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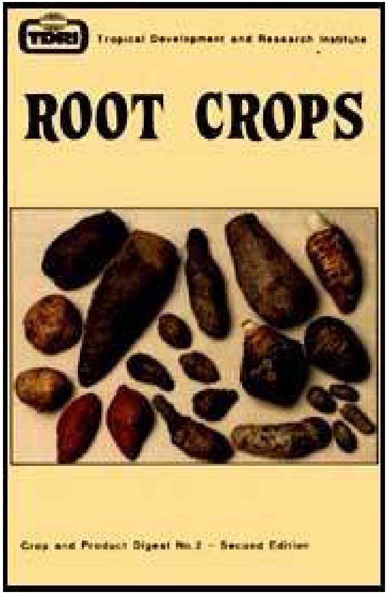

Root Crops (NRI, 1987, 308 p.)

- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma chamissonis)**
- **Sweet potato (Ipomaea batatas)**

Taro (Colocasia esculenta)

Common names

TARO, Dashe(e)n, Eddo(e), Old cocoyam.

Botanical name

Colocasia esculenta (L.) Schott.

Family

Araceae.

Other names

Abalong, Amalong (Philipp.); Arvi (Ind.); Barbados eddoe (W.l.); Bari (W. Afr.); Chinese eddoe (W.l.); Chinese sayer (Guyana); Chonque (Col.); Chou bouton (St. Lucia); Chou de Chine (W.l.); Colulu (Polyn.); Coco (Ant.); Cocoyam', Curcas (W.l.); Dagmay (Philipp.); Dalo (Fiji); Danchi (Venez.); Elephant's ear, Gabi, Gablos, Gahula (Philipp.); Guagui (Cuba); Igname (Fr. and It.); Imo (Japan); Inhame (Port.); Keladi (Mal.); Khoai au nu'oc bang, Khou-au ku'oc tuiang (Viet.); Koko (W.

Afr.); Kolkas (Egypt); Kolokasi (Cy.); Linsa, Logbui, Lubingan (Philipp.); Madre (Carib.); Malanga(y), Malangu (C. Am.); Ocumo culin (Venez.); Pising (Philipp.); Quiquisque (Guat.); Qolq(u)as (Egypt); Satoimo (Japan); Taioba (Braz.); Taro de Chine (Indon.); Taro kalo, Tato (Fiji); Tayoba (Sp.); White eddoe (Barb.); Ya (China); Ya br (W. Afr.); Yu-tao (China).

Botany

A herbaceous perennial 0.5-2 m tall, with an underground starchy corm which produces at its apex a whorl of large leaves with long robust petioles. The leaves are heart-shaped, 20 - 50 cm long, with rounded basal lobes; the leaf stalk joins the blade some distance inward from the notch between the lobes (ie the leaf is peltate - a feature which distinguishes the plant from

the rather similar Xanthosoma). The inflorescence is on a stout peduncle, shorter than the leaf stalks, with a pale yellow spathe about 20 cm long: seeds are extremely rare. The corms vary greatly in size and are round/cylindrical, up to 35 cm long and 15 cm in diameter, and are surrounded by a number of secondary corms (cormels); the root system is superficial and fibrous.

There are about 1000 recognised cultivars, but these fall mainly into two groups: the eddoe type of taro, which has a relatively small corm surrounded by large well-developed cormels (and 42 chromosomes), and the dasheen, which has a large central corm and numerous but small cormels arising from its surface (and 28 chromosomes). The two types of C. esculenta are frequently referred to as separate species in the literature, C. antiquorum and C. esculenta, but it is more

generally accepted that the taros are a polymorphic species, C. esculenta, and under this classification the eddoe is C. esculenta var. antiquorum (syn. C. esculenta var. globulifera) and the dasheen is C. esculenta var. esculenta.

Origin and distribution

The plant appears to have originated in India and spread eastwards to Burma and China, and southwards to Indonesia. Subsequently, it was taken to Japan, Melanesia, Polynesia and Hawaii; in historical times it spread to Egypt and the eastern Mediterranean, thence to Africa, the Guinea coast, and, along with the African slaves, to the Caribbean.

Cultivation conditions

Taros are grown, mostly as a staple or subsistence crop, throughout the tropics, subtropics, and in many warmer regions of the temperate zone. There are cultivars which are adapted to such varied conditions as swamps, tropical wet rainforest, dry uplands and to the foothills of the Himalayas. Only in a few areas, eg Hawaii, Egypt, the Philippines and certain islands in the Pacific and the Caribbean, does the taro attain the status of a commercial crop. In general the eddoes are hardier than the dasheens and can be grown in drier conditions on poorer soils.

Temperature - for optimum results taros require hot humid conditions, with daily average temperatures of 21-27°C; when grown in more temperate areas or at high altitudes there must be a 6-7 month frost-free period.

Rainfall - taros are primarily adapted to moist environments, but can be grown under a wide range of conditions, ranging from paddy culture to dry upland conditions under irrigation. An annual rainfall of approximately 250 cm is considered satisfactory; they can be grown in upland areas where the rainfall is about 175 cm provided this is evenly distributed throughout the growing period. When grown in dry upland areas with less than 175 cm of rain, irrigation is necessary to provide sufficient water for vegetative growth and leaf development and the use of furrow and sprinkler irrigation has proved satisfactory. In Egypt, the crop is irrigated at bi-weekly intervals for the first 6-8 weeks, then weekly for the next 4 weeks and then every 4-5 days, until near harvest. Dasheen corms grown under erratic moisture conditions show peculiar dumbell-like shapes, reflecting constrictions in growth during dry periods, and under water stress eddoes produce few

cormels.
Soil - taros are grown on a wide range of soil types, but the best results are obtained on deep, well-drained, friable loams, particularly alluvial loams, with a high water-table; a pH of 5.5-6.5 is reported to be best.

Taro has a high requirement for potassium and for calcium. Traditionally, in particular in South-East Asia and the Pacific islands, inorganic fertiliser is not used, and reliance is placed on FYM and mulches of leaves, etc, which have the added advantage of providing substantial weed control. A cover crop of siratro (Phaseolus atropurpureus) grown in a fallow period before planting the taro, then destroyed by herbicide, is regarded as an ideal mulch that also enriches the soil with nitrogen. Where mineral fertilising is used, a complete formulation such as 12:6:20 NPK is recommended, particularly on poor soils. Split

applications are desirable, with the last application not later than 3 months before harvest. Severe calcium deficiency produces 'metsubure' symptoms in which the developmental sequence of mother, daughter and tertiary corms is disturbed and the yield diminished.

Altitude - taro may be grown from sea level up to 2 400 m; the choice of cultivar is important.

Planting procedure

Material - taros are propagated vegetatively, using suckers, whole corms or cormels, pieces of corms or setts (the lower 30-50 cm of the petiole with the top 1-2 cm of the corms). It is of major importance to ensure that the planting material is free from disease (taken from completely healthy plants).

Method - Lowland or wet culture (paddy culture) - the field preparation resembles that for rice, with ploughing, discing and harrowing to produce a well-puddled soil. Setts are normally used and the base pushed by hand into the mud to a depth of 20-30 cm. The water level should not be more than 30 cm above the top of the mud and it must not become stagnant: an outlet is essential. Planting may be done throughout the year.

Patch culture - used in swampy areas which are not constantly under water. The muddy soil is formed into 'patches' of various sizes, eg 7 x 20 m, with a ditch around the patch in which water constantly flows. After cultivation the patch may be covered with coconut leaves and the taro planted through this mulch.

