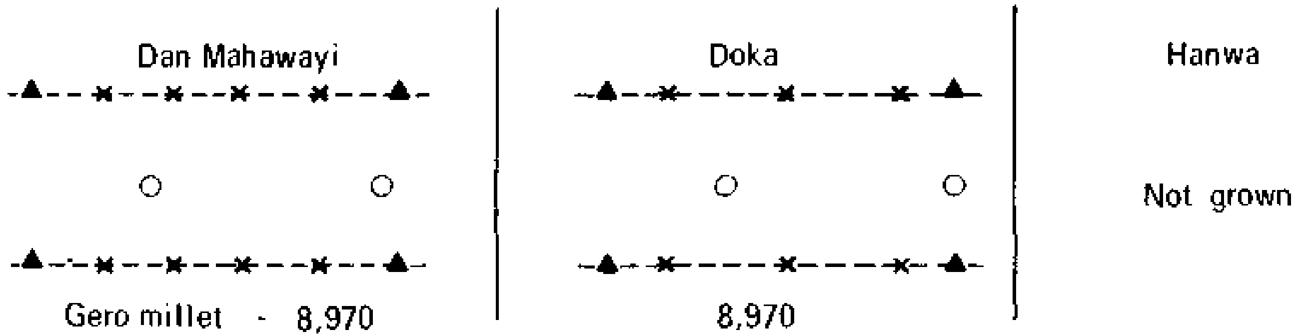
OKRA/PEPPER



	Dan Mahawayi	Doka	Hanwa
Okra	4,480	4,100	4,450
Pepper	31,380	28,680	28,690

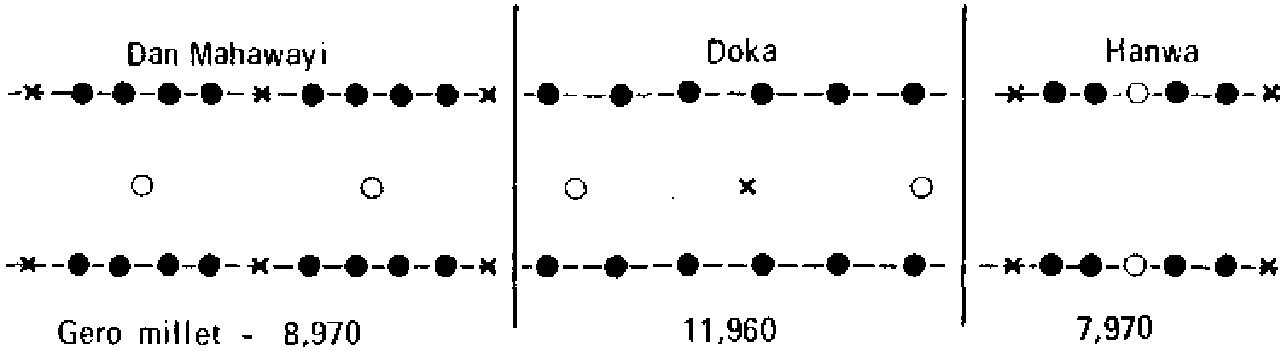
THREE CROP MIXTURES

GERO MILLET/MAIWA MILLET/SORGHUM



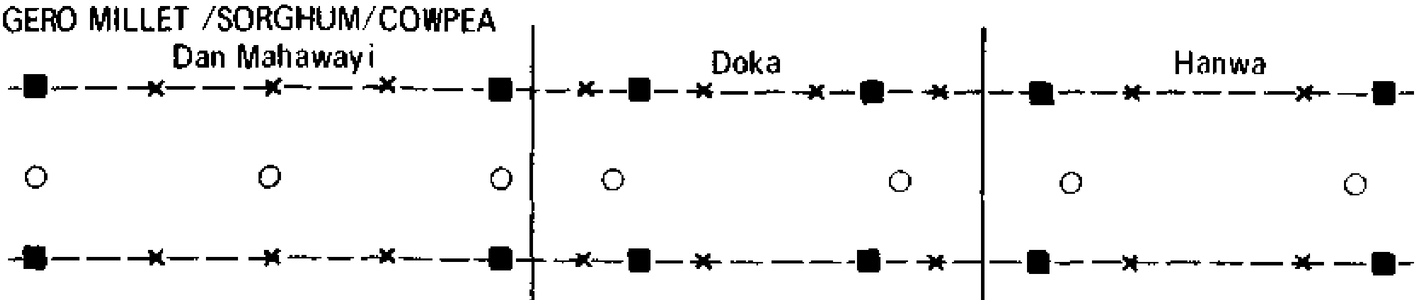
	Dan Mahawayi	Doka
Gero millet	8,970	8,970
Maiwa millet	5,740	5,980
Sorghum	22,960	17,930

