COURSE CODE:	**PCP 505**
COURSE TITLE:	**CROP NPRODUCTION II ARABLE**
NUMBER OF UNITS:	**3 UNITS**
COURSE DURATION:	**Three hours per week**

COURSE DETAILS:

Course Coordinator: **Dr. A. A. Oyekanmi.; M.Sc., Ph.D**
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Office Location: **Colplant Building Room 145**
Other Lecturers: **Prof. J.A. Adigun and Dr. S.O. Adigbo**

COURSE CONTENT:

This is a compulsory course for all final year students in COLPLANT. In view of nthis,students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

COURSE REQUIREMENTS:

This is a compulsory course for all students in the University. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

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LECTURE NOTES

CEREALS.

The origin, economic importance, morphological description and agronomy of four most important cereals (Wheat (*Triticum aestivum L*), Rice (*Oryza sativa L.*), Maize (*Zea Mays L.*), and Sorghum *(Sorghum bicolor (L.) Moench)*) in the food security of Nigeria are discussed.

WHEAT (Triticum aestivum L.)

Family

Poaceae (Gramineae)

Origin

The Bread wheat originated from Armenia in Transcaucasia to the south-west coastal areas of the Caspian Sea in Iran. The Hybridization of a wild *Aegilops* species (*Aegilops tauschii* Coss., with the D-genome) with emmer, an old type of cultivated wheat belonging to *Triticum turgidum* L., gave rise to the hexaploid wheats i.e bread wheat (Triticum aestivum L.) and spelt wheat (*Triticum spelta* L.). The D-genome conferred on bread wheat and spelt wheat the adaptation to cold winters and humid summers thus allowing them to conquer temperate Europe and Asia.

ECONOMIC IMPORTANCE

According to FAO estimates, the average world production of wheat grain (bread wheat and durum wheat together) in 1999–2003 amounted to 576 million t/year from 209 million ha. Worldwide, bread wheat constitutes more than 90% of the area under the cultivated wheats. Wheat production in tropical Africa in 1999–2003 was 2.5 million t/year from 1.6 million ha, and in Nigeria (75,000 t/year from 53,000 ha. The main importer in tropical Africa is Nigeria (1.9 million t/year in 1998–2002),

CULTIVATED SPECIES

- Common wheat or Bread wheat (*T. aestivum*) – A hexaploid species that is the most widely cultivated in the world.
- Durum (*T. durum*) – The only tetraploid form of wheat widely used today, and the second most widely cultivated wheat.
- Einkorn (*T. monococcum*) – A diploid species with wild and cultivated variants.
- Emmer (*T. dicoccum*) – A tetraploid species, cultivated in ancient times but no longer in widespread use.
- Spelt (*T. spelta*) – Another hexaploid species cultivated in limited quantities.

CLASSES

- Durum – Very hard, translucent, light-colored grain used to make semolina flour for pasta .
- Hard Red Spring – Hard, brownish, high-protein wheat used for bread and hard baked goods.
- Hard Red Winter – Hard, brownish, mellow high-protein wheat used for bread, hard baked goods.
- Soft Red Winter – Soft, low-protein wheat used for cakes, pie crusts, biscuits, and muffins.

- Hard White – Hard, light-colored, opaque, chalky, medium-protein wheat planted in dry, temperate areas. Used for bread and brewing.
- Soft White – Soft, light-colored, very low protein wheat grown in temperate moist areas.

MORPHOLOGICAL DESCRIPTION

Annual, tufted grass up to 150 cm tall, with 2–5(–40) tillers. The stem (culm) cylindrical, smooth, hollow except at nodes. The leaves distichously alternate, simple and entire; leaf sheath rounded, auricled; ligule membranous; blade linear, 15–40 cm × 1–2 cm, parallel-veined, flat, glabrous or pubescent. The inflorescence is a terminal, distichous spike 4–18 cm long, with sessile spikelets borne solitary on zigzag rachis. The spikelet 10–15 mm long, laterally compressed, 3– 9-flowered, with bisexual florets, but 1–2 uppermost ones usually rudimentary. The fruit is an ellipsoid caryopsis (grain), at one side with a central groove, reddish brown to yellow or white.

ECOLOGY.

Bread wheat is most successful between 30–60°N and 27–40°S. The optimum temperatures for development are 10–24°C, with minima of 3–4°C and maxima of 30–32°C. Average temperature of about 18°C is optimal for yield. Temperatures above 35°C stop photosynthesis and growth, and at 40°C the heat kills the crop. In the tropics it is best grown at higher elevations (1200–3000 m) or in the cooler months of the year as Wheat does not grow well under very warm conditions with high relative humidity. At least 250 mm water required during the growing season for a good crop; it can be grown in areas that receive 250–750 mm rain annually. Wheat flower earlier at long daylengths, but do not require a particular daylength to induce flowering. The soils should be well aerated, well drained, and deep, with 0.5% or more organic matter. Optimum soil pH ranges between 5.5 and 7.5. Wheat is sensitive to soil salinity.

PROPAGATION AND PLANTING

Propagation is by seed. The 1000-seed weight is 30–50 g. Make use of seeds that has been treated with fungicides against soil- and seed-borne diseases. Wheat is sown by hand or machine. Seeds can be broadcast, drilled, or dibbled and incorporated in the soil using an animal-drawn plough or machine-drawn disc. The common seed rates are 150–200 kg/ha for broadcasting and 75–120 kg/ha for row-planting. The optimum spacing is 10–25 cm between rows, but it may extend up to 35 cm. The sowing depth is 2–5(–12) cm, with deeper planting required in dry conditions. At a sowing depth beyond 10–12 cm seedling emergence is poor. For rainfed wheat, the seed can be dry-sown, before the start of the rainy season, or when the soil is moist. Bread wheat is usually grown in sole cropping.

GROWTH AND DEVELOPMENT

Germination occurs at temperatures of 4–37°C, the optimum is 12–25°C. The radicle emerges first and the coleoptile emerges 4–6 days after germination. The first true leaf of the seedling emerges from the coleoptile. The primary roots may remain functional for life unless destroyed by disease or mechanical injury. Secondary roots start to develop about 2 wks after seedling emergence. They arise from the basal nodes and form the permanent root system, which spreads out and may penetrate as deep as 2 m, but normally not more than 1 m. Leaf and tiller production increase rapidly soon after crop emergence. The duration of the vegetative stage may vary from 20–150 days depending on temperature and the cultivar's vernalization and daylength response. For floral induction, spring types usually require temperatures between 7°C and 18°C for 5–15 days, while winter types require temperatures between 0°C and 7°C for 30–60 days. Flowering begins at the middle third of the spike and continues towards the basal and apical parts in 3–5 days. All spike-bearing tillers eventually flower almost simultaneously. Wheat is normally self-pollinated; cross-pollination is 1–4%. Pollen is largely shed within the floret. Stigmas remain receptive for 4–13 days. Pollen is viable for up to 30 minutes only. Grains in the centre of the spike and in the proximal florets tend to be larger than the other ones. Physiological maturity is reached when the flag leaf (uppermost leaf) and spikes turn yellow and the moisture content of the fully formed grain has dropped to 25–35%. The complete crop cycle of bread wheat varies from 50–200 days in tropical Africa.

MANAGEMENT

Uniform crop stand and early vigour discourage weed growth in bread wheat. Tillering allows the crop to compensate for poor stands and variable weather conditions. Yield losses due to weeds are caused by early competition in the first 4–5 weeks. Hand weeding, tillage practices, stubble management, pre-sowing irrigation, proper crop rotation and herbicides may control weeds. In Nigeria wheat production is restricted to the river basin irrigation schemes of the northern states. The mean nutrient removal per 1 t/ha of grain is 40–43 kg N, 5–8 kg P, 25–35 kg K, 2–4 kg S, 3–4 kg Ca, 3–3.5 kg Mg, and smaller amounts of micronutrients. The exact values depend on the available nutrients and water in the soil, the temperature, and the cultivar. Average fertilizer rates range from 9 kg N and 10 kg P on rainfed wheat to 180 kg N, 84 kg P and 50 kg K on irrigated wheat. Boron deficiency, resulting in grain set failure, can be observed on certain soils. Wheat is best rotated with non-grass crops, particularly with pulses. In some regions double cropping systems are common, with irrigated wheat grown in the cool dry season and crops such as cotton, sorghum, maize, soya bean and groundnut in the hot rainy season..

DISEASES

- Stripe rust or yellow rust (*Puccinia striiformis*), spread by air-borne uredospores.
- Septoria leaf blotch (*Septoria tritici*, synonym:*Mycosphaerella graminicola*).
- Stem rust or black rust (*Puccinia graminis*)
- Common bunt (*Tilletia* spp.),
- loose smut (*Ustilago tritici*, synonym:*Ustilago nuda* f.sp. *tritici*),
- Bacterial leaf streak or black chaff (*Xanthomonas translucens*).

PESTS

- Important insect pests are aphids, which may also transmit viruses.
- The African migratory locust (*Locusta migratoria*) is a periodic pest.
- The Hessian fly (*Mayetiola destructor)*
- Important storage insects, include *Sitophilus* spp. on whole grains
- *Tribolium* spp. and *Ephestia cautella* (synonym: *Cadra cautella*, flower moth) on wheat flour.
- Clean storage conditions and maintaining grain moisture and temperature at sufficiently low levels inhibit insect activity and development. Rodents, mainly the black rat (*Rattus rattus*), also damage stored seeds.

YIELD

The mean yield of wheat in tropical Africa is estimated at about 1.5 t/ha. Lower yields are due to high temperature, high humidity, disease pressure and the low levels of fertilizer applied. Maximum recorded grain yields of irrigated winter and spring wheats are 14 and 9.5 t/ha, respectively; the absolute maximum yield, based on genetic potential, is estimated at 20 t/ha.

HANDLING AND HARVEST

Threshed grain of bread wheat is winnowed, cleaned and prepared for store or market. Seeds should be dried to a moisture content of 13–14% for safe storage. High temperatures and moist conditions may result in spoilage. Regular re-drying may be necessary to maintain seed viability, if the seed is not stored in an airtight container.

NUTRITIONAL COMPOSITION

The composition of wheat grain is 7–8% coat material, 90% endosperm and 2–3% embryo. The embryo mainly comprises oil and protein, and little starch. The endosperm is starchy, and is surrounded by the aleurone layer which is rich in proteins. When a wheat grain is milled, the outer layers and embryo are separated from the endosperm. The pulverized endosperm becomes wheat flour, while the other parts form the bran. Hard bread wheat grain is best suited for bread making while the soft wheat grain is best for cookies, cakes and pastries. Flour colour varies from white to slightly yellow

USES

- Bread wheat flour is made into bread, pastries, crackers, biscuits, noodles, breakfast foods, baby foods and food thickeners. It is also used as a brewing ingredient in certain beverages (white beer). Industrial uses of wheat products centre on the production of glues, alcohol, oil and gluten. By-products of flour milling, particularly the bran, are used almost entirely to feed livestock, poultry or prawns. Wheat germ (from wheat embryos) is sold as a human food supplement. Straw is fed to ruminants or used for bedding material, thatching, wickerwork, newsprint, cardboard, packing material, fuel and as substrate for mushroom production. In many dry parts of the world it is chopped and mixed with clay to produce building material.

RICE (Oryza sativa L.)

Family

Poaceae (Gramineae)

ORIGIN

Oryza sativa evolved in Asia, but the exact time and place of its domestication are not known for certain. Remains of rice in China have been dated to 6500 BC; the earliest archaeological evidence from India goes back to 2500 BC. *Oryza sativa* was brought from Asia into tropical Africa along different routes. Most probably *Oryza sativa* migrated from Egypt, where it was introduced about 800–900 AD, to West Africa. The final penetration of *Oryza sativa* into Africa was along the slave trading routes from the East African coast and Zanzibar to DR Congo from about 1500 AD onwards. Nowadays it is cultivated throughout the humid tropics and in many subtropical and temperate areas with a frost-free period longer than 130 days

ECONOMIC IMPORTANCE

According to FAO estimates the average annual world production during 1999–2003 was 593 million t paddy (unhusked grain) from 153 million ha. Asia accounts for 90% of the world production and area. During 1999–2003 tropical Africa produced on average 11.9 million t paddy (2% of world production) annually on 7.7 million ha (5% of world area); these data include African rice (*Oryza glaberrima* Steud.), which occupies less than 20% of the rice area in West Africa. Nigeria produced 3.5 million t from 2.9 million ha. Thailand is the world's largest exporter of milled rice (26% of world trade during 1998–2002) followed by Vietnam, India, the United States, China and Pakistan.
Main rice importers are Nigeria, Senegal and Côte d'Ivoire. Per capita annual milled rice consumption in tropical Africa varies tremendously between 0.15 kg and 95 kg with an average of about 18 kg for the period 1998–2002.

CULTIVATED SPECIES.

The New Rice for Africa (NERICA) has been spreading rapidly in sub-Saharan Africa(SSA) since the seeds of the high yielding rice varieties was introduced in 1996. In 2006, a onservative estimate of area grown to NERICA varieties in SSA was about 200,000 hectares.
West African rice ecosystem are conventionally classified as irrigated, rainfed-lowland, rainfed-upland, mangrove swamp and deep-water systems. The total area under rice cultivation is currently about 4.4 million hectares (ha), with the rainfed upland and rainfed lowland ecosystems each accounting for about 1.7m ha and irrigated rice for another 0.5m ha, making these the high-impact ecologie

Total area (hectares) under rice cultivation in various ecologies in Nigeria.

Country	Total area (ha)	Mangroove swamp	Deep water	Irrigated lowland	Rainfed lowland	Rainfed upland
Nigeria	1,642,000	16,420	82,100	262,720	788,160	492,600

Source: Lançon F. and O. Erenstein (2002).

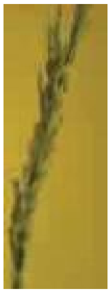
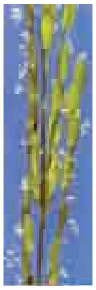
NERICA

NERICA growing very well in a farmer's field (WARDA, 2006)

NERICA is a genetic material derived from successful crossing of the two species of cultivated rice, the African rice (O. Glabberima steud.) and Asian rice (O.sativa L.) to produce a progeny (known as interspecifics) that combines the best traits of both parents. These includes high yield from the Asian parent and ability from the African parent to thrive in harsh environment.

O.Sativa as female parent

O.Glabberima as male parent

NERICA is produced through conventional crossbreeding and therefore not a genetically modified rice.

In 2000 WARDA named NERICAS 1-7 and in December 2005 WARDA named upland NERICAS 8-18.

Other improved varieties.

- ITA 150 * ITA321 * ITA360
- ITA235 * ITA257 * ITA128

MORPHOLOGICAL DESCRIPTION

Annual grass up to 1.8 m tall (up to 5 m long in some floating types), forming small tufts; roots fibrous, arising from the base of the shoots; stem (culm) erect or ascending from a geniculate base. Leaves alternate, simple; sheath coarsely striate, tight when young, later somewhat loose, ligule 1.5–3 cm long,; auricles often present, falcate, 1–5 mm long. Inflorescence a terminal panicle up to 50 cm long, erect, curved or drooping, with 50–500 spikelets; branches solitary or clustered, nearly erect to spreading. Spikelet solitary, asymmetrically oblong to elliptical-oblong, 7–11 mm × 2.5–3.5 mm. Fruit a caryopsis (grain), ovoid, ellipsoid or cylindrical, 5–7.5 mm × 2–3.5 mm, often whitish yellow or brown to brownish grey.