Dry land culture - loamy or clay-loam soil is mainly used for dry land taro in areas where there is sufficient

rainfall or where irrigation is possible. The dasheen type (C. esculenta var. esculenta) has higher water requirements than the eddoe type (C. esculenta var. antiquorum), and the latter is often grown in dry land culture as a plantation crop (eg in rotation with sugar cane in some Caribbean territories), where it is planted as cormels or pieces of corm in fields prepared by ridging, or as an intercrop in peasant agriculture.

Weed control - is frequently by a combination of mulching and handweeding: the flooding practiced in paddy culture is usually sufficient to control weeds. Chemical herbicides are becoming increasingly used in the more sophisticated areas; pre-emergence herbicides include prometryn, diuron and nitrofen. Shielded sprays of paraquat or weed oils have been used as contact herbicides among standing crops.

Mechanisation of taro culture - recent work in Hawaii has shown that mechanised planting, weed control and harvesting of dry land taro is practicable, planting being on well-cultivated (rotavated) soil using a modified transplanter handling taro setts. Reaping is by a modified potato harvester. For wet culture, planting would be before flooding of the field and a promising system of harvesting is under study.

Field spacing - in high rainfall areas with heavy cloud, where exceptionally large leaves will be produced, wide spacing appears to be optimal, as much as 90x90 cm (12 000 plants/ha). For Fiji, 60x60 cm has been shown to give maximum yields of marketable tubers, though where mechanisation is practiced rows 100 cm apart and plants at 45-60 cm in the row are recommended. Typical spacing in paddy culture is usually 45-60 cm (49 000-27 000/ha).

Pests and diseases

Pests - in many countries pests do not appear to present a serious problem. However, in some places they are of major importance and over 180 insects have been listed as damaging the leaves, and about 40 as causing damage to the corms; snails, slugs, birds, rodents and other mammals are pests on occasion. Among the more important insects may be noted the taro leaf hopper, Tarophagus proserpina, in the Pacific islands, which also transmits virus infections. The egg predator, Cyrtorhinus fulvus has successfully controlled this pest in the Philippines and other Pacific areas.

Taro hornworm (Hippotion celerio), the cluster caterpillar (Spodoptera litura), whiteflies (Bemisia spp.), spider mites (Tetranychus spp.) and aphids also attack the leaves. Chemical control includes the use of

methomyl, carbaryl, diazinon, malathion and dimethoate, but avoidance of indiscriminate spraying is important as a measure of natural biological control frequently operates, and it is important not to eliminate the beneficial organisms: emphasis should be given to integrated control. The corms are sometimes affected by the taro beetle (Papuana spp.), a suggested control is by gamma-HCH applied to the planting holes and again at intervals after planting. Root knot nematodes (Meloidogyne spp.) can cause severe damage, producing galls on the corms. Treatment of planting material by immersion in water at 50°C for 40 minutes is suggested.

Diseases - include leaf blight (due to Phytophthora spp.), which can cause defoliation, and (usually much less serious) Phyllosticta spot (Phyllosticta spp.): both can be controlled by copper fungicides. Dasheen mosaic is a viral condition transmitted by aphids or leaf hoppers

and is not usually severe, though destruction of diseased plants is advised. Fungal root rots may be serious. Soft rot (caused by Pythium spp.) is widespread in lowland taro, and care should be taken to avoid planting infected material. Southern blight (due to Corticium rolfsii) sometimes attacks dry land taro and has been controlled by dicloran or quintozene. Two diseases of unknown etiology are hard rot and loliloli: the former destroys the vascular system of the corm, the latter produces a corm that is without starch and is soft and watery in patches.

Growth period

The maturation period varies according to the cultivar, and ranges from 6 to 18 months. The shortest crop duration reported is 3 months in Sri Lanka, others are: India 7-9 months, the Philippines 7-11 months, Hawaii

(lowland crop) 12-15 months, Fiji 10-12 months, Nigeria 6-8 months, Trinidad 8-10 months (dasheens), 5-6 months (eddoes). Growing conditions affect the rate of maturation of the crop: eg in Hawaii, in the warmer areas with high levels of solar radiation, 12 months, in the cooler and more cloudy areas, 15 months.

Harvesting and handling

Taros are ready for harvesting when the leaves begin to turn yellow and start to wither; harvesting can be delayed for some weeks in dry weather without the corms deteriorating, and post-harvest storage can thus be reduced to a minimum. Normally the plants are lifted by hand using a long stick with a sharpened point or a cutlass. In large-scale production the plants are sometimes ploughed out. Harvesting should always be carried out in dry weather. Developments in mechanical

harvesting have already been noted.

The storage life is usually limited by fungal or bacterial rots; the most common are due to Phytophthora colocasiae, Pythium sp., Botryodiplodia theobromae, Fusarium so/ani, Ceratocysfis fimbriata and Corticium rolfsii. Entry of pathogens is commonly through wounds, eg where the numerous small cormels have been removed from the main tubers of dasheens. Dipping in benomyl delays storage decay where Botryodiplodia is the main cause but is ineffective against Phytophthora and Pythium; sodium hypochlorite, however, controls all common decay organisms in the Pacific except Corticium rolfsii. Storage of the corms under conditions which allow desiccation is no longer recommended, as it has been shown that conditions which keep corms physiologically active promote curing of wounds and minimise water loss. Both dasheen and eddoe type

corms can be kept in good condition for upwards of 4 weeks in the tropics: thus dasheens with tops attached and minimal wounding, and good quality eddoes, can be stored in pits dug in well-drained soil and lined with leaves, and well-shaded, on trays or in small heaps under houses, or in cellars or barns. For commercial handling it has been recommended that the sound corms, after fungicide dipping, draining and air-drying, be packed in polyethylene bags; such bags, overpacked in banana cartons, have been successfully used for shipping taros in the Pacific at ambient temperatures, and the storage life has been from 26 to 40 days. In connection with shipping, however, it should be noted that fumigation shortens the storage life of taro.

Taro appears to suffer chilling damage at 3-5°C having a life of only 5-6 weeks, but, in Egypt, taros are successfully stored for periods of 12-15 weeks at 7°C.

Primary product

Corms and cormels-the underground parts of the taro consist of one or more edible, central corms and a considerable number of edible cormels or lateral tubers. In the dasheens the central corm is large, cylindrical, up to 35 cm long and 15 cm in diameter, with small side cormels, and it is the central corm that is used for food. In the eddoes the central corm is smaller and bears many small side cormels, which are normally eaten. The coarser central corm is edible and is often used in soups. The flesh of both types varies in colour from white through yellow and orange to reddish or purple-the last especially in dasheen types.

Yield

Yields vary greatly according to cultivar, local

conditions, crop duration, etc. Recorded average yields (t/ha) in various areas are: East Africa 5-12.5; West Africa 5-10; Cook Islands 14; Egypt 26; Fiji 7.5-15; Hawaii 37.5-75 (irrigated, heavily fertilised); Hawaii 15-25 (dry land, heavily fertilised); India 34; Malaysia 9-10; the Philippines 25; Trinidad (dasheen) 10-15; Trinidad (eddoe) 5-10.

Substantially higher yields have been obtained in trials or carefully controlled conditions: Fiji 24; New Caledonia 20; Papua New Guinea 17; Vanuatu 30-40 (wet land); Vanuatu 15-20 (dry land).

Main use

Taros are an important food crop in many parts of the tropical world. The corms and cormels are rich in starch and may be eaten in a manner similar to potatoes,

boiled, baked, roasted, fried or as a basis for soups.