GERO MILLET/SORGHUM/GROUNDNUT



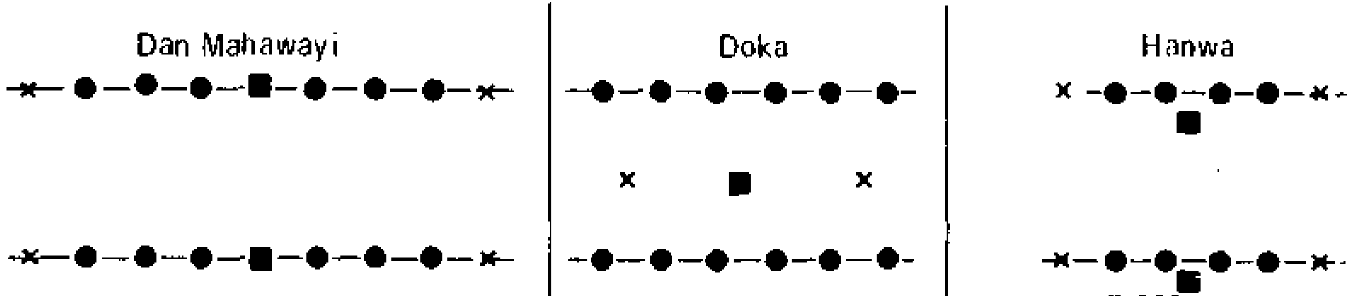
	Dan Mahawayi	Doka	Hanwa
Gero millet	8,970	11,960	7,970
Sorghum	8,970	11,960	7,970
Groundnut	35,860	28,690	31,880

GERO MILLET /SORGHUM/COWPEA



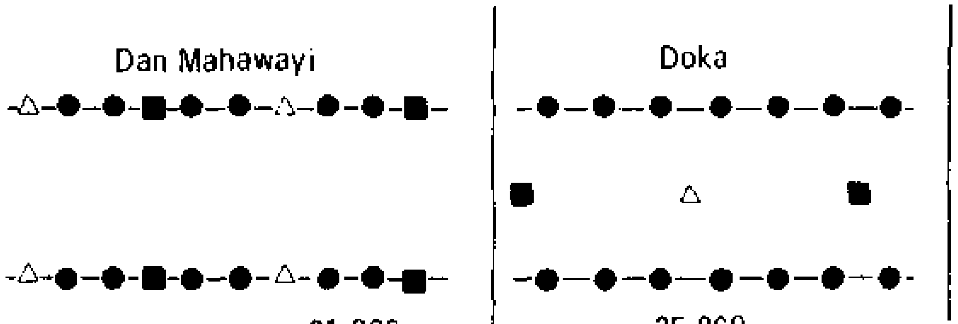
	Dan Mahawayi	Doka	Hanwa
Gero millet	8,970	7,170	7,170
Sorghum	13,450	17,930	11,960
Cowpea	4,480	8,970	5,980