ECOLOGY

Rice grows on dry or flooded soil and at elevations ranging from sea level to at least 2400 m. The average temperature during the growing season varies from 20–38°C. Night temperatures below 15°C can cause spikelet sterility. Temperatures above 21°C at flowering are needed for anthesis and pollination. Upland rice requires an assured rainfall of at least 750 mm over a period of 3–4 months and does not tolerate desiccation. Lowland rice tends to be concentrated in flat lowlands, river basins and deltas. The average water requirement for irrigated rice is 1200 mm per crop or 200 mm of rainfall per month or an equivalent amount from irrigation. Traditional cultivars are generally photoperiod sensitive, and flower when daylengths are short (critical daylength of 12.5–14 hours). Many modern cultivars are photoperiod insensitive.
The soils on which rice grows vary greatly: texture ranges from sand to clay, organic matter content from 1–50%, pH from 3–10, salt content up to 1%, and nutrient availability from acute deficiencies to surplus. Rice does best in fertile heavy soils. The optimum pH for flooded soil is 6.5–7.0. The often sandy texture of soils in tropical Africa is a constraint to productivity due to drought stress, low inherent soil fertility and leaching. Groundwater salinity problems occur in the dry Sahel zone where rice is grown under irrigation.

PROPAGATION AND PLANTING

Rice is propagated by seed. The 1000-seed weight is 20–35 g. The seed may either be broadcast or drilled directly in the field, or seedlings may be grown in nurseries and transplanted. Direct seeding is done in dry or puddled soil. In puddled soil the (pre-germinated) seeds are broadcast. After sowing the water level is kept at 0–5 cm under tropical conditions. In dry soil the seeds are sown just before or after land preparation. In the latter case the seeds are then covered lightly with soil. The seeds are sown just before the rains begin and germination occurs after heavy continuous rains. This method makes it possible to have initial crop growth from early rains.

In tropical Africa various rice-growing systems are distinguished:

– Upland rice, which may be subdivided into dryland rice, whereby moisture supply is entirely dependent on rainfall, and hydromorphic rice where the rooting zone is periodically saturated by a fluctuating water table, in addition to rainfall;

– Lowland rice, including mangrove swamp rice along the coastal regions with tidal intrusion, inland swamp rice on flat or V-shaped valley bottoms with varying degrees of flooding, and rice on bunded fields under rainfed or irrigated conditions;

– Deepwater rice, in which the rapid growth of the internodes keeps pace with the rising water up to 5 m or more, starting from 50 cm of standing water.

In upland rice cultivation the fields are normally cleared through the slash-and-burn practice. Soil preparation is normally minimal. The rice is broadcast or dibbled when the rains start. It is often grown as the first crop in rotation or intercropped with other crops such as cassava, maize, sorghum, cowpea, groundnut and other pulse crops.

In lowland rainfed-rice areas the land is mostly prepared while it is wet and only in rare occasions when it is dry. The wetland tillage method consists of soaking the land until the soil is saturated, ploughing to a depth of 10–20 cm using a plough drawn by oxen/small machines or by using a hand hoe, preferably when there is a little water on the land, and harrowing, during which big clods of soil are broken and puddled with water. The important benefits of puddling include the apparent reduction of moisture loss by percolation, better weed control, and easy transplanting. In lowland rice cultivation seedlings are mostly raised on wet nursery beds and sometimes on dry nursery beds. Wet nursery beds are made in the puddled or wet field. Normally farmers use 50–60 kg of rice seeds to plant one ha. Seeds are pre-germinated and spread on the bed which is kept constantly wet. Dry nursery beds are prepared near the water source before land preparation. The seeds are sown and then covered with a thin layer of soil and watered until saturation for uniform germination. Further watering is applied as needed. In both cases the seedlings are ready for transplanting 20–35 days after sowing. At transplanting heavy tillering cultivars in fertile valley bottoms are wider spaced (30 cm × 30 cm) than slightly tillering cultivars in upper, sandy fields (20 cm × 20 cm). The spacing in irrigated rice is normally 20 cm × 20 cm with 2–4 plants per hill (500, 000–1,000,000 plants/ha). Rice is generally a sole crop under lowland conditions. Near harvest, relay planting is rarely practised. In many parts of the tropics 2 or even 3 crops of rice can be grown per year.

GROWTH AND DEVELOPMENT

Rice seed germinates in 24–48 hours. The optimum temperature for germination is 30–32°C.. Ten days after germination the plant becomes independent as the seed reserve is exhausted. Tillering begins thereafter, although it may be a week later in transplanted seedlings. In modern cultivars with an average maturation period, maximum tillering stage is attained around 45 days after transplanting and coincides with panicle initiation. The duration of the vegetative stage ranges from 7 to more than 120 days. The reproductive stage starts at panicle initiation, and the period from panicle initiation to flowering is around 35 days. Rice is almost 100% self-pollinating, but small amounts of cross pollination by wind do occur. It takes around 7 days to complete the anthesis of all spikelets in a panicle, starting from the top and progressing downwards. The period from flowering to full ripeness of all the grains in a panicle is usually about 30 days. Low temperature can delay maturity and high temperature accelerates it.

MANAGEMENT

The agronomy of rice is diverse due to the differences in cultivation systems. Growing of upland rice is usually relatively labour-extensive, but transplanting rice by hand in puddled soil is a labour-intensive operation. Weeding is generally not necessary in the first 2 weeks. Manual and chemical weeding are common practice

In the cultivation of lowland rice, the land is inundated from the time of planting until the approach of harvest. The water is supplied either by flooding during the rainy season, by growing the crop in naturally swampy land or by controlled irrigation. The water level is kept at a height of 5–15 cm to suppress weed growth and to ensure water availability. Continuous flooding at a static 2.5–7.5 cm depth is best. The fields may be drained temporarily to facilitate weeding and fertilizing. At flowering the water level is gradually reduced until the field is almost dry at harvest. Generally 1.5–2 m of water (rainfall plus irrigation) are required to produce a good crop. The period in which rice is most sensitive to water shortage is from 20 days before to 10 days after the beginning of flowering.

The amount of fertilizer used is usually 60–120 kg N, 10–20 kg P and 0–30 kg K per ha. Higher nitrogen rates are used during the dry season when solar radiation is higher and increase in grain yield is larger. Generally, nitrogen fertilizer is only topdressed, mostly before or at panicle initiation. Fertilizer is broadcast by hand.

The most common mineral deficiencies in rice cultivation are of nitrogen and phosphorus, with potassium and sulphur in limited areas and sometimes zinc and silicon on peaty soils.

The degree of mechanization is in general limited in rice cultivation in tropical Africa. Occasionally farmers use tractors or small two-wheel power tillers for land preparation and powered threshing machines during harvest.

For various reasons many rice fields are left fallow in the dry season. In areas with suitable climatic and soil conditions for dry-season cultivation, rice may be rotated with crops such as other cereals, pulses and vegetables.

DISEASES

Blast (*Pyricularia grisea*, synonym: *Pyricularia oryzae*). Although this disease is often related to drought stress and therefore especially severe in upland and drought-prone areas, it may also be severe elsewhere.

Bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*),

Rice yellow mottle virus (RYMV, only found in Africa),

Brown spot (*Cochliobolus miyabeanus*),

Leaf scald (*Microdochium oryzae*),

Sheath blight (*Thanatephorus cucumeris*),

Narrow brown leaf spot (*Cercospora janseana*)

Sheath rot caused by *Sarocladium oryzae.*

Nematodes attack roots and young, unfurled leaves and reduce rice production in certain parts of tropical Africa.

PESTS

White stem borer (*Maliarpha separatella*),

Pink stem borers (*Sesamia* spp.)

Striped stem borer (*Chilo* spp.). Damage results from larvae feeding within the stem, severing the vascular system.

Dead heart is the damage to the tiller before flowering.

White head is the damage after flowering which causes the entire panicle to dry.

Stalk-eyed fly (mainly*Diopsis macrophthalma*) resembles the dead heart damage from stem borers as it generally attacks the rice plant at the early tillering stage.

Gall midge maggot (*Orseolia oryzivora*) stimulates the leaf sheath to grow into a gall and tillers with galls do not bear panicles.

Termites and mole crickets attack rice plants especially in rainfed upland rice.

Pests of stored rice are the rice weevil (*Sitophilus oryzae*)

Grain borer (*Rhyzopertha dominica*). These insects can completely destroy the grain.

HARVESTING.

Grain should be harvested before it is fully mature (around 21–24% moisture), usually about 30 days after flowering, or when 90% of the grains are firm and do not have a greenish tint. Wetting and drying cause grain cracking, cracks being formed more readily when the grain is quite hard. Harvesting by hand, the commonest method, is very labour-intensive. In some areas a small knife is used, but in many areas farmers use a sickle to cut the panicles plus some or all of the culms. Mechanical harvesters are very rare in tropical Africa. The harvested rice plants are either allowed to dry in the field or bundled for processing in a selected area.

YIELD

Average rice yields are 1.4 t/ha in tropical Africa, 4.1 t/ha in Asia and 4.0 t/ha in the world in general. Yields are generally higher during the dry season than during the wet season, and higher in lowland rice than in upland rice. The yield of upland rice varies between 0.5 and 1.5 t/ha in tropical Africa

HANDLING AFTER HARVEST

Threshing is generally done by hand, by beating the bundles on a stone or drum, or by beating the panicles with wooden sticks on a canvas. However, motorized and pedal-driven threshing machines are becoming popular. Winnowing is usually done by shaking and tossing the grain on a basket-work tray with a narrow rim.
Proper drying of the rice grains is important to prevent germination and rapid loss of quality. Optimum moisture content for storage is 12.5%. Rice grain is mostly stored in sacks after drying.
In rice milling the aim is to avoid breaking the kernels because whole kernels command a higher price. There are different methods of milling. On milling, the grain gives approximately: husk 20%, whole kernels 50%, broken kernels 16%, bran and meal 14%. The husked or hulled rice is usually called brown rice, and this is then milled to remove the outer layers, after which it is polished to produce white rice. During milling and polishing some of the protein and much of the fat, minerals and vitamins are removed, reducing the nutritional value but increasing storability and reducing cooking time. Parboiling (soaking, boiling and drying) before milling improves the nutrient value of the grains but it is not common in tropical Africa.

NUTRITIONAL COMPOSITION

Raw brown rice contains per 100 g edible portion: water 13.9 g, energy 1518 kJ (363 kcal), protein 6.7 g, fat 2.8 g, carbohydrate 81.3 g, dietary fibre 3.8 g, Ca 10 mg, Mg 110 mg, P 310 mg, Fe 1.4 mg, Zn 1.8 mg, thiamin 0.59 mg, riboflavin 0.07 mg, niacin 5.3 mg, vitamin B_6 0.56 mg, folate 49 µg, ascorbic acid 0 mg.
Raw polished rice contains per 100 g edible portion: water 11.7 g, energy 1536 kJ (367 kcal), protein 6.5 g, fat 1.0 g, carbohydrate 86.8 g, dietary fibre 2.2 g, Ca 4 mg, Mg 13 mg, P 100 mg, Fe 0.5 mg, Zn 1.3 mg, thiamin 0.08 mg, riboflavin 0.02 mg, niacin 1.5 mg, vitamin B_6 0.30 mg, folate 20 µg, ascorbic acid 0 mg (Holland, Unwin & Buss, 1988).

USES

The rice grain is cooked by boiling or steaming, and eaten mostly with pulses, vegetables, fish or meat. Flour from rice is used for breakfast foods, baby foods, bread and cake mixes

and cosmetics. Starch made from broken rice is used as laundry starch and in foods, cosmetics and textile manufacture. Beers, wines and spirits are made from rice.
The husk or hull is used as fuel, bedding, absorbent, packing material and as carrier for vitamins and drugs; it is also made into building board. The charred hull is used for filtration of impurities in water, a medium for hydroponics and manufacture of charcoal briquettes. Rice bran or meal obtained in pearling and polishing is a valuable livestock and poultry feed. Oil is extracted from the bran. Rice straw is used for animal feed and bedding, for the manufacture of straw boards and pulp for paper, for the production of compost and mushroom growing medium, for mulching vegetable crops, for making ropes, sacks, mats and hats, for roof thatching, and to make plastering material (mixed with clay mud) for the construction of houses, and for incorporation into the soil or burning on the field as a way to maintain/improve soil fertility.

MAIZE (Zea mays L.)

Family

Poaceae (Gramineae)

ORIGIN

Maize was domesticated in southern Mexico around 4000 BC. Early civilizations of the Americas depended on maize cultivation. When the Europeans arrived in the Americas, maize had already spread from Chile to Canada. Maize was reported for the first time in West Africa in 1498, six years after Columbus discovered the West Indies.

Maize has an extremely wide distribution. It is grown in all countries of Africa, from the coast through savanna regions to the semi-arid regions of West Africa, and from sea-level to the mid- and high-altitudes of East and Central Africa.

STREAK AND DOWNY MILDEW RESISTANT VARIETIES

- DMR-LSR-W
- DMR-ESR-W
- Suwan 1-SR

* DMR-LSR-Y
* DMR-ESR-Y

OPEN POLLINATED VARIETIES

- TZL Comp4-DMR
- TZL Comp3x4CO
- AK93DMR-LSR
- AL9322-DMR-SR

GREEN MAIZE VARIETIES

- ART-98-STW1/OLOYIN ;high carotene content, 14% crude protein and medium maturing 88-95days.
- ART98SW10B
- ART98SW20B e.t.c

MORPHOLOGICAL DESCRIPTION

Robust annual grass up to 4(–6) m tall; root system consisting of adventitious roots, developing from the lower nodes of the stem near the soil surface, usually limited to the upper 75 cm of the soil, but single roots sometimes penetrating to a depth of over 2 m; stem (culm) usually single and simple, solid. Leaves alternate, simple; leaf sheaths overlapping, auricled at the top; ligule c. 5 mm long, colourless; blade linear-lanceolate, 30–150 cm × 5–15 cm, acuminate, margins smooth, midrib pronounced. Male and female inflorescences separate on the same plant; male inflorescence (‘tassel’) a terminal panicle up to 40 cm long; female inflorescence a modified spike, usually 1–3 per plant in leaf axils about half way up the stem, composed of a thick spongy axis with paired sessile spikelets. Has a single superior ovary and a long threadlike style and stigma (‘silk’) up to 45 cm in length and emerging from the top of the inflorescence, receptive throughout most of its length. Fruit a caryopsis (grain), usually obovate and wedge-shaped, variously coloured from white, through yellow, red and purple to almost black, up to 1000 together in an infructescence (‘cob’) enclosed by modified leaves up to 45 cm × 8 cm.