Subsidiary uses

In Hawaii and some of the Polynesian islands the corms of the dasheens are milled and the resultant slurry allowed to ferment to produce 'poi'. A steamed pudding made from grated taro and coconut is very popular in

Hawaii. The peeled tubers, after pre-cooking and drying, can be used to produce a flour, similar to potato flour, which is used in the preparation of soups, biscuits, bread, beverages, infant foods and puddings. In recent years there has been interest in the use of taro as a speciality food in the management of gluten allergy in infants, and as a cereal substitute in coeliac diseases, largely because of its exceptionally small starch grains.

Secondary and waste products

Leaves and petioles-may be cooked and eaten as a vegetable. In Hawaii the leaves are canned for local sale. A silage of moderate quality may also be prepared from the leaves and petioles.

Corms and cormels-are rich in mucilage which can be utilised in the paper industry or possibly in medicinal tablet manufacture. They can also be used as a source of power alcohol, or may be fermented to produce a drink known as 'chica'.

Stems-are sometimes used medicinally, notably in the treatment of snake bites.

Starch-consideration is being given to the use of taro starch as a filler for plastics.

Special features

Corms and cormels-are rich in starch; the flesh is mealy to smooth and usually has a somewhat nutty flavour. The composition of the edible portion of the corms has been given as: energy 373-406 kJ/100 g; water 73-78 per cent; protein 1.4-3 per cent; fat 0.1-1.5 per cent; carbohydrate 19-21 per cent; fibre 0.4-2.9 per cent; ash 0.6-1.3 per cent; calcium 32-40 mg/ 100 g; iron 0.8-1.7 mg/100 g; phosphorus 64-140 mg/100 g; potassium 514-550 mg/100 g; sodium 7-9 mg/100 g; carotene trace-67 IU/100 g; thiamine 0.09-0.18 mg/100 g; riboflavin 0.03-0.04 mg/100 g; niacin 0.4-0.9 mg/100 g; ascorbic acid 0-10 mg/100 g.

The starch grains are very small and consist of a mixture of two types, one 1-1.5 microns and the other 3-4 microns in diameter. For this reason taros are easily

digested, but unsuitable as a source of industrial starch. They are rich in a mucilage, which on hydrolysis yields eight sugars, the pre dominant ones being d-galactose and l-arabinose in the ratio 8:1. Most cultivars, particularly the dasheens, contain oxalic acid (0.1-0.4 per cent fresh weight) mainly in the form of 'raphides', ie bunches of needle-shaped crystals of calcium oxalate embedded in the tissues. An unidentified irritant(s) may also be present in the tissues; boiling reduces irritancy.

Leaves and petioles-both the leaves and petioles can be utilised as vegetables and are useful sources of vitamins A and C: vitamin A, leaves 20 885 IU/100 g, petioles 335 IU/100 g edible portion; vitamin C, leaves 142 mg/100 g, petioles 8 mg/100 g.

Processing

'Poi'-is prepared on a commercial scale in Hawaii, by first pressure cooking the corms and cormels in steam retorts, after which they are washed, peeled and milled; the resultant semi-fluid product is strained or centrifuged to remove fibre, and usually filled into plastic bags, which are distributed at room temperature through the normal retail channels. Under these conditions, fermentation due to Lactobacillus spp. is rapid and in 3-4 days the pH drops from 5.5-6 to 3.8-4. This fermented product is preferred to the fresh material. Public health regulations in Hawaii require 'poi' to have a total solids content of at least 30 per cent, or 18 per cent for ready mixed 'poi', which has been prepared by dilution with water. Fresh and fermented 'poi' can be canned satisfactorily; the former product is filled into cans at 76.6°C and retorted for 100 minutes at 98.8°C. Fermented 'poi' is heated to 93.2°C, filled hot, and cooled immediately without further heat

treatment.

Flour-is prepared by peeling and slicing the corms and cormels, and then washing the slices thoroughly in water so as to remove as much mucilaginous material as possible. After washing, the slices are left soaking in water overnight, then washed again and finally immersed for 3 hours in 0.25 per cent bisulphite solution. They are next blanched in boiling water for 4-5 minutes, drained and dried, preferably in a tunnel drier at 57-60°C. The dried slices are ground, sieved to 40-50 mesh and packaged.

Extruded products-taro rice, noodles and macaroni are being developed from Colocosia flour. In polyethylene packs these products have a shelf life of 12 months when stored at 38°C or below.

Instant taro flakes-have been manufactured commercially in Taiwan: peeled corms are trimmed, sliced to about 2 mm thick, steam cooked for 30 minutes, pureed to contain 20 per cent total solids with 5 per cent glucose solution, and drum-dried. The reconstituted product was reported to have good flavour, texture and colour.

Production and trade

Production-information about taro production is incomplete and scattered. The edible aroids (Colocasia, Xanthosoma, Alocasia and Cyrtosperma) are stated to contribute 1.6 per cent of the total food energy of the tropics and subtropics, or about 3.3 per cent of all root crops. However, in the Pacific area the aroids constitute a very high proportion of the root crops and are a major staple. In many of the islands in the Philippines taro

ranks third in tonnage among locally-grown root crops, and has shown substantial increases in production in recent years: 1973, 28 498 ha, 100 672 t; 1975, 36 830 ha, 123 523 t.

Similarly, in some Caribbean islands, taro (dasheen) is of considerable importance, accounting for about 60 per cent of all root crop production in St. Vincent and 45 per cent in St. Lucia.

Trade-figures for taro are scant. In the South Pacific in 1982 Tonga exported approximately 35 000 t and Western Samoa 3 800 t of dasheens, mainly to New Zealand, a substantial increase from the 1 500 t imported by that country in 1973. In the Caribbean, St. Vincent exports 300-400 t of dasheens per year to neighbouring territories. There is also a small import trade in dasheens and eddoes by the UK.

Major influences

The importance of taro in the Pacific islands is well established, and with continuous population growth and the availability of new markets for processed taro, both as human food and for livestock feed, taro cultivation is on the increase throughout the Pacific region. Similarly, throughout India and South-East Asia, much of Africa, tropical America and the Caribbean, taro is a valuable staple carbohydrate food, relatively easy and inexpensive to produce, and should maintain its position. In Indonesia, which is importing rice, the government is encouraging food diversification and taro should obtain a greater share of the carbohydrate contribution to the diet. Germplasm is being collected and may be expected to result in improved cultivars; this and better cultural practices should lead to greater yields per unit area, while the development of full

mechanisation should result in lower unit costs and encourage larger-scale production.

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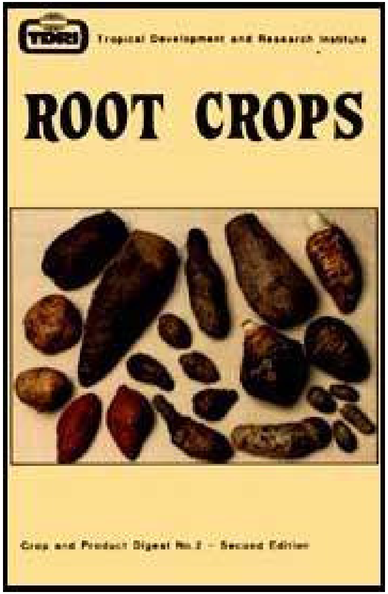
TDRI Tropical Development and Research Institute
ROOT CROPS
Crop and Product Digest No.2 – Second Edition

spp.)

- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**

🗀 Appendixes

Topee tambo (Calathea allouia)

Common names

TOPEE TAMBO(U), Allouya.

Botanical name

Calathea allouia (Aubl.) Lindl. Also referred to as Allouya americana (Lamk.).

Family

Marantaceae.