SORGHUM/GROUNDNUT/COWPEA



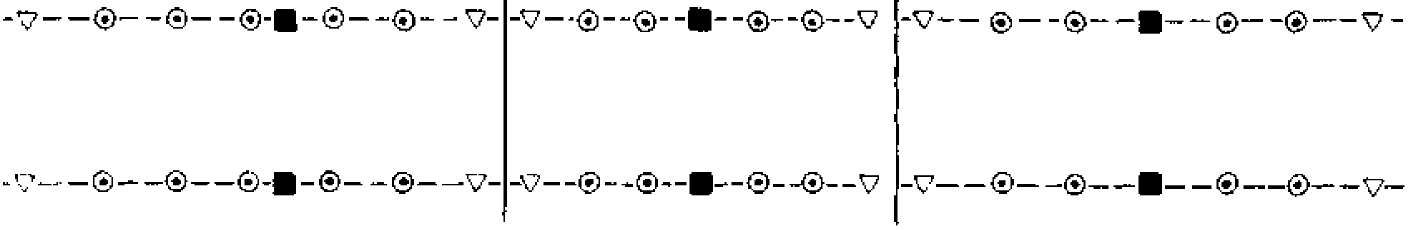
	Dan Mahawayi	Doka	Hanwa
Sorghum	4,480	8,970	7,980
Groundnut	26,900	35,860	31,880
Cowpea	4,480	8,970	7,970

GROUNDNUT/COWPEA/OKRA



	Dan Mahawayi	Doka	Hanwa
Groundnut	31,880	35,860	Not grown
Cowpea	7,970	5,980	
Okra	7,970	5,980	

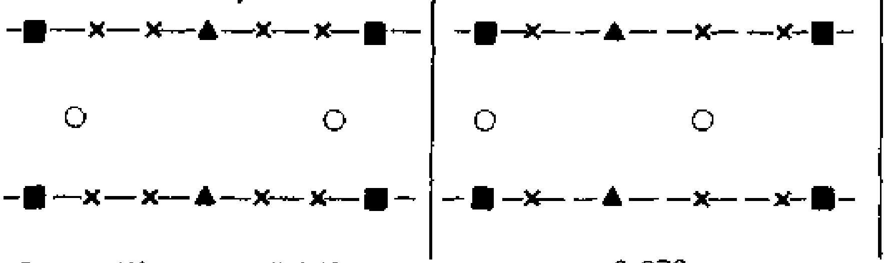
COWPEA/SWEET POTATO/COTTON



	Dan Mahawayi	Doka	Hanwa
Cowpea	4,480	5,980	4,480
Sweet potato	4,480	5,980	4,480
Cotton	22,420	23,910	18,180