ECOLOGY

Maize is adapted to a wide range of environments, but it is essentially a crop of warm regions where moisture is adequate. The bulk of the crop is grown in tropical and subtropical regions. Maize is generally less suited to semi-arid or equatorial climates, although drought-tolerant cultivars adapted to semi-arid conditions are now available. The crop requires an average daily temperature of at least 20°C for adequate growth and development; the optimum temperature for growth and development is 25–30°C; temperatures above 35° reduce yields. Frost is not tolerated. Maize requires abundant sunlight for optimum yields. The time of flowering is influenced by photoperiod and temperature; maize is considered a quantitative short-day plant. Maize is less drought-resistant than sorghum, pearl millet and finger millet. In the tropics it does best with 600–900 mm well-distributed rainfall during the growing season. It is especially sensitive to drought and high temperatures around the time of flowering. Maize performs best on well-drained, well-aerated, deep soils containing adequate organic matter and well supplied with nutrients. The high yield of maize is a heavy drain on soil nutrients and maize is therefore often grown as a first crop in the rotation. It can be grown on soils with a pH of 5–8, but 5.5–7 is optimal. It does not tolerate waterlogging and is sensitive to salinity. Since a young crop leaves much of the ground uncovered, soil erosion and water losses can be severe and attention should be paid to adequate soil and water

PROPAGATION AND PLANTING

Maize is propagated by seed mostly by direct sowing. The 1000-grain weight is 150–300 g. Sowing should preferably be done early in the season, as soon as soil conditions and temperature are favourable and the rainfall is well established. Planting by hand requires 5–10 man-days/ha. Seed is dropped in the plough furrow or in holes made with a planting stick or hoe. Planting may be done on hills or in rows, on flat land or on ridges. Ridging or heaping is usually done on heavy soils, to improve drainage. The seed rate is up to 25 kg/ha in sole cropping, and 10–15 kg/ha in intercropping. When maize is sown in rows, the spacing is usually 75–90 cm between rows and 25–50 cm within the row, with 1–3 seeds per pocket, resulting in a plant density of 40,000–80,000 plants/ha. Wide spacing results in more weed growth and increases erosion. To obtain a high yield, a uniform crop stand is very important, as the tillering capacity of maize is limited. The sowing depth is commonly 3–8 cm, depending on soil conditions and temperature. Deep sowing is recommended on light, dry soils. Sometimes animal manure or fertilizers are applied at the time of planting. Maize may be grown as a sole crop or in intercropping with other food crops such as common bean, cowpea, pigeon pea, groundnut, yam, cassava, sweet potato, pumpkin, melon or watermelon. In southern Nigeria two crops of maize are planted per year.

GROWTH AND DEVELOPMENT

The first leaf of maize emerges from the soil usually 4–6 days after planting. The minimum temperature for germination is 10°C; the optimum around 20°C. The plant sometimes has a few tillers that are of value in low density stands. Flower initiation is generally 20–30 days after germination. Maize is protandrous: in cultivars that mature in 4 months the male inflorescence emerges 50–60 days after planting and the styles of the female inflorescence appear about a week later. Maize is mature 7–8 weeks after flowering. The period from planting to harvesting varies considerably. It may be as short as 70 days in some extra early cultivars and as long as 200 days in some very late cultivars. Climatic conditions, latitude and altitude influence growth duration. In tropical highland areas it may take 9–10 months to maturity. Maize is predominantly cross-pollinating (90–95%), but is self-fertile. Maize follows the C_4-cycle photosynthetic pathway.

MANAGEMENT

Maize is very sensitive to weed competition during the first 4–6 weeks after emergence, and weed control is very important. Weeding is mostly done by hand, requiring at least 25 man-days/ha. Chemical weed control is gaining importance in tropical Africa, because hand weeding is time-consuming and expensive as a result of the increasing scarcity of labour. Ridging or earthing-up is sometimes practised. Most maize production in tropical Africa is rainfed. Occasionally it is grown on bunds in irrigation schemes. Maize usually responds well to fertilizers. A maize crop yielding 2 t grain and 5 t stover per ha removes about 60 kg N, 10 kg P and 70 kg K per ha from the soil. Maize has a high demand for nitrogen, which is often the limiting nutrient. High nitrogen levels should be applied in 2 doses; the first dose at planting or 2–3 weeks after emergence and the second one about 2 weeks before flowering. It is advisable to apply organic manures before ploughing to improve soil structure and supply nutrients. Maize is grown in rotation with groundnut, common bean, cowpea, cotton and tobacco. Rotation with soya bean is gaining popularity in northern Nigeria; it increases maize yields by providing nitrogen and by reducing parasitism.

DISEASES

Important fungal diseases of maize in tropical Africa are

- Rots affecting female inflorescences (*Fusarium* spp. and other fungi)
- Stalk-rot complex (*Diplodia maydis*, *Fusarium moniliforme*, *Macrophomina phaseoli* and*Pythium aphanidermatum*)
- Leaf blights (*Exserohilum turcicum* and *Bipolaris maydis*).
- Downy mildew (*Peronosclerospora sorghi*),
- smut (*Ustilago maydis*) and
- rusts (*Puccinia sorghi* and *Puccinia polysora*).
- Grey leaf spot (*Cercospora zeae-maydis*)
- The most important virus disease of maize is maize streak virus (MSV), which is restricted to Africa and may cause 100% yield loss. It is transmitted by leafhoppers (*Cicadulina* spp.) and is most serious in late-planted crops.
- Of lesser importance in tropical Africa are maize dwarf mosaic virus (MDMV),
- Maize chlorotic mottle virus (MCMV). Maize is relatively tolerant to nematodes occurring in tropical soils.

PESTS

- Cutworms (*Agrotis* spp.),
- Stem borers (especially *Busseola fusca*, *Eldana saccharina*, *Sesamia*

calamistis and *Chilo partellus*),
- Cob borer (*Mussidia nigrivenella*),
- Cotton bollworm (*Helicoverpa armigera*),
- Armyworm (*Spodoptera exempta*),
- Leafhoppers (*Cicadulina* spp.) and less commonly variegated grasshopper (*Zonocerus variegatus*).

* Common storage pests of maize are
- Grain moths (*Sitotroga cerealella* and *Ephestia cautella*),
- Grain weevils (*Sitophilus*spp.)
- Larger grain borer (*Prostephanus truncatus*).
- The parasitic witchweed (*Striga* spp.) is a serious constraint to maize production in many parts of tropical Africa, especially *Striga hermonthica* (Delile) Benth. in West and Central Africa.

YIELD

Maize has the highest yield potential among the cereal crops. The current average world yield of maize is 4.4 t/ha, but grain yields over 20 t/ha are possible. Average grain yields of maize in tropical Africa are about 1.25 t/ha, varying greatly from less than 1 t/ha for smallholders to about 6 t/ha in commercial farms.

HANDLING AND HARVEST

The major post-harvest problems of maize in most production areas are reducing the moisture content of the grain to 12–15%, protection from insects and rodents, and proper storage. A high grain moisture content combined with high ambient temperatures can cause considerable damage, making the product unsuitable for consumption by humans and livestock.

NUTRITIONAL COMPOSITION

The composition of mature white maize grain per 100 g edible portion is: water 10.4 g, energy 1527 kJ (365 kcal), protein 9.4 g, fat 4.7 g, carbohydrate 74.3 g, dietary fibre 7.3 g, Ca 7 mg, Mg 127 mg, P 210 mg, Fe 2.7 mg, Zn 2.2 mg, thiamin 0.39 mg, riboflavin 0.20 mg, niacin 3.6 mg, vitamin B_6 0.62 mg, folate 19 µg and ascorbic acid 0 mg. The essential amino-acid composition per 100 g edible portion is: tryptophan 67 mg, lysine 265 mg, methionine 197 mg, phenylalanine 463 mg, threonine 354 mg, valine 477 mg, leucine 1155 mg and isoleucine 337 mg

USES

Maize grain is used for three main purposes: as a staple food, as feed for livestock and poultry, and as a raw material for many industrial products. In tropical Africa nearly all maize grain is used for human food, prepared and consumed in many ways. It may be eaten fresh on the cob and simply roasted, but the grain is usually ground and the meal is boiled into porridge or fermented into beer. It is commonly eaten with cooked vegetables and, when available, meat. A thin porridge (‘ogi’ in Nigeria,) is also commonly eaten especially as weaning food.

SORGHUM (Sorghum bicolor (L.) Moench)

Family

Poaceae (Gramineae)

ORIGIN

The greatest diversity in both cultivated and wild types of *Sorghum* is found in north-eastern tropical Africa. The crop may have been domesticated in that region, possibly Ethiopia. Various hypotheses have been put forward as to when the crop was domesticated, from as early as 5000–3000 BC to around 1000 BC, but the latter period is more widely accepted now.

ECONOMIC IMPORTANCE

Sorghum grain is the fifth most important cereal in the world after wheat, rice, maize and barley. In Africa it comes second after maize in terms of production. According to FAO estimates, the average world production of sorghum grain in 1999–2003 amounted to 57.7 million t/year from 42.6 million ha. The production in sub-Saharan Africa was 19.0 million t/year from 22.8 million ha. Nigeria produces 7.6 million t/year from 6.9 million ha.

CULTIVATED SPECIES

The 5 basic races of Sorghum are:

– Bicolor: the most primitive cultivated sorghum.

– Caudatum: characterized by turtle-backed grains that are flat on one side and curved on the other. Cultivars are widely grown in north-eastern Nigeria. The types used for dyeing also belong here and are known as ‘karan dafi’ by the Hausa people in Nigeria.

– Durra: characterized by compact inflorescences. Most of them are drought resistant.

– Guinea: the grain is typically flattened.

– Kafir: have compact panicles that are often cylindrical in shape.

MORPHOLOGICAL DESCRIPTION

Annual grass up to 5 m tall, with one to many tillers. Stem (culm) solid, usually erect. Leaves alternate and simple. Inflorescence is a terminal panicle up to 60 cm long. Fruit is a caryopsis (grain), 4–8 mm in diameter, rounded and bluntly pointed.

ECOLOGY

Sorghum is primarily a plant of hot, semi-arid tropical environments that are too dry for maize. It is particularly adapted to drought due to a number of morphological and physiological characteristics, including an extensive root system, waxy bloom on leaves that reduces water loss, and the ability to stop growth in periods of drought and resume it when the stress is relieved. A rainfall of 500–800 mm evenly distributed over the cropping season is normally adequate for cultivars maturing in 3–4 months. Sorghum tolerates waterlogging and can also be grown in areas of high rainfall. It tolerates a wide range of temperatures and is also grown widely in temperate regions and at altitudes up to 2300 m in the tropics. The optimum temperature is 25–31ºC, but temperatures as low as 21ºC will not dramatically affect growth and yield. Sterility can occur when night temperatures fall below 12–15°C during the flowering period. Sorghum is susceptible to frost, but to a lesser extent than maize and light night-frosts during ripening cause little damage. Sorghum is a short-day plant with a wide range of reactions to photoperiod. Some tropical cultivars fail to flower or to set seed at high latitudes Sorghum is well suited to grow on heavy Vertisols commonly found in the tropics. The best growth is achieved on loams and sandy loams. Sorghum tolerates a range of soil pH from 5.0–8.5 and is more tolerant of salinity than maize. It is adapted to poor soils and can produce grain on soils where many other crops would fail.

PROPAGATION AND PLANTING

Sorghum is normally grown from seed. The 1000-grain weight is 13–40 g. Seed dormancy is not common in cultivated sorghum. A fine seedbed is preferable but is often not achieved. The seed is usually sown directly into a furrow following a plough, but can also be broadcast and harrowed into the soil. Optimum plant spacing depends on soil type and availability of moisture. In low-rainfall areas a population of 20,000 plants/ha is normal, in high-rainfall areas 60,000 plants/ha. For favourable conditions, spacings of 45–75 cm between rows and 15–25 cm within the row, resulting in 80,000–180,000 pockets per ha, are normal; for drier or less fertile conditions rows 1 m apart, or broadcasting at 6 kg seed per ha. A planting depth of 2.5–5 cm is common, and up to 25 seeds may be sown per pocket. Occasionally, seedlings are grown in a nursery and transplanted into the field early in the dry season, e.g. on the floodplains round Lake Chad in Africa. Sorghum may be harvested more than once as a ratoon crop, e.g. in locations with a bimodal rainfall pattern. Sorghum is often grown in intercropping systems with maize, pearl millet, cowpea, common bean, groundnut and bambara groundnut.

GROWTH AND DEVELOPMENT

The optimum temperature for sorghum seed germination is 27–35°C. Seedling emergence takes 3–10 days. Panicle initiation takes place after approximately one third of the growth cycle. By this stage the total number of leaves (7–24) has been determined and about one-third of total leaf area has developed. Rapid leaf development, stem elongation and internode expansion follow panicle initiation. During the boot stage, the developing panicle has almost reached its full size and is clearly visible in the leaf sheath; leaf expansion is complete. The peduncle grows rapidly and the panicle emerges from the leaf sheath. Flowering follows soon after panicle emergence, with the interval largely determined by temperature. Individual panicles start flowering from the tip downwards and flowering may extend over 4–9 days. Sorghum is predominantly self-pollinating; cross-pollination may range from 0–50%, but is on average about 5–6%. Grain filling occurs rapidly between flowering and the soft dough stage, with about half the total dry weight accumulating in this period. Lower leaves continue to senesce and die. By the hard dough stage, grain dry weight has reached about three-quarters of its final level. At physiological maturity, determined by the appearance of a dark layer at the hilum (where the grain is attached to the panicle), maximum dry weight has been achieved. Moisture content of the grain is usually between 25–35% at this stage. The time taken between flowering and maturity depends on environmental conditions but normally represents about one-third of the duration of the crop cycle. Further drying of the grain takes place between physiological maturity and harvest, which usually occurs when grain moisture content has fallen below 20%. Leaves may senesce rapidly or stay green with further growth if conditions are favourable. Early maturing sorghum cultivars take only 100 days or less, whereas long-duration sorghum requires 5–7 months. Sorghum follows the C_4-cycle photosynthetic pathway.

MANAGEMENT

Sorghum does not compete well with weeds during the early stages of growth, and it is recommended that weeding be done early during the seedling stage. Thinning can be carried out at the same time as hand weeding, or at intervals during the crop cycle, particularly where thinnings are used to feed livestock. Subsistence farmers rarely apply fertilizer, but application of farmyard manure or ash is common. It is grown in rotations with maize, pearl millet, finger millet, cotton and other crops. It is often planted late in the rotation, as it tolerates low soil fertility. Under certain conditions decomposing roots of sorghum have an allelopathic effect on the subsequent crop, including sorghum.

DISEASES.

- Common seed and seedling rot diseases in sorghum are caused by soil- and seed-borne *Aspergillus*, *Fusarium*,*Pythium*, *Rhizoctonia* and *Rhizopus* spp. They are controlled by treatment of the seed with fungicides.

- Anthracnose (*Colletotrichum graminicola*) is common in hot and humid Africa.

- Downy mildew (*Peronosclerospora sorghi*) may cause serious yield losses; the use of resistant cultivars and seed treatment are recommended.

- Smuts (*Sporisorium* spp.) are important panicle diseases.

- Grain mould is caused by a complex of fungal pathogens (predominantly *Cochliobolus lunatus* (synonym: *Curvularia lunata*), *Fusarium* spp. and *Phoma sorghina*).

PESTS

- Shoot fly (*Atherigona soccata*)
- Stem borers (particularly *Busseola fusca*, *Chilo partellus* and *Sesamia calamistis*).
- Foliage pests include army worms (*Spodoptera* and *Mythimna* spp.);
- Larvae of the sorghum midge (*Stenodiplosis sorghicola*, synonym: *Contarinia sorghicola*) feed on the young grains in the panicle.
- Head bugs (*Eurystylus* and *Calocoris* spp.) suck on developing grains
- Early sowing is particularly important as a mechanism to avoid large insect populations at times when plants are most susceptible to damage.
- Birds, especially *Quelea quelea*, cause important yield losses.

Storage pests, the main are

- Rice weevil (*Sitophilus oryzae*),
- Flour beetle(*Tribolium castaneum*)
- Grain moth (*Sitotroga cerealella*).

YIELD

Average sorghum grain yields on farmers' fields in Africa are as low as 0.5–0.9 t/ha because sorghum is often grown in marginal areas under traditional farming practices (low inputs, traditional landraces). Under favourable conditions sorghum can produce grain yields up to 13 t/ha

Forage yields from single-cut cultivars and hybrids can reach 20 t/ha of dry matter. Multi-cut cultivars and hybrids usually give only slightly higher total yields but produce better quality forage.