Other names

Agua bendita (Venez.); Allluia (Fr.); Ari (S. Am.); Cocurito (Venez.); Curcuma d'Amerique (Fr.); Guinea arrowroot (Carib.); Kopffomige marante (Ger.); Liren, Leren (S. Am.); L(l)erenes (P. Rico); Sweet corn root (Carib.); Topinambour (blanco) (Ant.); Topitambo/u (W.I.); Touple nambours (St. Lucia); Tumpinambou, Uari (S. Am.).

Botany

The plant is a herbaceous perennial, with a fleshy rootstock bearing erect or almost erect leaves with long, grooved petioles and elongated, oval blades reaching to a height of 0.5-1 m. In old plants there is a pseudostem, consisting of a short stalk, 10-30 cm long, bearing a few greenish to yellow or white flowers which rarely set seeds. At the base of the plant are fibrous roots, some of which produce clusters of ovoid tubers in the upper soil

surface.

Origin and distribution

Evidence is scant, but the plant is generally believed to be native to northern South America, some of the lesser Antilles, Hispaniola and Puerto Rico: it has been introduced to Madagascar, India, Sri Lanka, Malaysia, Indonesia and the Philippines.

Cultivation conditions

Topee tambo is adapted to a tropical climate of alternating wet and dry seasons, with the dry season occurring during the short day season of the tropical winter. A moderate annual rainfall of 150-200 cm is required. Planting is shortly before the start of the rainy season.

Soil-ideally a loose loam or clay that permits good drainage. The addition of FYM or other organic manure is particularly beneficial. Neither very heavy clays nor sandy soils are suitable.

Planting procedure

Material-the seed material usually consists of 'suckers', short sections of the rhizome with an upright terminal bud, which are obtained by breaking up the clump of rhizomes forming the basal portion of an old plant. After harvest the rhizomes are normally stored in a cool, dry place until required for planting, and they are not divided until that time. Germination is often erratic, but it has been shown that immersing the suckers in water at 48°C for 10 minutes gave over 90 per cent sprouting. Under some conditions the rhizomes may be left in the ground until the approach of the planting season:

however, intense shoot competition arising under such conditions leads to depressed yields unless they are separated. The yield from a single replanted offshoot is often greater than that of a whole clump, with very much larger individual tubers.

Method-preparation of the soil should take into account its water relations. Where regular, heavy rainfall is expected planting should be on ridges, with moderate rainfall planting on the flat is satisfactory, but if rainfall is likely to be limited and the soil has poor water-holding capacity planting should be in small pits to which organic matter has been added. Weeding in the early stages of growth is important.

Field spacing-recommended distances are about 40 cm between plants on ridges 80-100 cm apart (25 000-31 000 plants/ha) or on the flat 40-80 cm apart (16 000-62

000 plants/ha).

Pests and diseases

The insect Calopodes ethlius is reported to attack the tubers. Fungal or bacterial rotting of rhizomes that suffer excessive flooding may occur. The foliage appears to suffer little from pests or diseases.

Growth period

A crop of tubers is produced 9-12 months after planting.

Harvesting

The small tubers are usually dug up by hand with a fork.

Primary product

Tuberous roots-which resemble small potatoes. They are ovoid, usually 3.5-6 cm long with a diameter of 2.5-3.5 cm, and covered with a thin parchment-like skin and yellowish-gray in colour.

Yield

Yields of 2-12 t/ha have been reported. Low yields have been associated with drought towards the end of the (normally) wet season. Irrigation would be necessary in such circumstances.

Main use

The tuberous roots are free of fibre and are normally eaten boiled. After 15 minutes boiling the initial raw flavour disappears and the product is crisp in texture and said to have a unique flavour, somewhat resembling

sweet corn, though with a slightly bitter but not unpleasant aftertaste. The unusual texture and flavour have been described as making these tubers 'a gourmet item that should compete with popular hors d'oeuvres'. Longer cooking, up to 60 minutes, makes the texture more floury, like that of potato.

Secondary and waste products

A tincture of the leaves is reported to be used in traditional South American medicine for the treatment of cystitis and as a diuretic.

Special features

An analysis of the edible portion of the tubers has been published as: energy 395 kJ/100 g; water 75.7 per cent; protein 1.5 per cent; fat 0.3 per cent; carbohydrate 21.4

per cent. About 70 per cent of the carbohydrate is starch. A carbohydrate similar to laevulose is present. The tubers are reported to be rather mucilaginous.

Major influences

Although Calathea allouia is currently a crop of only minor importance, said to be partly due to its intolerance of both drought and waterlogging, recent reports from Puerto Rico emphasise its possibilities as a specialist food. In the Amazon region of Brazil it is being collected for germplasm as a potentially important basic food, similar to potatoes but more suited to Amazon conditions.

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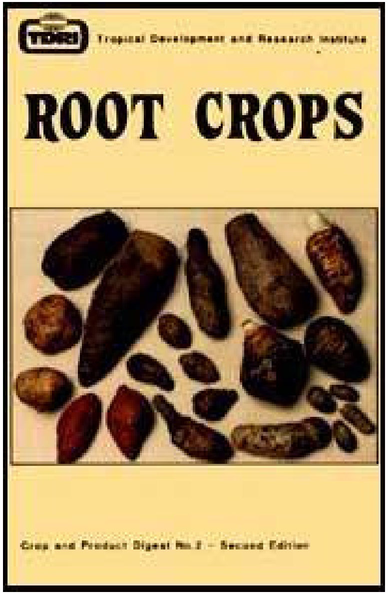

Root Crops (NRI, 1987, 308 p.)

sagittifolia)

- **Arrowroot (Maranta arundinacea)**
- **Cassava (Manihot esculenta)**
- **Chavar (Hitchenia caulina)**
- **Chinese water chestnut (Eleocharis dulcis)**
- **Chufa (Cyperus esculentus)**
- **East Indian arrowroot (Tacca leontopetaloides)**
- **Elephant yam (Amorphophallus spp.)**
- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon**

rotundifolius)

- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma chamissonis)**
- **Sweet potato (Ipomaea batatas)**

Ullucu (Ullucus tuberosus)

Common name

ULLUCU(S).

Botanical name

Ullucus tuberosus Caldas

Family

Basellaceae.

Other names

Chigua (Col.); Chuguas (Ecu.); Hubas (Ecu., Col.); Melloco (Ecu., Col.); Michiru, Miguri, Muchuchi (Venez.); Olloco (Ecu., Col.); Papa Lisa (Sp.); Ruba(s) (S. Am.); Timbos, Tiquio (Venez.); Ulluco(s) (Arg., Peru).

Botany

Ullucu is a perennial herb with a small number of erect stems 20-30 cm high, and fibrous roots, some of which

thicken at the end and produce tubers. Stolons arise in the leaf axils and trail over the ground, rooting and producing small tubers at the nodes: often tubers are borne aerially on stolons that do not reach the ground. The alternate leaves are broadly oval to cordate, 5-20 cm long and 5-12 cm broad, somewhat fleshy, variable in colour according to cultivar, ranging from dull green to bright green with red spots and purplish-yellow borders. The skin of the tubers also varies with cultivar, being white, red or yellow or red-spotted and the flesh is normally yellow: over 70 cultivars have been recognised. A yield of 30 tubers per plant is described as 'average'. The tubers are small, rather longer than broad, measuring 3-7 cm in length.

Origin and distribution

Ullucu originated in the high Andes of Peru, Bolivia and

north-west Argentina. It was introduced into Sri Lanka early in the present century, but its cultivation is still virtually confined to the Andes.

Cultivation conditions

The plant grows best in cool moist conditions under short day-lengths of about 12 hours (the production of stolons and stolon-borne tubers is stimulated by even shorter days of 10 hours). Ullucu has considerable resistance to frost and thus it is well suited to the Andean altiplano or high valley conditions. It is cultivated at elevations between 1 500 and 4 000 m, where it gives higher yields than the Andean cultivars of potato. It is frequently intercropped with oca (Oxalis tuberosa).