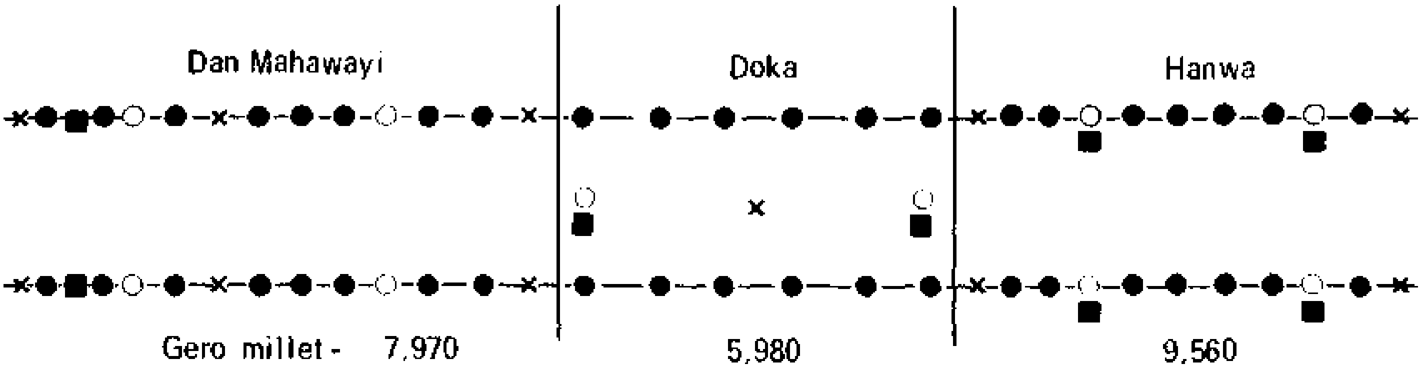
FOUR CROP MIXTURES

GERO MILLET/MAIWA MILLET/SORGHUM/COWPEA



	Dan Mahawayi	Doka	Hanwa
Gero millet	7,970	8,970	Not grown
Maiwa millet	5,980	5,980	
Sorghum	23,910	17,930	
Cowpea	5,980	5,980	

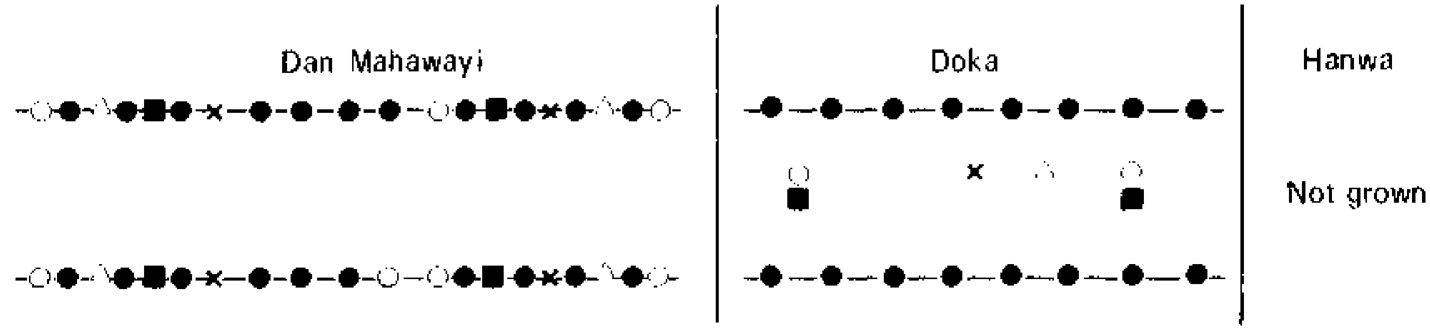
GERO MILLET/SORGHUM/GROUNDNUT/COWPEA



Gero millet -	7,970	5,980	9,560
Sorghum -	7,970	5,980	4,780
Groundnut -	31,870	28,690	33,470
Cowpea -	3,980	5,980	9,560

FIVE CROP MIXTURES

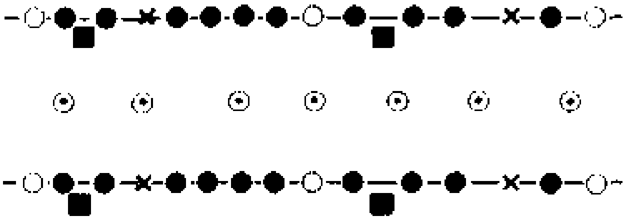
GERO MILLET/SORGHUM/GROUNDNUT/COWPEAS OKRA



Gero millet -	6,470	6,470
Sorghum -	6,470	6,470
Groundnut -	35,860	33,110
Cowpea -	6,470	6,470
Okra -	6,470	6,470

GEROMILLET/SORGHUM/GROUNDNUT/COWPEA/COTTON

Dan Mahawayi



Gero millet - 7,170
Sorghum - 7,170
Groundnut - 35,860
Cowpea - 7,170
Cotton - 24,400

Doka & Hanwa

Not grown explicitly. Cotton appearing is from the previous year's crop.

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