HANDLING AND HARVEST

The harvested grain of sorghum is usually sun-dried, often in the panicle. Panicles, particularly those to be retained for seed, may be stored hanging from the ceiling of kitchens over cooking fires where the smoke helps to deter insect attack. Alternatively, the heads may be threshed after drying and the grain stored in granaries, above or below ground, designed to prevent insect attack.

NUTRITIONAL COMPOSITION

The composition of sorghum grain per 100 g edible portion is: water 9.2 g, energy 1418 kJ (339 kcal), protein 11.3 g, fat 3.3 g, carbohydrate 74.6 g, Ca 28 mg, P 287 mg, Fe 4.4 mg, vitamin A 0 IU, thiamin 0.24 mg, riboflavin 0.14 mg, niacin 2.9 mg and ascorbic acid 0 mg. The essential amino acid composition per 100 g edible portion is: tryptophan 124 mg, lysine 229 mg, methionine 169 mg, phenylalanine 546 mg, threonine 346 mg, valine 561 mg, leucine 1491 mg and isoleucine 433 mg..

USES.

Sorghum is an important staple food, particularly in semi-arid tropical regions of Africa.. In the simplest food preparations, the whole grain is boiled (to produce a food resembling rice), roasted (usually at the dough stage), or popped (like maize). More often the grain is ground or pounded into flour, often after hulling. Sorghum flour is used to make thick or thin porridge, pancake, dumplings or couscous, opaque and cloudy beers and non-alcoholic fermented beverages. In Africa sorghum grain is germinated, dried and ground to form malt, which is used as a substratum for fermentation in local beer production. White grain is generally preferred for cooking while red and brown grains are normally used for beer making.

PROF. J. A. ADIGUN : ROOT AND TUBER CROPS

General Characteristics

- Tubers are crops that store their food in underground tissues
- The crops in this section are adapted to varying elevations.
- Most are herbaceous and are produced from parts of tubers
- The major rot and tubers crops grown in the tropics are
- Cassava (*Manihot esculenta*)
- Yams (*Discorea sp*)
- Sweet potaoes (*Ipomea batatas*)
- Cocoyams (*Colocasia esculenta*)

Ecological Factors

- Due to their diversity, few of these root and tuber crops have ecological requirements in common
- They generally require deep well-drained soils which are well prepared before planting so that the underground portion can develop without restriction.
- Many of these crops are grown on ridges due to high rainfall conditions.
- Many intercropping patterns exist among various root and tuber crops
- High temperature tolerance is a feature of many root and tuber crops although high soil temperatures are generally damaging.
- Many crops in this group tolerate high rainfall, particularly the lowland crops such as cocyam
- Irrigation in any period is essential for the medium and high elevation crops to maintain a regular growth rate.
- Nutrient requirements vary with each species but a high level of organic material in the soil is necessary for the successful production of most crops.
- Nitrogen and potassium are mostly in demanded and additional dressings in the early stages of growth are generally recommended.

Economic Importance

- These crops provide an essential part of the carbohydrate content of the average diet.
- They are grown for domestic consumption or sale in local markets.
- The possibilities for export are limited because of their short post-harvest life.
- Post-harvest diseases and diseases and pests can be serious on these crops hence adequate measure should be taken to maintain god storage
- The tubers and corms are used as boiled vegetables. Many are roasted, baked or fried.
- The young shoots and leaves of cocoyam and sweet potatoes are frequently used as boiled vegetables.

YAM (*Discorea spp*) are among the most values tuber crops in the tropics.

- West Africa is one of the three largest yam-producing regions in the world and Nigeria is the largest producer of yams in the world.
- Most of the yams grown in Nigeria are from smallholder farmlands.
- The various species of yam are as follows:
    - *Discorea rotundata* Poir (White yam)

- *Discorea cayanensis* Lamn (Yellow yam)
- *Discorea esculenta* (Chinese yam)
- *Discorea bulbifera* Linn (bulbil or potato yam)

Discorea rotundata **Poir (White yam)**

- This variety has long narrow, pale green oppositely arranged leaves, which tend to be triangular in shape.
- The stems are prickly.

Discorea cayanensis **Lamn (Yellow yam)**

- Tuber of this variety has a yellow colour when peeled and this is the main difference from the white yam.
- It possesses short broad heart shaped, deep green leaves.
- It does not keep for as long as white yam.

Discorea alata **Lin (Water yam)**

- This variety normally yields more heavily than the previous two and can also do better in poor soils.
- It contains a higher proportion of water than either the white or yellow yam.
- The tuber may be white, yellow, brown or almost red in colour.
- The leaves are distinctively different from the other being heart shaped, long brad and winged at the petiole.
- The stem climbs round the stake.

Areas of Yam Production

- The major yam producing areas in Nigeria include: Middle belt-Benue, Kabba, Ilorin, Easter part of Nigeria-Owerri, Onitsha, Port Harcourt, Umuahia and Delta areas and the south western part-Ondo, Benin, Oyo, Ibadan.
- Yam is well distributed in the humid tropics of southern part of West Africa where they are valued as an important source of food.

Environmental Requirement

Discorea species are essential tropical plants.

Their growth is restricted to areas with temperature of about 20^0C and they generally require temperature of 25-35^0C for normal growth and optimum yield.

Moisture

Yam thrives best when supplied with ample moisture throughout their growth cycle (7 –

9 months: (planting to harvest)

If yam must be grown where the dry period is longer than 3 – 4months supplementary irrigation must be provided.

Well distributed annual rainfall of over 150cm is reqiured

Soil Requirement

- High soil fertility is required for good growth and yield of yam marginal soils, used for the production of cassava or sweet potato cannot support the production of yam.
- Virgin soils, rich in organic mater are good for yam production.
- Loamy soils with low cation exchange capacity and clay soils which tend to become water logged are not suitable for yam production. They also make harvesting difficult.
- Stony or graveling soils should be avoided in yam production, because tubers growing, through such soils could be distorted.
- The soil must be well drained. Yam cannot tolerate water logging poorly drained and poorly aerated soils may lead to tuber rot.

Light

Light plays an important role in yam production

- Day length plays an important role in tuber formation and tuber growth
- High light intensity is required during active vegetative growth
- It is not a shade loving plant so plant grown extremely small tubers due to poor exposure of foliage to light interception.

Planting Date

- Early planting is done in November, while the soil is still moist
- Late planting is done in February to April.
- For good yam production planting at high stand density can be carried out in May.

Land Preparation

- Land clearing for yam cultivation in traditional agriculture is done essentially with hand tools.

- In such instances clearing is selectively done and several upright slender trees are deliberately left standing to serve as stakes.

Seedbed Preparation and Planting Material

- Tubers require a friable soil in which the tubers can grown with little hindrance. Many tuber crops grow initially from roots or stolons that penetrate the soil and later begin to enlarge to form tubers as in cassava and potato.
- In the case of yam, however, tuber formation is not preceeded by any stolon formation. In that case, it is the relatively enlarged lower meristematic part of the tuber that accomplishes penetration through the soil.
- On the basis of the type of tillage four general methods of planting yam exist:
    - Planting on mounds
    - Ridges
    - Holes
    - Flat
- Yam is propagated by means of the tuber which may be planted whole or divided into smaller pieces called sets weighing between 150-300gm.
- Tops with buds are better than bottoms. It is advisable to plant whole tubers and early maturing tops, separately from bottoms or middles which sprouts late.
- Germination starts 30 – 60 days after planting depending on rainfall. Germination may take a longer period of bottoms and middles are planted.

Crop Management

- **Mulching:** Covering yam setts planted on mounts or ridges with grasses or leaves is essential on the dry months.

Mulching reduces soil temperature as well as conserve soil moisture, thereby providing optimum condition for growth.

- **Staking:** When the yam vines are about 1m tall, they should be provided with stakes which they twines. This should be done about a month after emergence.
- **Weed control:** Weeding is the major operation after staking.

Weeding must be done carefully if hoes are used in order not to injure the shallow yam roots.

Chemical weed control can also be done using pre-emergence herbicide of different 1.0kga.i/ha followed by supplementary hoe-wedding at about 8 weeks after sowing.

Fertilizers at the rate of 125-250kg/ha of compound fertilizers is widely used.

Organic manure is also beneficial.

It is best to apply fertilizer ne month after emergence

Harvesting

The early crop matures at the end of July and the main crop from month of October – January.

Two types of harvesting – each crop is harvested twice.

Single harvesting each harvesting is done only one time.

Storage: Barn storage, platform storage or underfront storage.

Problems of Yam Production

- Planting materials are bulky.
- Production operations are labour intensive.
- In storage, the shelf life is shorter

CASSAVA (*Manihot esculanta*)

- Cassava belongs to the *geruis manihot* of the natural order euphorbia
- Cassava is a staple food crop in many parts of the topics and it is capable of producing high yields under condition of poor soil fertility and rainfall.
- Cassava is also an import component of traditional cropping systems.

Varieties

- Many varieties of cassava and cultivated in Nigeria
- The varieties can be differentiated by their height color of the stem, petiole and skin of the root, late or early maternity
- Cassava varieties are grouped into two large species, the bitter varieties (*Manihot utilissma*) and the sweet varieties (*Manihot plamata*)
- The bitter varieties contain prussic acid either free or combined as a constituent of the glycoside linamarine
- While the sweet variety is considered to be free from this glycoside
- Both the sweet and the bitter cassava have been shown to contain hydrocyanic acid or prussic acid although this acid thirds to concentrate in the peel of the sweet varieties and is lardy removed by peeling.
- The most common high yielding varieties are TMS 30572, 30555 TMS 14(2)1425. All developed by IITA Ibadan.

- Odongbo is an unimproved but high yielding local variety.
- Improved disease resistant varieties of cassava should be planted.

Production System

Cassava can be planted on moulds, ridges or on the flat after ploughing. In most traditional cropping systems, cassava is interplanted with cereals such as maize and rice or legumes such as cowpea and soyabeans in the first three months after planting.

Soil Requirement

Cassava can tolerate poor soils, but it does very well drained, rich and viable soil.

Fertilizer Application

Cassava responds favourably to N, P and K application, particularly on poor soils:

- Where the soil is moderately rich and legumes are ploughed in it, it is recommended that 10kg of 10-10-20 fertilizer be applied.
- Ideally, nitrogen and phosphorus should be applied after the cutting have been planted or at land preparation.
- Fertilizers can be applied by broadcast at land preparation or by side by side placement after the cuttings have been planted.
- A complete fertilizer (NPK) should be applied in addition manure or compost before planting.
- Dressings of N & K are also beneficial during the growing period.
- Plants are often earthed up after they have become established to encourage corm development.
- Most varieties mature in 180 – 120 days.
- The corms are lifted by hand and the main tuber is often harvested with the smaller corms left to develop later.
- Yields may range from 4 – 6 t/ha (500g/m^2). Yields of 15 t/ha have been recorded.
-

Planting

- Usually cassava is propagated from stem cuttings of 20-30mm which at maturity carries 4-6 growth buds.
- It is cut and planted either horizontally or slanting at an angle of 45^0 with the buds facing up.

- Cuttings are taking from cassava that have been harvested or ready for harvest
- Spacing at 100 × 100 cm for sole crop for mixed crop of cassava/maize can be planted at 200× 50 cm.
- Optimum spacing is 80 × 100 cm or 100×100 cm in the tropical rain forest.

Weed Control

- Weeds can be controlled both mechanically or chemically or by a combination of both.
- Two to three manual weedings are required
- Herbicides can be applied pre- emergence: primextra, diuron or lasso can be used.
- Pest and disease control
- Use improved high yielding and disease resistant varieties.
- Select healthy cuttings.
- Use balanced fertilizer to reduce the incidence of bacteria blight.
- Maintain good crop management.

Harvesting

This is done manually although mechanical single-row harvester has been developed, but the use of this is not yet wide spread.

SWEET POTATO (*Ipomoea batata)*

General Characteristics

Sweet potato is a perennial herb cultivated as an annual with trailing or twinning stem 1-5 m in length.

The stems are mainly prosrate, sometimes twinning and light green to purple.

The leaves are spirally arranged and either simple or deeply lobed.

They are up to 15 cm long with pointed tips and may be green to purple

The root system is extensive and roots grow from the stem nodes where nodes contact the soil

Tuber structure is mainly globular and smooth or ridge

The tuber surface may be white, yellow, orange, red or purple

The flowers may be single or in cluster(cymes). The calyx is five-lobed the corolla is funnel-shaped or tubular and petals are purple with pale margins.

Environmental Factors

Sweet potatoes are grown at optimum temperature of 24-25^{0C} and well distributed rainfall in the range of 75-125 cm per year

Full exposure to sun is essential

Sweet potato is a short day plant and a photoperiod of less than 11 hours induces flowering

The plant tolerate a range of soil conditions, but a well drained sandy loam with a Ph of about 6.0 is preferable.

The crop is sensitive to water logging

Cultural techniques

- stem cuttings are most frequently used for planting
- These are 25 – 45cm in length obtained from terminal shoots.
- Ridges are constructed about 45cm high and 75cm apart and the cuttings are inserted 26 – 30cm apart
- If soil moisture content is not adequate, furrow irrigation may be used.
- Sweet potatoes respond may well to manure although too much Nitrogen may promote excess stem and leaf growth instead of tuberous roots .

Planting

- Planting is done between April and September.
- May and June being the best time.
- Vine of 25 to 30 cm long are planted on ridges at an agle of 45 degrees.
- Spacing can be 1.5 – 2.0m apart.
- Seed rate 21,750 cuttings per ha – requiring about 800 kg green lines per ha.
- It is planted in May – June when the rains are stable.
- It is planted like yams on low mounds or ridges.
- Depth of planting is 10 – 15cm at the set per stand using cormel.
- Spacing 100cm x 100cm
- Seed rate: 2.45 tons – 3.40 tons/ha.
- Maturation: 6 – 8 months.
- Harvest: by hand uprooting of the corms.

Weed Control

- Is done manually.
- About two like weeding are required at 3 and 6 WAS.
- Subsequently weeds will be smothers by the plant itself.

Maturity

- It takes about 4 – 6 months to mature.
- The stems turn from green to brown at maturity.

Pests

- Root – knot nematode (*Meloidogyne spp)*
- Stem borer (*magastes grandalis*)
- Sweet potato hawk moth (*Agrius convoliuli*)
- Sweet potato weevil (*Cylas formicarius, C. brunneus*)

Diseases

Black rot (*Ceratocystis fimbriata*)

Sclerotial wilt (*Sclerotium rolfsii)*

Soft rot (*Rhizopus nigricans. R.. Stolonifer*)

Storage or black rot (*Botrgodiplodia theobromae*)

COCOYAM (*Colocasia esculenta, Xanthosoma sagittifolia*)

General Characteristics

- Cocoyam is an erect herbaceous perennial.
- The crop usually has a main corn and several other corms (corme(s) at the base.
- The leaves are large, pale green and oval with long petioles.
- Two forms exist – one with green and the other with purple petioles.
- Cocoyam rarely flowers.

Environmental Factors

- The Cocoyam produces optimum yields when planted in fertile soils with a high water retaining capacity.
- It is traditionally planted along streams or rivers but some forms tolerate upland conditions.
- Cocoyam is adapted to high temp areas with high humidity and most forms respond well to stable temp.

Cultural Techniques

- Propagation is by corms or sections of corms.
- Preferably planted during the wet season after they have gebun sprouting.
- For bed planting rows should be 90 – 100cm apart with 30 – 45cm between plants in the row.
- For ridge planting they should be 1m apart with 45 – 60 cm between plants.

DR.S.O.ADIGBO : LEGUMINOUS AND PULSES.