Planting procedure

Material-usually small tubers, weighing about 20 g.

Method-the tubers are planted in September-October in furrows in well-cultivated soil. Weeding is important. The plants are earthed up two or three times during their growing period to aid tuberisation.

Field spacing-highest yield of usable tubers has been observed with furrows 80-90 cm apart and plants at 30 cm along the rows.

Pests and diseases

The most important pest is stated to be the Andean weevil, Premnotrypes solani. Nematodes of Globodera spp. attack the plant. Reported fungi include Aecidium cantense and Rhizoctonia solani. A number of viruses have been found in virtually all ullucu material

examined; these include an ullucu strain of tobacco mosaic virus (TMV/U) and of papaya mosaic virus (PMV/U), as well as three new viruses designated ullucu virus A, B and C respectively. Apart from slight leaf mottling, these viruses appear to be symptomless, but laboratory experiments using virus-free material prepared by meristem culture suggest that growth and yield are considerably retarded by their presence-which is the general state of the crop as at present cultivated. No vector is known to be involved in transmitting these viruses.

Growth period

The tubers are ready for harvest in 4-6 months.

Harvesting and handling

The tubers are dug by hand and often eaten immediately.

Primary product

Tubers-which may be cylindrical, ellipsoidal or spherical, with shallow eyes, often resembling small potatoes. The skin is soft and the flesh is normally yellow and mucilaginous.

Yield

Yields are reported to average 5-11 t/ha.

Main use

Ullucu is a staple carbohydrate foodstuff in parts of the Andes where it is cooked and eaten in a manner similar to potatoes.

Subsidiary use

The tubers may be made into chuo (see Potato-Processing), called 'lingli' in the Cusco region, in which form they may be left for several months.

Secondary and waste products

It has been suggested that the leaves could be cooked as a vegetable.

Special features

An analysis of the edible portion of the tubers has been published as: energy 214 kJ/100 g; water 85.9 per cent; protein I per cent; fat 0 per cent; carbohydrate 12.5 per cent; fibre 0.6 per cent; ash 0.6 per cent; calcium 3 mg/100 g; iron 0.8 mg/100 g; phosphorus 35 mg/100 g; vitamin A 0 mg/100 g; thiamine 0.04 mg/100 g;

riboflavin 0.02 mg/100 g; niacin 0.3 mg/100 g; ascorbic acid 23 mg/100 g.

The high level of ascorbic acid is noteworthy.

Production and trade

Ullucu is a popular root crop in parts of South America, notably Peru, where production was estimated to be about 35 000 t/a in the middle 1960s, of which 26 000 t was for human consumption, 5 000 t was used for seed, and losses due to spoilage were estimated at about 3 600 t. At the time it was projected that the demand for ullucu in Peru would increase to 66 000 t by 1980, but up to date information appears not to be available.

Major influences

Ullucu is an important tuber crop in the Andean region

and germplasm collections are being made, housed at Cusco and Puno in Peru. It is considered a delicacy by many people and is found on sale in modern packaging in many supermarkets in Peru. Attempts to introduce it into Europe at the time of the potato famine in the mid-19th century were unsuccessful, as were attempts to introduce it into Sri Lanka in the early part of this century. However, especially if virus-free material can be substituted commercially, thus increasing yields and reducing costs, a wider market may be found for the processed product.

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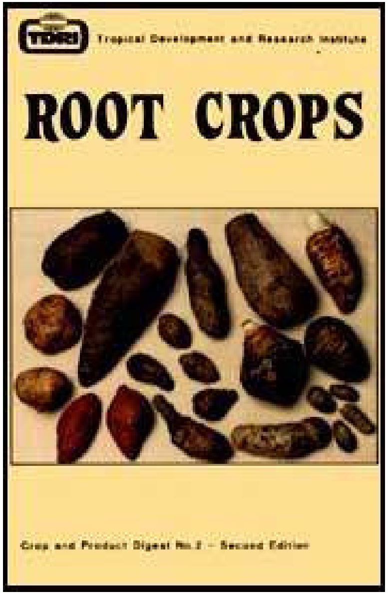

- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma**

Winged bean (Psophocarpus tetragonolobus)

Common names

WINGED BEAN, Aparagus bean, or pea, Four-angled, or Four-cornered bean, Goa bean3, Manila bean, Mauntius bean5.

Botanical name

Psophocarpus tetragonolobus (L.) DC.

Family

Leguminosae.

Other names

Amali, Batong-baimbing (Philipp.); Burma haricot; Calamismis (Philipp.); Chara konisem (Beng.); Chaudhaari-phali (Hind.); Chavdhari-ghevda (Bom.);

Chichipir, Chipir (Indon.); Cigarillas (Philipp.); Dara d(h)ambala (Sri La.); Du cau (Viet.); Dragon bean, Fava de cavallo (Port.); Flgelbohne (Ger.); Garbanso (Philipp.); Haricot dragon (Fr.); Kachang blimbing, Kachang botol, Kachang botor (Mal.); Kachang embing (Indon.); Kachang kelisah, Kachang kotor (Mal.); Kalamismis (Philipp.); Katchang botor (Mal.); Katjeper, Kechipir, Ktjeepir (blinger), Ktjeper (Indon.); Lakar-sem (Beng.); Morisuavarai, Murukavari (Tam.); Pallang, Parupa-gulung (Philipp.); P-myt, Psaung-sa (-ye or -za) (Burma); Pois ail, Pois carr (Fr.); Princess pea, Sabidokong (Philipp.); See-kok-tau (China); Segidilla, Seguidilla, Sequidilla, Sererella (Philipp.); Sesquidilla (Sp.); Shambe kayi (Ind.); Sigarilya (Philipp.); Tjeepir bee-bas, Tjeepir we-loo, Tjeetjeepir (Indon.); Too-a poo, Tua pu (Thai.); Winged pea.

Introductory note

The winged bean is attracting attention as a potentially valuable multipurpose crop, pods, seeds, tubers and vegetative parts all being used, and it has been documented as such in a companion volume (TPI Crop and Product Digest No. 3-Food Legumes). The present account considers its uses as a tuber crop in greater detail, but in view of the value of its pods and seeds it seems unlikely that it will often be grown as a tuber crop alone; rather the tubers will continue to be a bonus from a primarily legume crop.

Botany

A climbing perennial, producing new growth annually from shallow, persistent roots, but for optimum results the winged bean is treated as an annual. The fibrous roots are numerous with the main laterals running horizontally near the soil surface; after a few months

they usually become thickened and tuberous, near the base of the plant, though this does not occur in all strains. The roots are normally heavily nodulated. Plants in Malaysia may carry up to 440 large nodules each and their fresh weight can reach 800 kg/ha. A single nodule may weigh 0.6 g and have a diameter of up to 1.2 cm. The stem is moderately thick, slightly ridged and grooved, and can reach 3-3.6 m in height, if given support. The leaves are trifoliate, on long, stiff petioles; the leaflets are ovate, 7.5-15 cm long with the terminal one usually longer than the laterals and attached to the petiole by a marked pulvinus. The inflorescence is borne on an axillary raceme, up to 15 cm in length, with 2-10 flowers, which may be blue, white or lilac. It has been reported that pollination in some species is by bees, and in their absence pod-set is very low. The pods are four-sided, with characteristic serrated wings running down the four corners. They contain 5-20 seeds which can

vary in colour from white, through varying shades of yellow and brown to black, and may also be mottled.