Pulses can be defined as leguminous species (members of the families Papilionaceae, Caesalpniaceae, Mimosaceae often considered as one family leguminosae (fabiaceae) produces edible mature seeds. Most species of pulses are adapted to a wide range of ecological conditions. The majority love heat. Only lens culinaries, Pisum sativum and Vicia faba do not thrive at high temperatures, and so are grown in the cool season of the year, or high altitude above sea-level. Also *Cicer arietinum*, *Lathyrus sativus*, *Lupins* spp. and *Trigonella foenum* prefer lower temperatures, although they can stand more heat than the first three species mentioned. For a high yield of seed, most pulses need full sunshine. Some pulses were originally definitely short-day plants, but ever for these there are now day-neutral cultivars available (*Lablab purpureus*, *Vigna unguiculata*, *Glysine max*).

Many of the pulses do not have high requirements in terms of water supply. Because of their deep-rooted system, they have a large volume of soil at their disposal and can survive long dry periods. The following are particularly drought tolerant: Cajanus cajan, Macrotyloma uniflorum, *Larthyrus sativus*, Phaseolus acutifolius, *Vigna unguiculata*, and *V. subterranean*. On the other hand, there are species which are of interest because they can stand moist conditions and there is an increased cultivation of these pulses in the humid tropic. They are *Canavalia* spp., *Glysine max*, *LablaB purpureus*, *Larthyrus sativa*, *Psophocarpus tetragonolobus*, *Vigna radiate* etc. Waterlogging damages all of them, and in the regions with high rainfall, deep, well-drained soil is the pre-condition for good growth.

There is a range of legumes which make very few demands on soil fertility. *Cajanus cajan*, *Macrotyloma uniflorum*, *Lablab purpureus*, *Lathyrus sativus* and others grow well even on very poor soils. Species such as *Glysine max*, *Phaseolus vulgaris* and *Pisum sativum* have greater need for fertile soil and for high yield, they need a soil with soil with a good structure and high nutrient content. Many tropical legumes also thrive on acid soils (cultivars of *Glysine max* and *V. unguiculata*, *V. subterranea* etc.)

As a result of their symbiosis with rhzobia, legumes have the ability to fix molecular nitrogen. With most species, the use of N-fertilizer is not necessary to achieve maximum yields, however, with high-yielding cultivars such as pea and beans N supplies of up to 120 t ha^{-1} can be economically justifiable.

For efficient N-fixation, it is frequently necessary to inoculate the seed with rhizobia specific for the genus or the species, or even with bacterial strain selected for a particular cultivar. However, from numerous genera, more than one species of rhizobia have been isolated (particularly *Rhizobium loti* and *Bradyrhizobium* spp.) and tropical soil rhizobia are often so abundant that inoculation is not necessary. Further conditions for efficient N-fixation include adequate supplies of Ca, Mo Co, Fe and Cu, a high rate of photosynthesis and soil temperatures below 32 ^{o}C.

The 1st 2 weeks are often decisions for the good development of the plants. If the soil is very low in N, it is recommended to give a light dressing of N fertilizer at sowing (about 10-20 kg N ha^{-1}). If the elements named above are deficient, then it is usually sufficient to pelletize the seed with them (Ca, Mo etc) in order to ensure early nodulation.

SOYABEAN (*Glycine max*)

Origin and geographic distribution

Soya bean was domesticated in the north-east of China around the 11th century BC. From there, it spread to Manchuria, Korea, Japan and other parts of Asia. Soya bean was introduced into Korea between 30 BC and 70 AD, and it was mentioned in Japanese literature around 712 AD. It reached Europe before 1737. Soya bean was introduced into the United States in 1765 and into Brazil in 1882. It is unclear when soya bean first reached tropical Africa. There are reports of its cultivation in Tanzania in 1907 and Malawi in 1909, but it is likely that soya bean was introduced during the 19th century by Chinese traders who were active along the east coast of Africa. Nowadays, soya bean is widely cultivated in tropical, subtropical and temperate regions throughout the world. The slow distribution outside Asia is explained by the absence of soya bean specific rhizobia in the soils of other regions; the crop only developed in the United States at the beginning of the 20th century, following the discovery of the nodulation process by scientists.

Uses

In tropical Africa dry soya bean seeds are boiled for use in relishes, or used in the preparation of milk substitutes and flour. A popular use of soya bean milk in Nigeria is to make a tofu-like product that is deep fried and sold as a snack or breakfast food. The flour is used as a component of bread or mixed with maize flour to make a fortified porridge (‘ugali’, ‘sadza’). In West Africa soya bean flour is used to thicken soup and to replace a traditional flour that is made from the seed of egusi melon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai). ‘Okara’ is the pulp and bran left over from making soya milk; this cake is used in almost all the same ways as soya bean flour. Soya bean seeds are dry roasted and used directly as a snack or as a coffee substitute. The seed is also milled into flour and mixed with maize meal to serve as a relief food during famine. In Asia soya bean is used in the preparation of a variety of fresh, fermented and dried food products like milk, tofu, tempeh, miso, yuba, soya sauce and bean sprouts (soya bean sprouts are meant here, and not mung bean sprouts, which are more common in Western countries, and which are often called ‘germes de soja’ in French). Immature soya bean seeds are eaten as a vegetable.

Soya bean seed is processed to extract oil for food and for numerous industrial purposes; the crop is currently the world’s most important source of vegetable oil. The edible oil enters the market as cooking oil, salad oil, margarine and shortening. Soya bean lecithins are used as emulsifier in the food industry, in pharmacy, and in the industrial production of decorating materials, printing inks and pesticides. Soya bean oil is the main commercial source of α-tocopherol (natural vitamin E) and contains stigmasterol, which is used for the commercial synthesis of steroid hormones and other pharmaceutical products. The cake remaining after oil extraction is rich in protein and is an important animal feed. Uses of soya bean proteins in food include defatted flours and grits, concentrates, isolates, textured flours and textured concentrates (commonly used as meat extender). The protein is also used in the production of synthetic fibres, glues and foams. Soya bean is also grown as fodder and as green manure; it is suitable for haymaking and silaging. The leafy stems remaining after pod removal can also be used as fodder.

Botany

Usually erect, bushy annual herb up to 2 m tall, sometimes viny; taproot branched, up to 2 m long, lateral roots spreading horizontally to a distance of up to 2.5 m in the upper 20 cm of the soil; stem brownish or greyish pubescent. Leaves alternate, 3(–7)-foliolate; stipules broadly ovate, 3–7 mm long; petiole 2–20 cm long, especially in lower leaves;

leaflets ovate to lanceolate, 3–15 cm × 2–6(–10) cm, base cuneate or rounded, apex acute to obtuse, entire, glabrous to pubescent. Inflorescence an axillary false raceme up to 3.5 cm long, often compact, densely hairy, (2–)5–8(–35)-flowered. Flowers bisexual, papilionaceous; pedicel up to 3 mm long; calyx tubular, with 2 upper and 3 lower lobes, hairy; corolla 5–7 mm long, white, pink, purple or bluish, standard obovate to rounded, c. 5 mm long, glabrous, wings obovate, keel shorter than the wings; stamens 10, 9 fused and 1 free; ovary superior, style curved with head-shaped stigma. Fruit a slightly curved and usually compressed pod 2.5–8(–15) cm × 1–1.5 cm, hairy, dehiscent, (1–)2–3(–5)-seeded. Seeds globose to ovoid or rhomboid, 6–11 mm × 5–8 mm, yellow, green, brown or black, or blotched and mottled in combinations of those colours; hilum small, black, brown or yellow. Seedling with epigeal germination; cotyledons thick and fleshy, yellow or green; first leaves simple and opposite.

Growth and development

Soya bean seedlings emerge within 5–15 days after sowing; a seedbed temperature of 25–33°C is optimal. Flowering starts from 25 days to more than 150 days after sowing, depending on daylength, temperature and cultivar. Flowering can take 1–15 days. Soya bean is normally self-pollinated and completely self-fertile with less than 1% cross-pollination. Pollen is normally shed in the morning, before the flowers have completely expanded. At higher altitudes with lower temperatures, flowers are usually cleistogamous. The time from flowering to pod maturity is 30–50 days. The total crop cycle from sowing to maturity is 65–200 days. Development to maturity is usually shorter with short days than with long days. The number of pods per plant varies from a few to more than 1000.

Although older literature indicates that soya bean is nodulated exclusively by slow-growing rhizobia (*Bradyrhizobium* spp.; initially called ‘cowpea-type rhizobia’) it is now well established that the fast-growing *Sinorhizobium fredii* can also form effective nodules with the crop. Soya bean genotypes differ enormously in their ability to nodulate with indigenous rhizobia in soils. The ability to nodulate spontaneously and prolifically with indigenous rhizobia is known as the ‘promiscuous’ character, compared with the ‘specific’ character of soya bean types that normally require inoculation with a specific type or with a few specific types of rhizobia in order to grow well. However, it has now been established that all soya bean genotypes nodulate to some extent with indigenous rhizobia, but the diversity of strains with which they can nodulate determines the extent of their promiscuity. Rates of N_2-fixation in soya bean are greatest in the more luxuriant and late maturing genotypes. Studies conducted in Nigeria have measured a N_2-fixation rate of 126 kg of N per ha for an uninoculated late-maturing soya bean line.

Propagation and planting

Soya bean is propagated by seed. The 1000-seed weight is 100–250 g. The seed can be sown before the start of the rainy season, or when the soil is moist. Seed rates are 40–120 kg/ha. Soya bean is sown in rows (20–)40(–75) cm apart. Within the rows, 2–3 seeds are sown in hills spaced at 7.5–10 cm intervals, at a depth of 2–5 cm. With intercropping, sowing rates are less than for sole cropping. In traditional agriculture the land is prepared by hand or animal traction before sowing. Soya bean is grown mainly on the flat, but sowing on hills or ridges may be practised where the soil is heavy, the water table high, or rainfall heavy. Small-scale farmers in tropical Africa grow soya bean as a sole crop or in mixed cropping with maize, sorghum or cassava.

Management

Soya bean is usually weeded 1–3 times during the first 6–8 weeks after planting, after which its canopy should be sufficiently developed to suppress weeds. Irrigation is uncommon except for dry season production. Basal fertilization with 20–25 kg P per ha is often required for adequate symbiotic N_2-fixation and general growth. Soya bean is commonly grown in rotation with cereals, such as maize, rice, sorghum, wheat and finger millet, whereby all fertilizer may be applied to the cereal.

Diseases and pests

Various fungal diseases affect soya bean. Soya bean rust (*Phakopsora pachyrhizi* and *Phakopsora meibomiae*) is a devastating disease that can reduce yields by as much as 90%. It is widespread; in tropical Africa it is recorded from Sierra Leone, Ghana, Nigeria, DR Congo, Uganda, Tanzania and Zambia. Partial resistance has been found in various cultivars; fungicides may reduce damage. Red leaf blotch (*Dactuliochaeta glycines*, synonym: *Pyrenochaeta glycines*) is confined to Africa; it is economically important in Zambia and Zimbabwe, where yield losses of up to 50% have been recorded. Seeds are not infected, but the fungus can survive in the soil for many years. Tolerant cultivars have been developed in Zimbabwe. Frogeye leaf spot (*Cercospora sojina*, synonym: *Passalora sojina*) occurs worldwide. It is primarily a leaf disease, but it may also affect stems, pods and seeds. It survives on stored seeds and crop residues and is spread by wind. Control measures include seed treatment (e.g. with thiram), deep-ploughing of crop residues, crop rotation and application of fungicides. Resistant cultivars are available. Purple seed stain and leaf blight are caused by *Cercospora kikuchii*, also occurring worldwide. Recommended control measures are crop rotation, the use of clean seed, ploughing back of crop residues, spraying with fungicides and the use of tolerant cultivars. Among the bacterial diseases of soya bean, bacterial blight (*Pseudomonas syringae* pv. *glycinea*, synonym: *Pseudomonas savastanoi* pv. *glycinea*) is common wherever soya bean is grown. Control practices of this foliar disease include the use of resistant cultivars, the use of clean seed, crop rotation and burying of crop residues. Bacterial pustule (*Xanthomonas campestris* pv. *glycines*, synonym: *Xanthomonas axonopodis* pv. *glycines*) is also widespread. It is seed-transmitted and survives on crop debris. Control measures are similar to those of bacterial blight. Virus diseases of soya bean include soya bean mosaic virus (SMV), cowpea mild mottle virus (CPMMV) and bean yellow mosaic virus (BYMV), but these are of little importance in tropical Africa.

Soya bean cyst nematode (*Heterodera glycines*) and root-knot nematodes (*Meloidogyne* spp.) can cause severe damage, especially on sandy soils. Therefore, soya bean should not be grown continuously or in rotation with other susceptible crops, such as tobacco. Soya bean cultivars resistant to nematodes are available.

The most widespread and probably most serious pest of soya bean in tropical Africa is the southern green stink bug or soya bean green stink bug (*Nezara viridula*), of which the nymphs and adults feed on soya been seeds. Control is by using insecticides. The most important leaf-eating pest is probably the soya bean looper (*Xanthodes graellsii*). Bean flies (mainly *Melanagromyza sojae* and *Ophiomyia centrosematis*) can cause complete yield loss. Soya bean seedlings are occasionally damaged by cutworms (*Agrotis* spp.). No major storage pests are recorded from Africa, except rodents.

Harvesting

Mature seeds of early-maturing soya bean cultivars can be harvested 65 days after planting; late maturing cultivars may need more than 150 days. In tropical Africa the plants are generally allowed to dry in the field and the whole plants (above ground) are collected by hand when most leaves have turned yellow and fallen, and when the pods have turned brown. The moisture content of the seeds at harvesting should be 14–15%. Pods of older cultivars have a tendency to shatter in the field when drying and plants need to be harvested on time to prevent major loss of yield. Combine-harvesting is used on large farms and estates. Soya bean seed for vegetable use is harvested when the pods are still green but the seeds fill the pod.

Yield

Average world soya bean yields are 2.25 t/ha; those in the United States 2.5 t/ha. Under smallholder farming conditions in tropical Africa yields are often as low as 0.5 t/ha due to a combination of poor soil conditions and poor management. However, yields of more than 2 t/ha have been recorded on smallholder farms in Zimbabwe and Nigeria, particularly when farmers are growing soya bean as a cash crop to sell in urban food markets or for processing for oil and feed. The average yield of commercial, large-scale farmers hovers around 2 t/ha. Under optimal growing conditions yields of more than 4.5 t/ha have been recorded in Zimbabwe. In Nigeria and most of West Africa the yield potential of soya bean is about 3 t/ha.

Handling after harvest

The whole plants are dried in the sun. They are then threshed by beating with sticks. The seeds are winnowed, cleaned and prepared for store or market. For on-farm storage a seed moisture content of 10–12% must be maintained. Deterioration of seed in storage is a major problem in the humid tropics and is attributable to poor storage conditions and pests. In the savanna region of West Africa producers have developed appropriate seed handling methods that ensure good seed germination when they save their own seeds.

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Cowpea (*Vigna unguiculata (L.) Walp*).

Origin and geographic distribution

Vigna unguiculata originated in Africa, where a large genetic diversity of wild types occurs throughout the continent, southern Africa being richest. It has been introduced in Madagascar and other Indian Ocean islands, where it is sometimes found as an escape from cultivation. The greatest genetic diversity of cultivated cowpea is found in West Africa, in the savanna region of Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria and Cameroon. Cowpea was probably brought to Europe around 300 BC and to India 200 BC. As a result of human selection in China, India and South-East Asia, cowpea underwent further diversification to produce two cultivar-groups, Sesquipedalis Group with long pods used as a vegetable, and Biflora Group grown for the pods, dry seeds and for fodder. Cowpea was probably introduced to tropical America in the 17th century by the Spanish and is widely grown in the United States, the Caribbean region and Brazil. Cowpea is the most important pulse crop in the savanna regions of West and Central Africa, where it is also an important vegetable and a valuable source of fodder. In East and southern Africa it is also important both as a vegetable and a pulse. Only in humid Central Africa is it less prominent.