There are many different local strains of the winged bean. The species is not found growing wild although it has been noted growing as an escape in Burma and the Philippines. There are four closely-related species found wild in Africa, of which P. palustris Desv. and P. scandens (Endl.) Verdc. (syn. P. Iongipedunculatus Hassk.) are occasionally cultivated.

Origin and distribution

The winged bean is thought to have originated in Africa (Madagascar or Mauritius) and to have spread to Asia, and is now cultivated usually as a market garden crop in southern India, Burma, Malaysia, New Guinea, Indonesia, the Philippines, China and Thailand, and to a

lesser extent in Africa, mainly in Ghana and Nigeria, and in the West Indies.

Cultivation conditions

Temperature-it is a tropical crop resistant to high temperatures, grown between 20°N and 15°S latitude.

Rainfall-well-distributed rainfall in excess of 150 cm per year is required and the plant thrives in areas with an annual rainfall of 250 cm or more. It can be grown as a dry season crop, provided that there is adequate irrigation and the water does not remain on the soil, as this tends to reduce the growth of roots and root tubers. Despite its perennial nature and extensive root-system, it does not survive prolonged drought, though drought-resistant cultivars are being developed.

Soil-the winged bean is not very demanding in its soil requirements, provided that there is adequate drainage. It cannot tolerate waterlogging or salinity. Well-cultivated, rich, sandy loams are best for optimum yields of pods; on clay soils the tubers are frequently small and lacking in flavour. It is frequently grown successfully in nitrogen-poor soils because of its exceptional ability to nodulate. However, recently in Nigeria, experimentally-grown winged beans have made comparatively slow growth accompanied by markedly chlorotic, light-green foliage, which suggests that the rate of nodulation is very dependent upon the availability of the most effective rhizobial strains, probably of the cowpea group. The manurial requirements of the winged bean have not been studied in detail, but it responds favourably to nitrogen fertilisation. When grown as a vegetable the routine application of standard NPK fertiliser at intervals of 14-21 days has been

recommended.

Altitude-it can be grown at elevations up to about 2 000 m in the tropics.

Day-length-the winged bean requires short days for normal flower induction, since when grown under a long photoperiod there is excessive vegetative growth at the expense of flowers. Recent experiments have shown that there is an interaction between day-length and day/night temperatures; both flowering and tuberisation are inhibited in 16 hour days, but with 8 hour days tubers formed regardless of temperature, but flowering was dependent upon the temperature regime used.

Planting procedure

Material-seed, which is viable for approximately one year, is normally used. Problems handicapping the future development of this crop are the lack of adequate commercial supplies of seeds and the genetic variability of existing supplies. In certain areas of Burma and the Philippines the crop is treated as a perennial and the tubers are left in the ground to produce fresh plants. A great deal of work is currently underway breeding new cultivars to suit specific conditions and for tuber production.

Method-the winged bean is often interplanted with sweet potatoes, taro, bananas, sugar cane or other vegetable crops. For pod and seed production planting is usually on the flat and the seeds are dibbed in holes about 2.5 cm deep, at the beginning of the rainy season. It is usual to provide the winged bean with supports; bamboo poles arranged singly, or in tripods, are often

used. When poles are used the plants may grow so tall that picking is difficult and the use of a trellis or wire fence 1-1.5 m high has been recommended. In Burma, where the crop is grown on a field scale for the production of tubers, the seeds are normally planted 5-7.5 cm deep on ridges and earthed up, stakes are frequently dispensed with, and the plants are left to ramble over the ground reaching a height of 30 cm. The effect of staking on the yield of root tubers has produced conflicting evidence, but the cost of staking may well offset any increase in yield. Seedlings make slow growth for the first 3-5 weeks and efficient weed control is usually necessary until they are well established.

Field spacing and pruning-in Burma, for tuber production on a field scale, planting is on ridges about 20 cm high and 60 cm crest to crest, at 7.5-15 cm along

the ridge (200 000-100 000/ha); recent work suggests that about 150 000/ha is the optimum figure. Often two or three seeds are used at each planting point; this requires approximately 500 kg seed/ha.

Although new varieties will produce fruit and root tubers, reproductive pruning (ie removal of flowers) increases root tuber production dramatically (an average of four-fold in reported experiments).

Pests and diseases

When grown in mixed market garden culture or shifting agriculture the winged bean is generally free from serious pests and diseases, though occasionally attacked by caterpillars, leaf miners, grasshoppers, spider mites and nematodes. Probably the most serious disease, which occurs in Papua

New Guinea, Java, the Philippines and Malaysia, is false rust, caused by Synchytrium psophocarpi, which may be controlled by copper fungicides. In plantations Cercospora spp. cause leaf spot, though not to the extent of producing defoliation. Caterpillars of Podalia spp. have been reported from Brazil as serious, and also the mites Polyphagotarsonemus latus and Tetranychus virticae. Viral symptoms have been observed in Nigeria and the Ivory Coast. It is probable that, as plantation-type plantings increase, disease problems will become more severe and many disease-causing organisms have been listed in recent literature. In particular, root knot nematodes have been reported to cause up to 70 per cent losses in tuberous roots: Meloidogyne incognita has been recorded as more aggressive than M. javanica.

Growth period

Production of pods starts within 2 months and continues for several weeks. However, when grown for tubers, harvesting is normally 4-8 months after sowing.

Harvesting and handling

The root tubers are normally harvested when they reach 2.5-5 cm in diameter and 7.5-12 cm in length. Lifting is usually by fork, care being taken to avoid damage; the practice of growing the plants on ridges facilitates this operation. Where grown on the flat, the ground is sometimes flooded to make digging easier and to reduce the possibility of injury. There is little information on storage of the root tubers as they are normally eaten immediately after harvest, but it has been found that under normal tropical conditions deterioration is rapid (loss of moisture, loss of vitamin C and long cooking time), but at lower temperatures and higher humidities

storage for a few weeks was possible, provided that fungal growth was prevented.

Primary product

In the present context, the tuberous portions of the roots are considered to be the primary product. These are roughly cylindrical, with a brown, fibrous skin, up to 12 cm in length and weighing about 50 g. The flesh is white and solid, and after peeling they are eaten raw or boiled. They are described as having the texture of an apple and tasting slightly sweet. They are most suitable for eating when quite small (about 2.5 cm thick), as they become increasingly fibrous and of poorer flavour when more mature.

Yields

Yields of root tubers are greatly influenced by conditions of growth, altitude, variety, etc, and virtually all reported yields are from crops grown primarily for pod or seed. Malaysia has reported 2.5-6 t/ha and the Philippines 2.3 t/ha. In Indonesia, higher altitudes were stated to favour root tuber production rather than that of pods, and in cool highlands yields were 6-16 t/ha, in lowland areas much less. In Papua New Guinea also, higher yields were reported from the highlands, and in recent experiments in Malaysia 14 t/ha from staked plants of selected strains in experimental plantings. In none of these cases was reproductive pruning practiced.

Other products

Pods, seeds, foliage and flowers are all used in human nutrition (see TPI Crop and Product Digest, No. 3-Food Legumes). There is also some use of the vegetative

parts or of the whole plant as animal feed.

Special features

Root tubers-the protein content is exceptionally high for root crops, normally 12-15 per cent of the fresh weight. The water content of the fresh tubers is 52-68 per cent. The composition of the dry matter has been given as: protein 13-20 per cent; fat 0.6-1.4 per cent; carbohydrate 63-77 per cent; fibre 1.5-21 per cent; ash 1.7-3.9 per cent; calcium 40 mg/100 g; iron 3 mg/100 g; phosphorus 64 mg/100 g.

The wide range of values appears to be associated with variety and possibly with maturity of the root tubers.

The carbohydrate is about 80 per cent starch and 20 per cent sugars. In this analysis the non-protein nitrogen

was 7.4-15 per cent of the crude protein but other reports have found values as high as 50 per cent. Sulphur-containing amino acids are low but the aspartic acid content is exceptionally high.

The root tubers have high levels of trypsin inhibitory activity (13 500 - 30 100 IU/mg fresh weight); this is inactivated by cooking.

Forage and animal feed-analyses of the whole plant in connection with its possible use as animal feed are:

Seeds-protein 42 per cent; neutral detergent soluble fraction 77 per cent; in vitro digestibility 92 per cent.

Young leaves-protein 34 per cent; neutral detergent soluble fraction 69 per cent.

Old leaves-protein 24 per cent.

Green pods-protein 22 per cent.

Dry pods without seeds-protein 9 per cent; lignin 15 per cent; in vitro digestibility 62 per cent.

Old stems-protein 11 per cent; lignin 17 per cent; in vitro digestibility 58 per cent.

Young stems-lignin 13 per cent; in vitro digestibility 64 per cent.

Root tubers-protein 20 per cent; neutral detergent soluble fraction 72 per cent; in vitro digestibility 95 per cent.

The neutral detergent soluble fraction is the carbohydrate and protein available to ruminants. Lignin was the most important factor in depressing in vitro digestibility.

The use of sun-dried chips of the root tubers, dried haulms, leaves and seed cakes, mixed with tapioca chips and pelletised, has been proposed for animal feed.

Production and trade

No statistical data are available.

Major influences

Winged bean is of rapidly increasing interest as a high-protein multipurpose crop, particularly for cultivation in the humid tropics, where the incidence of protein deficiency in human diets is often very difficult to remedy. All parts of the plant are edible, ie seeds, root tubers, leaves and flowers. The seeds, which are very similar nutritionally to soyabeans, have the advantage that they have a pleasant sweet flavour in contrast to

the rather bitter flavour of the soyabean. Like the soyabean, the winged bean could be utilised as a source of edible oil and has potential as a substitute if commercial production could be developed. Another interesting feature of the crop is the high protein content of the root tubers which could help alleviate protein deficiency in local diets. In addition, the exceptional ability of the crop to fix atmospheric nitrogen by bacteria in the root nodules should not be overlooked, in view of the world shortage and rising prices of artificial nitrogenous fertilisers.

It has been suggested that in the future the winged bean could become as important as the soyabean in world agriculture, with the added bonus of yielding substantial quantities of edible, high-protein root tubers. Considerable research is currently underway. While the plant in its present form is suitable for garden

or smallholding use, requiring staking or rambling tangled over the ground, large-scale cultivation would be much more practicable with a low-growing determinate cultivar; also, a plant with a clearly-defined flowering season would enable deflowering to be carried out as a single field operation if the crop were being grown specifically for tubers.

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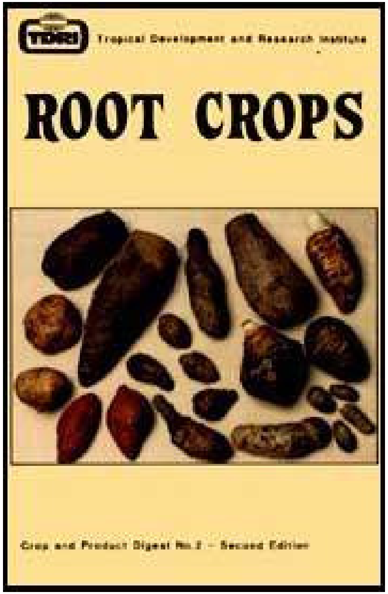
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senegalensis)

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Yacn (Polymnia sonchifolia)

Common names

YACN, Jiquima.

Botanical name

Polymnia sonchifolia Poepp. and Endl. syn. P. edulis Wedd.

Family

Compositae.

Other names

Arboloco (Col.); Aricoma, Aricuma (Peru, Bol.); Jiquimilla (Venez., Col.); Llacn (Arg., Bol., Peru); Poire

de terre cochet (Fr.);

Botany

A herbaceous plant, the stem of which is composed of a subterranean perennial part, which gives rise to annual aerial stems. The tall aerial stems are covered with fine hairs and green in colour with purple spots and can reach about 1.5 m in height. The leaves are opposite, thin and smooth, with serrated edges. From the lower leaf axils additional stems arise and at the end of these stems the yellow or orange-yellow composite flowers are borne. The subterranean part of the main stem thickens to give rise to the tubers which are usually ellipsoid or cylindrical in shape.

Origin and distribution

The plant originated in the central Andes, and has from early prehistoric times been cultivated in the cool conditions of the subtropical and tropical Andes, at elevations between 1 000 and 3 300 m in Peru, Bolivia, Colombia and north-west Argentina.

Planting procedure

Material-propagated vegetatively from sprouting runners (slips), about 10-20 cm long, taken from the base of the main stem with a few roots attached. Method-the slips are planted throughout the year, provided there is adequate soil moisture, and receive little attention apart from being kept free from weeds.

Growth period

The crop reaches maturity in about 7 months.

Harvesting and handling

The tubers are lifted by hand and, if kept in a dark, dry place, can be stored for several months.

Primary product

Tubers-the tuberous fusiform roots are edible and can reach 20 cm in length and 3-10 cm in diameter, and weigh up to 2 kg though 100-500 g is more usual. There is considerable variation in the form and composition according to the cultivar, but most have a soft purplish, bark-like skin and can be spheroid or ellipsoid with somewhat translucent yellow flesh.

Yield

Yields of up to 38 t/ha have been reported.

Main use

Yacn is used as a vegetable and may be cooked or eaten raw; sometimes the tubers are dried in the sun before cooking, since this is said to sweeten them and improve their flavour.

Subsidiary uses

The tubers may be used as a source of inulin or fermented to produce alcohol.

Secondary and waste products

The main stem is also eaten as a vegetable and the dried leaves, which have a protein content of approximately 11-17 per cent, are used as an animal feedingstuff.

Special features

An analysis of the edible portion of the tubers has been quoted as: water 69.5-82.7 per cent; protein 0.44-2.22 per cent; nitrogen-free extract 2.65 10.5 per cent; fat 0.1-0.13 per cent; carbohydrate 19.67 per cent; fibre 0.28-1.75 per cent; ash 0.26-2.04 per cent.

The carbohydrate consists mainly of inulin, and contents ranging from 61 to 69 per cent have been obtained for the dry roots.

Major influences

It has been suggested that the yacn could be a useful fodder crop for cultivation at high altitudes in the tropics or subtropics. This plant is high in priority for conservation of genetic resources.

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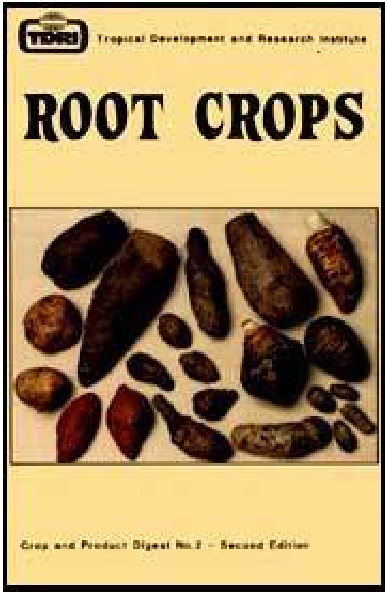

Root Crops (NRI, 1987, 308 p.)

Yam (Dioscorea spp.)

Common name

YAM.

Botanical name

Dioscorea spp.

Family name

Dioscoreaceae.