Ecology

Wild types of *Vigna unguiculata* grow in savanna vegetation, often in disturbed localities or as a weed, up to 1500 m altitude, but some can be found in grassland subject to regular burning, sandy localities close to the coast, woodland, forest edges or swampy areas, occasionally up to 2500 m altitude.
Cowpea grows best at day temperatures of 25–35°C; night temperatures should not be less than 15ºC and consequently cultivation is restricted to low and medium altitudes. At altitudes above 700 m growth is retarded. Cowpea does not tolerate frost, and temperatures above 35°C cause flower and pod shedding. It performs best under full sunlight but tolerates some shade. Cowpea is generally grown as a rainfed crop in sub-Saharan Africa, but in Asia it is sometimes grown on residual moisture after an irrigated rice crop. Short-duration determinate types can be grown with less than 500 mm rainfall per year; in experiments in Senegal 'Ein al Ghazal' produced 2400 kg/ha of seeds with only 450 mm rain. Long-duration types require 600–1500 mm. Yard-long bean tolerates high rainfall; a fully-grown crop has a water requirement of 6–8 mm per day. Cultivation in the dry season with ample irrigation is practiced, as well as cultivation during the rainy season, although sowing during the rainy season can result in damage to the emerging or young plants. Most cowpea cultivars are quantitative short-day plants, but day-neutral types also exist. Cowpea can be grown on a wide range of soil types with pH 5.5–6.5(–7.5), provided they are well drained. It is moderately sensitive to salinity and exhibits greater salt tolerance during later stages of growth.

Botany

Climbing, trailing or more or less erect annual or perennial herb, cultivated as an annual; taproot well developed, with many lateral and adventitious roots; stem up to 4 m long, angular or nearly cylindrical, slightly ribbed. Leaves alternate, 3-foliolate; stipules ovate, 0.5–2 cm long, spurred at base; petiole up to 15(–25) cm long, grooved above, swollen at base, rachis (0.5–)2.5–4.5(–6.5) cm long; stipels small; leaflets ovate or rhombic to lanceolate, (1.5–)7–14(–20) cm × (1–)4–10(–17) cm, basal ones asymmetrical, apical one symmetrical, entire, sometimes lobed, glabrous or slightly pubescent, 3-veined from the base. Inflorescence an axillary or terminal false raceme up to 35 cm long, with flowers clustered near the top; rachis tuberculate. Flowers bisexual, papilionaceous; pedicel 1–3 mm long, with spatulate, deciduous bracteoles; calyx campanulate, tube c. 5 mm long, lobes narrowly triangular, c. 5 mm long; corolla pink to purple, sometimes white or yellowish, standard very broadly obovate, hood-shaped, c. 2.5 cm long, wings obovate, c. 2 cm long, keel boat-shaped, c. 2 cm long; stamens 10, 9 fused and 1 free; ovary superior, c. 1.5 cm long, laterally compressed, style upturned, with fine hairs in upper part, stigma obliquely globular. Fruit a linear-cylindrical pod 8–30(–120) cm long, straight or slightly curved, with a short beak, glabrous or slightly pubescent, pale brown when ripe, 8– 30-seeded. Seeds shapes are oblong to almost globose, often laterally compressed, 0.5–1 cm long, black, brown, pink or white; hilum oblong, covered with a white tissue, with a blackish rim-like aril. Seedling with epigeal germination; cotyledons oblong or sickle-shaped, thick; first two leaves simple and opposite, subsequent leaves alternate, 3-foliolate.

Growth and development

Germination of cowpea takes 3–5 days at temperatures above 22°C. The optimum temperature for germination is about 35°C. Flowers open in the morning and close before noon; they fall the same day. In dry climates cowpea is almost entirely self-pollinated, but in areas with high air humidity cross-pollination by insects may amount to 40%. Only fairly large insects are heavy enough to open the keel. The length of the reproductive period is very variable, with the earliest cultivars taking 30 days from planting to flowering, and less than 60 days to mature seeds. When leaves are harvested during the early growth stages, senescence starts 1.5–2 months after sowing and the plant dies after 3–4 months, depending on crop health and intensity of harvesting. Late cultivars with indeterminate growth take 90–100 days to flower and up to 240 days for last pods to mature. Cowpea forms N-fixing nodules with *Sinorhizobium fredii* and several *Bradyrhizobium* species.

Propagation and planting

Farmers normally use farm-saved seed for planting. The 1000-seed weight of cowpea is 150–300 g. The seed rate for pure stands is 15–30 kg/ha. Seed dressing with an insecticide and a fungicide (e.g. thiram) prior to planting is recommended. In tropical Africa cowpea is mostly grown intercropped or in relay with other crops such as yam, maize, cassava, groundnut, sorghum or pearl millet. Pure stands are not common except in the coastal areas of East Africa, and also in Asia and Western countries. In the forest and Guinea savanna zones of West Africa cowpea is mainly intercropped with maize, cassava, yam or groundnut, at a very low density (1000–5000 hills/ha). In the northern Guinea savanna zone cowpea is intercropped with groundnut and/or sorghum. The component crops are normally planted in rows with systematic intercropping patterns, which may vary from alternate row intercropping to within-row intercropping with varying distance, giving a grid of groundnut or sorghum rows crossed by the cowpea rows every 2–3 m. The cowpea population is low, with individual plants spread over a 2–3 m radius. In the Sudan savanna cowpea is intercropped with pearl millet, sorghum

and/or groundnut, in diverse and complex traditional intercropping patterns with varying interplant distances and planting sequences of component crops. For instance, in some areas of Kano state in Nigeria (Minjibir and Gezawa areas) pearl millet is planted first in rows 1.5–3 m apart at the onset of the rains (May–June), with 1 m distance within the row, resulting in 4000–6000 hills/ha. When the rains become more stable towards the end of June, pulse-type early cowpea cultivars are planted between alternate pearl millet rows at a distance of 1 m. Fodder-type, late-maturing cowpea is planted later, in mid-July, in the remaining rows. When grown as a sole crop, cowpea is sown at densities ranging from 22,000 plants/ha for prostrate types to 100,000 plants/ha for erect types. Recommended planting distances for sole-cropped cowpea in Kenya are 60 cm between rows and 20 cm within the row. In Swaziland spacings are 50 cm between rows and 15 cm within the row for erect cultivars. For landraces the spacings are much wider, especially for the dual purpose types. Often 2–3 seeds are sown per pocket, with thinning afterwards, e.g. during weeding. The sowing depth is 4–5 cm. Cowpea requires soil with fine tilth for good root growth. Generally, deep ploughing followed by harrowing provides an adequate tilth. In intercropping systems, tillage normally follows the crop in which cowpea is interplanted.
Peri-urban vegetable farmers use special cultivars for ratoon cropping of the leaves. They broadcast the seed on raised beds, made on well-manured soil, aiming at a dense stand of about 25 plants per m^2.
Farmers in Africa use yard-long bean seed harvested from a previous crop, in contrast to South-East Asia, where many farmers procure healthy seed from improved cultivars. The 1000-seed weight of yard-long bean is lower than that of cowpea, 100–150 g. Seed is sown in pockets of 2–4 seeds. Cultivation is usually on raised beds for good drainage and easy surface irrigation and for easy staking and harvesting. Earthing-up the young plants protects the shallow root system and gives support to the seedlings. Some farmers apply mulch of rice straw, but this is not a common practice.

Management

Cowpea derives a significant amount of its nitrogen requirements from the atmosphere and may leave 75–150 kg/ha in the soil for the benefit of the succeeding crop. If cowpea is grown in localities where it has not been grown recently, inoculation with nitrogen-fixing bacteria has been found to be beneficial. Cowpea requires phosphorus for nodulation and root growth. Incorporation of 25 kg/ha P is adequate for plant growth in phosphorus-deficient soils. In soils known to be deficient in potassium, application of 25 kg/ha K is recommended. Cowpea must be kept weed free during the early stages of growth. Two to three weedings during the first 6 weeks after planting are recommended; once the crop is established it outcompetes weeds. Weeding is usually done by superficial hoeing.

Cowpea grown as a vegetable and yard-long bean have a high mineral uptake. In soils of average fertility an application is recommended of 5–10 t/ha of farmyard manure during soil preparation, together with N 20 kg/ha, K 25 kg/ha and P 40 kg/ha. Three weeks after emergence a top dressing of 50 kg/ha urea is given. In yard-long bean, 2–2.5 m long stakes are inserted near the seed beds before sowing or during the first two weeks after emergence, before the plants have reached a height of 30 cm. A cheap method of staking is to relay-plant yard-long bean next to the stems of maize before or just after the cobs are harvested.

Diseases and pests

Cowpea is susceptible to a wide range of diseases and pests. Yard-long bean suffers from the same diseases and pests as cowpea but seems less susceptible than cowpea under humid conditions. Fungal diseases are more troublesome during the rainy season, whereas insect and mite pests and virus diseases cause more damage during the dry season.

The major fungal diseases are anthracnose (*Colletotrichum lindemuthianum*), Ascochyta blight (*Phoma exigua*), brown blotch (*Colletotrichum truncatum*), leaf smut (*Protomycopsis phaseoli*), leaf spot (*Cercospora canescens*, *Septoria vignae*, *Mycosphaerella cruenta* synonym: *Pseudocercospora cruenta*), brown rust (*Uromyces appendiculatus*), scab (*Elsinoë phaseoli*), powdery mildew (*Erysiphe polygoni*), pythium soft stem rot (*Pythium aphanidermatum*), stem canker (*Macrophomina phaseolina*) and web blight (*Thanatephorus cucumeris*, synonym *Rhizoctonia solani*). Crop rotation and the use of chemicals and resistant cultivars are necessary for integrated disease control. Bacterial diseases include bacterial blight (*Xanthomonas campestris* pv. *vignicola*), which occurs worldwide, and bacterial pustules (*Xanthomonas axonopodis* pv. *glycines* synonym: *Xanthomonas campestris* pv. *vignaeunguiculatae*) reported from Nigeria. These bacteria are seed-transmitted and secondary spread occurs by wind-driven rain. Control measures include the use of pathogen-free seeds, seed treatment with a mixture of antibiotics and fungicides such as streptocycline plus captan, and strict crop rotation. Resistance genes are available for bacterial blight and bacterial pustules. Many viruses attack *Vigna unguiculata*. Some viruses of economic importance are cowpea aphid-borne mosaic potyvirus (CABMV), cowpea mottle carmovirus (CPMoV), cowpea yellow mosaic virus (CYMV), black eye cowpea mosaic potyvirus or bean common mosaic potyvirus (BCMV), cucumber mosaic cucumovirus (CMV-CS) and cowpea golden mosaic virus (CPGMV). Some of the viruses are seedborne, while aphids, white flies and beetles perform field transmission. Control measures include use of healthy seed of resistant cultivars if available, and weeding to remove alternative hosts. In poor sandy soils, cowpea is attacked by root-knot nematodes (*Meloidogyne* spp.). It is also a host plant of, among others, reniform nematodes (*Rotylenchus* spp.), root-lesion nematodes (*Pratylenchus* spp.) and lance nematodes (*Hoplolaimus* spp.). Crop rotation and resistant cultivars are used to control nematodes.

Insect pests are also a major factor limiting cowpea production and may even cause total seed loss. In tropical Africa much damage is caused by cowpea aphids (*Aphis craccivora*), flower thrips (*Megalurothrips sjostedti*), legume pod borers (*Maruca vitrata*, *Etiella zinckenella*), pod bugs and seed suckers (e.g. *Clavigralla tomentosicollis*, synonym: *Acanthomia tomentosicollis*). Lygus beetle (*Lygus hesperus*), cowpea curculio (*Chalcodermus aeneus*) and green leafhoppers (*Empoasca* spp.) are of less importance. Yard-long bean is especially attractive to aphids (*Myzus persicae*, *Aphis gossypii*), green stink bug (*Nezara viridula*) and red spider mite (*Tetranychus* spp.); greasy cutworms (*Agrotis ipsilon*) often cause damage just after emergence. The bean shoot fly (*Ophiomyia phaseoli*) is a common pest; the larvae tunnel in the leaves and stems, and severely attacked young plants will die, whereas older plants will suffer from hampered growth and serious yield reduction. Lodging incidence is generally high in infested fields; tolerant cultivars may produce aerial roots above the wound. Another common pest is the bean pod fly (*Melanagromyza sojae*). The larvae damage the petioles and young pods. Control of insect pests involves protecting the seed with a systemic insecticide (e.g. carbofuran) at sowing or applied as a solution to the emerging seedlings in the planting holes. Plant debris and affected plants must be burned. Cowpea seeds are extremely vulnerable to storage pests, with the cosmopolitan cowpea weevil (*Callosobruchus maculatus*) being the major storage pest. Measures to reduce pest damage include application of inoffensive vegetable oil, neem (*Azadirachta indica* A.Juss.) oil or wood ash, roasting and bagging the seeds in airtight plastic bags, and storing as whole pods.

Use of chemicals, resistant cultivars, biological control and proper crop management

such as intercropping and weeding are necessary for integrated pest management. Chemical control of insects is common practice on yard-long bean, but not on cowpea. Because of the risks for farmer and consumer (especially when leaves are harvested), these sprayings must be reduced to the strict minimum.
Two parasitic weeds are a serious problem: *Alectra vogelii* Benth. prevalent in the southern savanna regions of West Africa, East Africa and southern Africa, and *Striga gesnerioides* (Willd.) Vatke prevalent in the savanna regions of West and Central Africa. Crop rotation, deep cultivation, intercropping, early planting and use of resistant cultivars reduce infestation by these parasitic weeds.

Harvesting

Cowpea leaves are picked in a period from 4 weeks after emergence of the seedlings to the onset of flowering. In crops grown for the seed, farmers often harvest 10–20% of the leaves before the start of flowering with little detrimental effect on the seed yield. Stronger defoliation increasingly reduces flowering, fruiting and seed yield. Growers of leafy cowpea types cut the plants at about 10 cm above the ground for a succession of new shoots (ratooning). Green pods are harvested when the seed is still immature, 12–15 days after flowering. Harvesting of dry seed is done when at least two-thirds of the pods are dry and yellow. In indeterminate types harvesting is complicated by prolonged and uneven ripening; for some landraces harvesting may require 5–7 rounds. Mature seeds are usually harvested by hand. Sometimes plants are pulled out when most of the pods are mature. In the complex traditional intercrop patterns of Kano state (Nigeria), early cowpea and sorghum cultivars are harvested at the end of August or the beginning of September. The late cowpea and sorghum cultivars are harvested after the onset of the dry season, between October and November, when the leaves show signs of wilting. The fodder types are uprooted or cut from the base and rolled into bundles with the leaves intact. These bundles are then kept on roof tops or in tree forks for drying, and are used or sold in the peak dry season.

The first picking of yard-long bean pods in the desirable stage takes place 6–7 weeks after planting, depending on cultivar and market requirements. Normally the pods are picked when the outline of the seeds is just visible. Picking must be meticulous, because pods which are passed over until the next harvest will become tough and discoloured, with swollen seed, and may exhaust the plant. Successive harvests take place at least once a week (twice a week for a better tuned grading) during 4–8 weeks.

Yield

Farmers may harvest up to 400 kg/ha of cowpea leaves in a few rounds with no noticeable reduction of seed yields. In Nigeria climbing cultivars yielded 9–17 t/ha of fresh pods, whereas decumbent cultivars yielded 6–15 t/ha. The mean dry seed yield of the same cultivars was 1. 4–1.7 t/ha. The world average yield of dry cowpea seed is low, 240 kg/ha, and for fodder it is 500 kg/ha (air-dried leafy stems). Average yield of dry cowpea seeds under subsistence agriculture in tropical Africa is 100–500 kg/ha. The average seed yield in Niger is 120 kg/ha, in Nigeria 400 kg/ha, and in the United States 900 kg/ha. Apart from the effects of diseases and pests, the low yields are partly explained by the fact that the crop is mostly grown at low densities in intercropping systems, shaded by taller cereals. Furthermore, cowpea is often sown later in the rainy season, which results in a shorter crop duration due to photoperiod-sensitivity. A yield potential of 3 t/ha of seed and 4 t/ha of hay can be achieved in sole-cropping with good management. In the United States seed yields up to 7 t/ha have been obtained.
For yard-long bean, a total yield of 15 t/ha in a harvest period of at least one month is considered satisfactory, but yields as high as 30 t/ha have been reported.

Handling after harvest

Harvested leaves cannot be kept for long; they have to be sold within 2 days. The shoots can be kept longer by putting them in a basin with water. Cowpea leaves are frequently dried in the sun for preservation, either after boiling and squeezing to black balls, or directly as whole or broken leaves, or as powder. Green yard-long bean pods are tied in bundles of 20–40 and packed in baskets or crates for transport to the market. Yard-long bean is less susceptible to loss of weight by transpiration and to transport damage than most other vegetables. In cool storage (8ºC) the pods will keep for 4 weeks. Immature fresh cowpea seeds have a limited shelf life if stored at ambient temperatures, but at 8°C they can stay fresh for 8 days. In Europe, the United States and Japan, immature tender green pods are sometimes frozen or canned. As a pulse, the threshed seed should be dried thoroughly to a moisture content of 14% or less for good storability.

Uses

Cowpea is the preferred pulse in large parts of Africa. The mature seeds are cooked and eaten alone or together with vegetables, spices and often palm oil, to produce a thick bean

soup, which accompanies the staple food (cassava, yam, plantain). In West Africa the seeds are decorticated and ground into a flour and mixed with chopped onions and spices and made into cakes which are either deep fried ('akara balls'), or steamed ('moin moin'). In Malawi the seeds are boiled with their seed coat, or the latter is removed by soaking and leaving the seeds in the soil for a few hours. Small quantities of cowpea flour are processed into crackers, composite flour and baby foods in Senegal, Ghana and Benin.

The leaves and the immature seeds and pods of cowpea are eaten as vegetables. Cowpea leaves are served boiled or fried and are usually eaten with a porridge. The leaf may be preserved by sun-drying or boiling and then sun-drying to be used during the dry season. Leaves to be preserved for later use are generally plucked towards the end of the season. It is believed that leaves developed towards the end of the season are tastier as they tend to grow under conditions of stress. In Botswana and Zimbabwe boiled cowpea leaves are kneaded to a pulp and squeezed into small balls, which are dried and stored. Immature, green and still soft seeds are cooked to a thick soup and used as relish. The tender seedless cowpea pods are sometimes used as a cooked vegetable, as are young pods of yard-long bean. In Asia this is the most important use of cowpea, in Africa it is uncommon. In Benue State, Nigeria, the stringless coiled pods with little parchment of a landrace called 'Eje-O'Ha' are parboiled for a few minutes, opened and split in half. The seeds are eaten directly while the pod walls are dried and preserved for later use. Pods are also eaten locally in Benin. The roots are sometimes eaten, e.g. in Ethiopia and Sudan.
Cowpea is used as fodder in West Africa, Asia (especially India) and Australia; it is used for grazing or cut and mixed with dry cereals for animal feed. In the United States and elsewhere cowpea is grown as a green manure and cover crop. In Nigeria special cultivars are grown for the fibre extracted from the peduncle after retting; the strong fibre is especially suitable for fishing gear, and produces a good-quality paper. The dry seeds have been used as coffee substitute.

Various medicinal uses of cowpea have been reported: leaves and seeds are applied as a poultice to treat swellings and skin infections, leaves are chewed to treat tooth ailments, powdered carbonized seeds are applied on insect stings, the root is used as an antidote for snakebites and to treat epilepsy, chest pain, constipation and dysmenorrhoea, and unspecified plant parts are used as a sedative in tachycardia and against various pains.

Ground nut (*Arachis hypogaea* L.)

Botany

Annual herb, with erect or prostrate stem up to 70 cm long; root system consisting of a well-developed taproot with many lateral roots, up to 135 cm deep, but generally restricted to the upper layers of the soil. Leaves arranged spirally, 4-foliolate with two opposite pairs of leaflets; stipules 1.5–4 cm long, with a slender free tip, but fused to the petiole for about half their length; petiole 1.5–7 cm long; petiolules 1–2 mm long; leaflets obovate or elliptical, 1–7 cm × 0.5–3 cm, cuneate-rounded at base, rounded or emarginate and mucronate at apex. Inflorescence an axillary, 2–5-flowered spike. Flowers bisexual, papilionaceous, sessile; receptacle long and slender, pedicel-like, up to 4 cm long; calyx with 4 upper lobes joined, lower lobe free; corolla pale yellow to orange-red, rarely white, standard rounded, c. 1.5 cm × 1.5 cm, wings shorter, keel incurved; stamens (8–)10, alternately with small, globular anthers and larger, oblong anthers, joined at base; ovary superior but situated at base of receptacle tube, style free within the tube, very long, ending in a minute club-shaped stigma. Fruit an oblong or sausage-shaped pod, borne at the tip of an elongated fruit stalk (‘peg’) up to 20 cm long, 1–8 cm × 0.5–2 cm, surface constricted to varying degrees between the seeds and reticulately veined, 1– 6-seeded. Seeds cylindrical to ovoid, 1–2 cm × 0.5–1 cm, with pointed or flattened ends, enclosed in a thin papery seed coat ranging in colour from white to deep purple. Seedling with epigeal germination; cotyledons thick and fleshy.

Growth and development

Seeds of ‘Virginia’ types have a dormancy period of 1–3 months, whereas ‘Spanish’ and ‘Valencia’ types are without dormancy. The optimum soil temperature for seed germination is 25–30°C. Low temperatures retard germination and development and increase the risk of seedling diseases. Upon germination, the primary root elongates rapidly, reaching 10–12 cm before lateral roots appear. As growth proceeds, the outer layer of the primary root of a seedling is sloughed off so that root hairs do not form. Branching is dimorphic, with vegetative branches and reduced reproductive branches. Secondary and tertiary vegetative branches can develop from the primary vegetative branches. Flowering may start as early as 20 days after planting, but 30–40 days after planting is more usual. The number of flowers produced per day decreases as the seeds mature. Up to 50% of the embryos may abort even under ideal environmental conditions, but this percentage becomes much higher during times of drought or other environmental stress. However, plants can produce a ‘second crop’ of seeds if adequate moisture becomes available again. Groundnut is self-pollinating, but outcrossing can occur when bees pollinate the flowers. Groundnut generally produces more flowers under long day conditions, but reproductive efficiency is greater under short days. Only one of the flowers in an inflorescence opens at a given time. Flowers wither within 24 hours after anthesis. Fertilization usually occurs within 6 hours after pollination, when the basal part of the ovary starts elongating into a structure called ‘peg’. The embryo initiates a growth phase until it reaches an 8–16-cell stage. It then becomes quiescent during the 5–15 days required for the ‘peg’ to enter the soil. The ‘peg’ stops elongating within a day or two after soil penetration, the embryo then restarting growth. In wild *Arachis* species the ‘peg’ may continue to grow to a length of nearly 2 m.

Seeds in ‘Spanish’-type cultivars usually mature within 90–120 days after planting, whereas ‘Virginia’-type cultivars take 130 days or more. Pods of the same size may differ significantly in maturity and seed weight.

Groundnut is usually effectively nodulated by N_2-fixing *Bradyrhizobium* bacteria. Because root hairs are absent, the bacteria infect the root through cracks in the epidermis near multicellular hairs at the basis of the root.

Ecology

The optimum mean daily temperature for groundnut growth is 27–30°C; growth ceases when temperature drops below 15°C. Groundnut is mainly grown in areas with an average annual rainfall of 500–1000 mm; 500–600 mm of rain reasonably well distributed over the growing season allows satisfactory production. Nevertheless, groundnut is drought-tolerant and can withstand severe lack of water, though yield is generally reduced. A dry period is required for ripening and harvesting. The phenology of groundnut is determined primarily by temperature, with cool temperatures delaying flowering. In controlled environments, photoperiod has been shown to influence the proportion of flowers producing pods and distribution of assimilates between vegetative and reproductive structures (harvest index) in some cultivars. Long photoperiods (greater than 14 hours) generally increase vegetative growth and short photoperiods (less than 10 hours) increase reproductive growth. Groundnut can be grown up to 1500 m altitude. The best soils for groundnut are deep (at least 30–40 cm), friable, well-drained sandy loams, well-supplied with calcium and a moderate amount of organic matter. It is important to maintain near to neutral soil pH levels and Ca:K ratios lower than 3.

Propagation and planting

Groundnut is propagated by seed, but vegetative propagation using cuttings is possible. The 1000-seed weight ranges from 150 g to more than 1300 g. Sowing high-quality seed in a well-prepared, moist seedbed is essential for crop establishment. Groundnut seeds are often planted at a depth of 4–7 cm at a rate of 60–80 kg/ha. Groundnut pods intended for sowing are often hand-shelled 1–2 weeks before sowing. Only fully mature pods are selected. Before sowing, groundnut seed may be treated with a fungicide to control seedling diseases. In general, early sowing improves yields and seed quality. Early sown crops also suffer less risk of disease such as groundnut rosette virus. However the appropriate sowing date depends on the maturity period of the cultivar. Small-seeded ‘Spanish’ types are spaced at 60–75 cm between rows and 10 cm within the row. This gives an optimum plant population of 133,000–167,000 plants per ha. Large-seeded ‘Virginia’ types are spaced at 75 cm between rows and 15 cm within the row, giving an optimum plant population of 89,000 plants per ha. Groundnut can be grown on the flat, or on ridges as is often the case in Malawi. Groundnut grown on ridges tends to give higher yields, probably because of more loose soil favourable for pod development and easier uprooting.

In tropical Africa groundnut is grown as a sole crop or intercropped between rows of cereals such as maize, sorghum or pearl millet.

Management

Groundnut does not compete effectively with weeds, particularly in the early stages of development. The crop should be thoroughly weeded within the first 45 days. Once the development of the ‘peg’ begins, earthing-up is kept to a minimum. Weeds at this stage are hand pulled. Pre-and post-emergence herbicides may be used to eradicate weeds, but they are too expensive for most small-scale farmers in Africa. In sound rotation systems, groundnut benefits from residual fertility; in general no additional fertilizer is given if the crop is sown on a well-managed soil previously treated with a balanced fertilizer. However, in order to ensure good crop establishment, high yield and good seed quality, a fertilizer containing Ca, such as gypsum or single superphosphate, should be applied. Calcium is absorbed directly by the pods if soil moisture is adequate. A shortage of Ca in the zone where the pods develop will result in empty pods, particularly in cultivars of the ‘Virginia’ type. Groundnut is normally a rainfed crop, but it is grown under irrigation in Sudan.

Groundnut should preferably not be grown in the same field more than once in 3 years to limit damage by soil-borne diseases, nematodes and weeds. It fits into a wide range of rotations and it can follow any clean-weeded crop, e.g. maize, sorghum, pearl millet, cassava, sweet potato or sunflower. To reduce the incidence of diseases and pests, groundnut should not be sown after cotton or tobacco. Groundnut does well on virgin land or immediately following a grass ley or well-fertilized crop such as maize.

The intensity of management of groundnut varies considerably around the world, depending on the economic return for the crop or the role of groundnut in the farming system. In the United States, Australia and parts of South America the crop is grown with intensive management, generally with high levels of mechanical and chemical inputs. In many countries groundnut is grown as a cash crop primarily for export.

Diseases and pests

Groundnut is susceptible to a number of diseases, such as early leaf spot (*Cercospora arachidicola*), late leaf spot (*Cercosporidium personatum*, synonym: *Cercospora personata*), rust (*Puccinia arachidis*), groundnut rosette (caused by a complex of 3 agents: groundnut rosette virus (GRV), groundnut rosette assistor virus (GRAV) and a satellite RNA) and aflatoxin contamination caused by *Aspergillus* fungi. Foliar diseases of groundnut are among the most important yield-limiting factors in groundnut production. Early and late leaf spots and rust together may cause up to 70% yield losses; even where fungicides are applied significant yield reductions occur. Spraying with fungicide when the disease appears controls both leaf spots effectively. Dusting groundnut leaves with sulphur, early in the morning when there is still dew on the leaves, has been reported to control both early and late leaf spots. The use of sulphur has also been observed to increase leaf retention, thus increasing the quantity of leafy stems available for livestock feed. Cultural practices to control leaf spots include crop rotation and burning of crop residues. Cultivars with partial resistance to leaf spots have been developed. Rust generally occurs sporadically and at low severity, although it can cause crop losses up to 40% when an epidemic occurs. The cultural practices and fungicidal control measures recommended for leaf spots are also applicable to rust. Resistant cultivars are available. Groundnut rosette virus, transmitted by the aphid *Aphis craccivora*, is endemic to sub-Saharan Africa and widely prevalent in Ghana, Nigeria, Malawi and Zambia. It is the most destructive disease of groundnut leading to 30–100% yield loss. Early sowing at high plant populations controls the spread of groundnut rosette by giving complete soil coverage as quickly as possible and restricting the movement of aphids. Cultivars resistant to groundnut rosette are widely grown in Africa. In Malawi it is common practice for farmers to interplant groundnut and cowpea to control groundnut rosette. *Aspergillus* fungi can invade groundnut pods and seeds, producing toxic compounds known as aflatoxin. Contaminated produce can be poisonous to people and livestock, and cannot be exported. Aflatoxin contamination also affects groundnut seed, leading to low germination percentage and poor seedling establishment. It can occur before harvest, during field drying and curing, and in storage. Pre-harvest contamination is likely to be most serious under drought. Post-harvest contamination occurs if groundnut pods or seeds become moist and/or damaged. Various methods are used to control aflatoxin. They include avoiding mechanical damage to pods or seeds during weeding, harvesting and storage, harvesting as soon as the pods are mature, proper drying and curing, and storing in the shell at low temperature under moisture-free conditions.

Root-knot nematodes (*Meloidogyne* spp.) may cause considerable yield loss in groundnut; they can be controlled by crop rotation. On a global scale the most important insect pests include aphids (*Aphis craccivora*), thrips (*Frankliniella* spp.), jassids (*Empoasca dolichi*), white grubs (larvae of various beetles), termites (mainly *Microtermes* sp.) and the red tea bug *Hilda patruelis*. False wireworms and millipedes seem to occur less frequently. In general, soil pests cause more damage than foliage feeders or sucking pests. However, aphids are particularly harmful because they transmit groundnut rosette virus. In Asia and Africa white grubs, termites, millipedes and ants are important pests; in the United States the lesser cornstalk borer (*Elasmopalpus* *lignosellus*) and the southern corn rootworm (*Diabrotica undecimpunctata*) are the main insect pests of groundnut. Pests attacking stored groundnut pods and seeds include bruchids (*Caryedon serratus*, *Callosobruchus* spp., *Acanthoscelides* spp.) and flour beetles (*Tribolium* spp.). Parasitic plants (*Alectra vogelii* Benth. and *Striga* spp.) are recorded as causing damage to groundnut in various African countries.

Harvesting

The indeterminate flowering pattern of groundnut makes proper timing of harvest difficult, even though such timing is crucial for obtaining maximum yield and quality. Harvest at the proper time ensures that the maximum number of pods have attained their greatest weight and that pods are not falling off. Methods to determine the proper time for harvesting groundnut are available, but some are environment-specific or are prohibitively expensive. Presently only the shell-out method and the hull-scrape method are widely used for groundnut maturity determination. The shell-out method is based on colour changes within the pod wall ('hull') that occur as the pod matures. The internal pod wall surface of most cultivars changes from white to brown or black blotches covering a large percentage of the area. The colour of the seed coat changes from white to dark pink or tan at the same time. A sample of plants is taken and pods opened. The percentage of pods with dark colour inside the pod wall is determined. Harvesting should begin when the percentage is 60–80, but recommendations vary. The shell-out method is widely used because it can directly be used in the field without further handling of pods, requires no equipment and provides an immediate answer. The hull-scrape method, developed in the early 1990s, is currently accepted as the most accurate means of assessing the maturity of 'runner'-type groundnuts. The method is based on the fact that the pod mesocarp (the area just beneath the pale brown coloured exterior of the groundnut pod) changes from white to yellow to orange to brown to black as the crop matures. The method requires colour charts and a pocket knife to scrape the pod surface.

Harvesting is carried out manually in most parts of Africa, as well as Asia. In the United States harvesting is normally done using a digger shaker inverter. When plants are harvested manually, they are loosened with a hoe and pulled out of the ground, after which they are turned to expose the pods to the sun to facilitate drying. When dry, the pods are ripped off the plants. With mechanical harvesting, the plants are cleanly removed from the soil and deposited in inverted windrows. Pods have to remain in the windrows until the average moisture content is 18–24%. Pods are then picked using a combine. Rainfall during windrowing may promote mould growth resulting in reduced milling quality.

Yield

In tropical Africa the average yield of groundnut pods in the early 2000s was about 850 kg/ha, which is only slightly higher than the average yield in the 1970s (730 kg/ha). National average yields of groundnut pods in tropical Africa range from 300–1000 kg/ha. Average world yields of groundnut pods increased from 0.9 t/ha in the 1970s to 1.4 t/ha in the early 2000s. With good management practices and proper disease control, yields up to 5 t/ha can be achieved. On average 100 kg of pods yield 70 kg of seeds, containing 35 kg oil.

Handling after harvest

Produce quality is closely related to proper harvesting date, harvesting method and drying; every step is critical to obtaining or maintaining quality. Groundnut pods are dried to an average moisture content of about 10%. Removing foreign materials early helps to maintain quality during storage. Cleaning equipment to remove the foreign material has been developed and includes sand screens and belt screens. Groundnut pods are stored in granaries, tanks, bins, concrete silos, warehouses or in the

open. In storage, ventilation is crucial to prevent moisture build up which can promote mould growth and aflatoxin production. Excessive heat should be avoided. Storage structures should be examined frequently for moisture and insect problems as these can greatly reduce quality. Seeds can be protected from mechanical damage by storage and transport in the pods. In many areas groundnut is only shelled when it is to be used or sold; in local markets unshelled pods are often offered for sale. Both mechanical and manual shelling are common.
Groundnut removed from storage is transported to shelling centres where the pods are graded, cleaned and shelled, and the seeds are separated into commercial grade sizes. Shelling operations may damage the seeds. Shelling of 100 kg of groundnut pods yields 60–80 kg of seeds. Generally groundnut seeds can be stored at 1–5°C and 50–70% relative humidity for 1 year without loss of quality. Groundnut seeds tend to absorb gases and off-flavours, which should be avoided.
Oil is extracted from groundnut seed by expeller pressing, hydraulic pressing, solvent extraction, or a combination of these methods. Expeller pressing is most widely used.

Uses

Groundnut seed is mainly used as food and for oil extraction. The seeds are eaten raw, boiled or roasted, made into peanut butter, confectioneries and snack foods, and are used for thickening soups or made into sauces to be eaten with meat and rice. In northern Nigeria groundnut flour is mixed with 'gari' (coarse fermented cassava meal) and made into balls that are eaten as a snack. In the United States and Argentina most of the crop is used as food, but in most other countries the primary use of groundnut is for the oil market. Worldwide, more than 50% of groundnut production is crushed into oil for human consumption or industrial use (e.g. in cosmetics). In countries such as Senegal, Gambia and Nigeria oil extraction has been an important cottage industry for years. The use of groundnut in confectionery and for oil and meal production is increasing, and there is gradual shift taking place from oil and meal to confectionery use, especially in Latin America and the Caribbean. In South America groundnut seeds are fermented into alcoholic drinks.
The press cake from oil extraction is a feed rich in protein, but it is also made into groundnut flour, which is used in many human foods. Fermented groundnut cake is eaten fried in Indonesia. The cake finds industrial application in the production of glues, sizes for paper and starches for laundering and textile manufacture. Protein from groundnut cake is made into a wool-like fibre, which can be blended with wool or rayon. Groundnut shells are used as roughage in fodder, as fuel, fertilizer, mulch, in the manufacture of particle board and building blocks, and can be used as a source of activated carbon, combustible gases, organic chemicals, reducing sugars, alcohol and extender resins.
Young groundnut pods and leaves are consumed as a vegetable; in West Africa the leaves are added to soups. The foliage is an important fodder, especially in the Sahel; it may be eaten fresh or as hay or silage. In southern India the haulms are sometimes applied as a green manure.
Groundnut has a range of uses in traditional African medicine. Pod extracts are taken as a galactagogue, and used as eye-drops to treat conjunctivis. Macerations of peeled seeds are drunk to treat gonorrhoea, macerations of the seed coats against syphilis, while macerations of the seed coats and shells are applied against ophthalmia. Sap of ground leaves and seeds is used for ear-drops against ear discharge. Leaf macerations are drunk as a diuretic. Leaf infusions are drunk against female infertility, and used for eye-drops to treat eye injuries and cataract. Plant ash with salt is applied in case of caries. Pod extracts and young plants are credited with aphrodisiac properties. The plant is also used to relieve cough and is considered emollient and demulcent; emulsions are taken to treat pleurisy, enteritis (including colitis), and dysuria.
Agglutinins (lectins) from groundnut seeds are often used in medical research for histochemical investigations.

General characteristic of Fibre crops

Vegetable fibres have served mankind since our beginnings. Early in the prehistoric epoch man learned to process them into textiles by weaving. Some of the plants were among the first cultivated plants (fax, sunn hemp, cotton, kenaf). The most important fibres are those that can be processed to make the finest fabrics for clothing and bed-linen; of these, cotton has been by far the most important since the 19^{th} century. Other fibres are of greater economic importance too, such as those that are used for the production of bags and other packaging materials for curtain materials and floor covering (jute, kenaf, agave fibre), and those fibres which are indispensable for tear-proof paper. Finally some plant fibres are irreplaceable for doormats (coir), brooms (piassava, sorghum and others), and for basket-work and binding materials (raffia and other palm fibre, agave fibres). The tropics and subtropics have almost a monopoly in the production of plant fibres. In terms of value they provide 96% of the world's production

In spite of competition from the development of the synthetic fibre industry, plant fibres have retained their dominant role. Cotton alone supplies 46% of all fibres, the total for all plant fibres is 65%, animal fibres (wool and silk) supply 5% and artificial fibres (cellulose and synthetic) fibres) provide 30% of the world's production.

Quantitatively dominant role of plant fibres is based on their low price compared to animal and some synthetic fibres as well as their technical characteristics (e.g. high capacity for the absorption of moisture, which is indispensable for under wear and bedding, or for packaging materials). Other fibres are superior for other purposes (eases of dyeing and warming effect of wool and silk, tensile strength, shrink resistance and non-creasing qualities of many synthetic fibric).

From the view point of environmental effects, the biodegradability of natural fibres is to their advantage, especially for packing materials. The major share of the market will always remain with plant fibres. In the field of utilization, where they are in competition with the synthetic fibres, their market position is also relatively good, as long as efficient production methods are used, and as long as they are available at a maintained quality and in sufficient quantity.

The only fibre for which the production has risen further in the last decade is cotton, which provides 78% of the plant fibres. Jute, kenaf, and similar fibres provide 14%, sisal 2%. Then follow the two fibres which are predominantly produced in the temperate zone: flax 3% and hemp 1%. The remainder is extracted from a large number of other fibre plants moast of which are of only locally importance.

Cotton (***Gossypium spp***.)

The cultivated forms of cotton are divided into four species of genus Gossypium, Malvaceae.

1) G. herbaceum L, 2) G. arboretum L (old world species) 3) G. hirsutum L and 4) G. barbadense Mill (New world species). The origin of cotton are found in Africa (forms of G,herbaceum). Very early in prehistoric time, G.herbaceum reached South Asia and America, where the hybridization with indigenous Gossypium species took place.

Morphology and Anatomy

All cotton species are potentially perennial even though they are normally grown for only one year in modern agriculture. They form strong tap root, which develops even at the seedling stage, and which can reach depth of 3 meters. The shoot system is dimorphic: main axis and lower branches are monopodial and vegetative (that is no flower form on the leaf axils), the fruiting branches are sympodial (each flower stands at the end of the shoot, further occurs from the axil of the subtending leaf, so that the fruit appears to be inserted opposite the leaf). Leaves and stems are mostly hairy. All parts of the plant usually bear glands which are visible as dark spots, abnd gossypol is formed in these. Each flower is surrounded by three deeply divided bracts (epicalyx). The fibres themselves are single-celled hairs, which develop from the outer epidermis cells of the

integument. Some of the hairs remain short, and form the fuzz covering the ripe seeds (linters). The most useful ones are the long hairs (lint), which are more than 20 mm long in modern cultivars, in primitive types more than 9.5 mm.
The fruits (bolls) grow very quickly after pollination. After 20 days they reach their final size, and they are ripe after a further 25-45 days. With most species, the dry walls open in the middle of each carpel, and the fibre-mass emerges. However, the seeds remain clinging to the placenta, and are first separated from the fruit by picking (in unfavourable weather, this can also occur with strong winds). When the seed ripen, the hairs die and their wall collapses so that only a narrow cavity remains inside, which still contains the remainder of the protoplasm. The wall of the hairs is composed of many layers of cellulose fibres, which run spirally. The direction of the spiral bands reverses at certain points and changes from layer to layer. This explains the twisting which is characteristic for dry cotton fibre. As part of the epidermis, the hairs are covered with a cuticle. Because of the layer of wax, unprocessed cotton fibres feel fatty to the touch and repel water. Species and cultivar differences are found in the type of branching in the leaf shape of the bracts, in the length and shape of the bolls and in the amount and quality of the fibre. Modern cultivars are often difficult to identify on the basis of vegetative characteristics Reliable seed propagation methods are therefore especially important for the cultivation of cotton.

Ecophysiology

Cotton is a decidedly warmth –loving plant. The seed should not be sown at soil temperature under 18 ^{o}C and 35 ^{o}C is optimal. Further development, 27oC is the optimum. At temperatures over 40 oC, and strong insolation, the bolls will be damaged and fall. Cotton is extremely sensitive to frost. Its cultivation is only possible where 200 frost free days can relied on. G. hirsutum is mostly day-neutral, the flowering time being primarily governed by the temperature. But short daya accelerate the development if the temperature liessubstantially below the optimum. A lot of sunshine promotes flowering and fruit-setting. Therefore the highest yield are achieved in dry areas underirrigation.
Cotton originated in the semi-arid summer rainfall region. Cultivation is possible with rainfall of between 600-1500 mm. The ripening time should occur in a rainless period, because rainfall after opening of bolls damages the quality of the fibres, and can lead to considerable losses. The plants are drought tolerant due to their deep-reaching root systems. However, prolonged dryness during flowering and boll development leads to noticeable decreases in the yield. Strong winds can damage the seedlings, and can blow away the fibres after the opening of bolls
Cotton needs deep soil with sufficient drainage. Otherwise, its demands are slight. The pH should be lie between 6-8. It is relatively salt tolerant and salt content of 0.5- 0.6% generally causes no damage, although there are considerable difference among cultivars with regard to sensitivity to salt. The nutrient uptake ability is strong, and the nutrient requirements are moderate. Too much N fertilization encourage vegetative growth and extends the the vegetation period. Sufficient supplies of K are important for attaining good fibre quality and for disease resistance. The requirement for Ca is decidedly high. Deficiencies of B have been reported from various countries, and can be eliminated by spraying at the correct time. On the other hand, cotton withstands relatively high B concentration in the soil

Cultivation

Good preparation of the land is especially important before sowing cotton, because the seedlings which germinate epigeally, can only penetrate hard or crusted soils with difficulty and until they are three weeks old, they have little ability to compete with weeds. Sowing is carried out by hand in many countries. For mechanical sowing the fuzz must be removed from the seeds either mechanically or chemically because the seeds otherwise cling together. The density of sowing varies within wide limits, depending on the cultivar, soil fertility, cultivation and harvest methods. The row spacing lies between 50 and 120 cm, the spacing within the row between 20 and 60 cm. For mechanical harvesting, types which are weak branching are densely sown in order to achieve an early uniform ripening in the crop. Here, the spacings are reduced to 15-20 cm between the rows and 8- 10 cm within the rows. Such “short-season” cultivars are available only of G. hirsutum. The seed should be sown not deeper than 5 cm.

Cotton can be sown on level soil, in furrows (protected against drift sand), or on ridges Sowing on ridges is necessary with poorly drained soil. It make irrigation easier, and assists the entry of water into the soil. However, in regions with irregular rainfall, it makes the control of weeds and mechanical harvesting more difficult.

In USA, the most economical methods of weed control has proved to be the application of a strip of soil herbicide over the row of seeds, and later, the flaming of the weeds between the rows. At later stages weeds are not a serious pro blem where the seed is sown thickly with cultvars which have a strong tendency to shed their young bolls (up to 10 days after flowering), a spraying with NAA (napthylactic acid) is recommended. Considerable increases in yield have been reported from various countries where CCC (Cycocel) and other growth inhibitors (eg.mepiqual) have been utilized.

To decrease the infestation by pest and, to control the various soil0borne diseases, cotton is seldom cultivated in monoculture. In many countries, not only is crop rotation prescribed (the cotton is usually grown in the same field only every third year), also the destruction of thr harvested plants. For this, the plants should be pulled up with their roots, to eliminate the diseases carriers as much as possible

Harvesting and processing

The majority of the world’s harvest is picked by hand. It is a labour intensive operation (a picker gathers 20 to 80 kg of seed cotton a day), but it produces the cleanest cotton and highest yields per surface area (repeated picking 3, 4 or even more times). There is still no other procedure nowadays for fine, long-fibre cotton. In the USA, Russia and Australia, cotton is almost exclusively harvested by machines and other countries partially. Of the two types of bmachines, spindle pickers and stripper, spindle picker work more slowly, but it deliversa more uniform and less impure product than the stripper. For mechanical harvesting, only low growing, weakly branching cultivars can be considered. The main source of impurity are pieces of leaf. By spraying with defoliants, the leaves are therefore made to fall off before harvesting. In spite of this, a special cleaning of the fibre is necessary with mechanical harvesting and this is carried out in the gin, mostly after the seed removal process.

The yield of cotton (seed cotton) can reach 4 t/ha under optimal conditions, but in practice it is seldom over t and the global average is only 1.6 t because the yield in many countries is still very low (india 0.6 t/ha). With primitive cultivars the yield of fibres (ginning out-turn) is 20-25 %, good upland cultivars nowadays yield at least 35%, and the best more than 40%. The ginning in carried out mechanically in all countries. In grading of the fibres, apart from length and fineness, cleanness (colour and freedom from foreign matter) play decisive role.