Other names

Car (Braz.); Gname (It.); Ighnam (Ar.); Igname (Fr. and It.); Ignamekolle (Ger.); Inhame (Port.); Iniamas (Nether.); Name (Sp.); Nyambi (Fr.); Nyami (Sen.); Yamswurzel (Ger.).

Botany

Dioscorea is a large genus of over 600 species with subterranean tubers or rhizomes. The tubers are storage

organs and often grown to a considerable size; they produce short, fibrous roots and annual shoots, which are twining (except in dwarf species), the direction of twining being specific.

The leaves are petiolate, often cordate, with strongly marked reticulate veining (unusual for a monocotyledon), sometimes lobed, occasionally palmately compound. Many species produce bulbils in the axils of the leaves which have the morphology and appearance of condensed stems and in a few instances are relatively large and tuberous. The flowers are small, and borne in long racemes, with male and female separate and usually borne on different plants. The female flowers are followed by dehiscent capsules, usually trilocular, with 6 seeds, usually winged for wind dispersal, though many of the cultivated forms have become partially or highly sterile.

The genus Dioscorea is divided into a number of taxonomic sections; the important food yams are grouped in the following: Enantiophyllum-D. alata, D. rotundata/D. cayenensis complex, D. opposita and D. japonica; Lasiophyton-D. dumetorum and D. hispida; Combilium-D. esculenta; Macrogynodium-D. trifida; Opsophyton-D. bulbifera. There are some 60 species that have been used for food, but most are of little importance; the above (with the exception of D. japonica) are described in the chapters following this general chapter.

Origin and distribution

The genus Dioscorea is considered to be among the most primitive of the Angiosperms and was present and well diversified in part of the southern world at the end of the Cretaceous period (approximately 75 million

years ago), and the early spread appears to have been via an antarctic continent (whose climate was totally different in early geological times). The occurrence of Dioscorea spp. in southern Asia, Africa and South America long pre-dates human history and domestication of the different species in these areas appears to have been by aboriginal man. Wild yams and domesticated cultivars occur throughout the tropical and subtropical world, with one dwarf species (D. pyrenaica Bub. and Borders) as far north as the Pyrenees. West Africa is the most important cultivation zone, where yam is a major staple, producing about 93 per cent of the world's edible yams, but the crop is also of considerable importance in parts of eastern Africa, the Pacific area (including Japan), the Caribbean and tropical America.

Cultivation conditions

Temperature-most edible yams cannot withstand frost and make poor growth below 20°C. Optimum growth occurs at about 30°C; temperatures much above this have an adverse effect, especially if associated with drought. An exception is D. opposita (see Chinese yam).

Rainfall-although generally considered drought resistant, yams require adequate moisture throughout their growing period and there is a positive correlation between high and regular rainfall, vine growth and tuber yield. For optimum yields adequate moisture between the 14th and 20th weeks of growth is of great importance. The major areas of production are centred where there is a sharply demarcated dry season of 2-5 months and a rainfall of 120-150 cm or more during the growing season. In parts of West Africa yams are grown where the rainfall is as low as 60 cm per year, but yields are very poor, while crops are also obtained where the

annual rainfall reaches 300 cm.

Soil-good drainage is essential and for optimum yields a deep well-drained sandy loam is required. On heavy, waterlogged soils the tubers are liable to rot, while on poor soils the weak root system is unable to obtain sufficient water or nutrients to produce reasonably-sized tubers. Most yams are grown on land after it has been cleared from bush; fallow mulching is often practiced and FYM at the rate of 17.5-25 t/ha gives greatly increased yields. Fertilisers are not widely used but there is a wide response to treatment, particularly to the application of phosphorus and potassium. The use of potassium sulphate at the rate of 125-370 kg/ha or a 12:12:8 NPK mixture at the rate of about 60 g per mound has been recommended in Nigeria; while in Trinidad potassium muriate at 376 kg/ha and superphosphate at 376 kg/ha are used. In Barbados

yams grow well as a rotation crop in sugar cane land that has residual nitrogen and potassium from the previous cane crop, but yields have been substantially increased by the application of 225 kg/ha of a 9:10:23 NPK fertiliser. Application should be 2-3 months after growth commences. The application of potash alone has given yield increases in Nigeria, and it is also reported to increase the storage life of the tubers, while chlorine in the fertiliser adversely affects the starch content.

Altitude-most yams can be grown successfully at low or medium elevations and some, such as D. alata, are reported to be grown at altitudes up to 2 700 m in the Himalayas, but in general yields are considerably reduced above 900 m.

Day-length-the majority of Dioscorea spp. exhibit a photoperiodic response and although day-lengths

greater than 12 hours favour the growth of the vine, tuber development is normally most satisfactory under short-day conditions (10-11 hours of daylight).

Planting procedure

Material-edible yams are normally propagated by the use of small tubers (seed yams), cuttings off the tubers, setts (pre-sprouted tubers or pieces of tuber), or bulbils. It is possible to use vine cuttings, but tuber production by this method is generally uneconomic. (All types of vegetative planting material other than vine cuttings are commonly referred to as setts.) The best planting material is the small whole tuber and species such as D. esculenta and D. trifida, which produce a fairly large number of tubers, can be propagated very easily by reserving a few of the tubers and planting these at the beginning of the next season. Other species

such as D. bulbifera and some forms of D. alata produce aerial bulbils, which can be used, but the majority of the more important food yams only produce 1-3 tubers a season and in this case setts cut from the tuber are often used and are referred to as tops or 'heads' (proximal), middles, and bottoms or 'tails' (distal). In general, tops are preferred and the larger the sets, the earlier and greater is the rate of germination. The weight of sett used varies from about 0.25 to 2 kg but occasionally whole tubers weighing up to 4.5 kg are used, especially when extra large yams are required for ceremonial purposes. Sometimes the body of the yam is cut off and the head left in the soil to grow and produce seed yams for propagation; this practice is known as 'topping' or 'milking'. In addition, planting material may be produced in specialised yam nurseries, where one to four small setts of 85-150 g are planted in small heaps of soil, normally up to 12 500/ha, and these yield small

yams suitable for use as seed. Most yams have a definite period of dormancy, but this may be broken by the use of a chemical such as ethylene chlorhydrin, where production of out-of-season tubers is required.

A recent development has been the production in Barbados of virus-tested planting material, in which yams grown from virus-free meristem tip cultures are being multiplied in the field and, after inspection, distributed for planting. This material has been tested in a number of Caribbean islands and has given approximately double the yield obtained when conventional seed yams are planted, and the operation is now commercial.

Method-yams are usually intercropped with maize and vegetables, such as cucurbits, pumpkins, peppers and okra, but mono-culture, normally on small plots, is

increasing in certain areas of West Africa and the Caribbean. Three types of planting systems are practiced: the setts may be planted on the flat, they may be planted in trenches or holes, or they may be planted on mounds, ridges or raised beds. The last method is the most widespread and the mounds can vary from about 50 cm high and perhaps twice as wide at the bottom, to nearly 100 cm high and twice this width at the base. In the smaller mounds one sett is normally planted and in the larger ones three or four, or even eight to ten setts. In general, larger mounds are preferred and the setts are planted in holes dug in the sides near the natural ground level. They are planted deeply to avoid drying out of the young shoots and for this reason the head of the sett is also placed downwards. Sometimes, instead of individual mounds, ridges are used and the setts are planted along the sides of the ridges. Planting on the flat is only practiced in areas such as river flood plains,

where the soil is deep and soft. In this system, the setts are planted in holes just below the soil surface. Support for the growing vines is usually provided, most often stakes or trellises, or strings attached to horizontal ropes or trees, sometimes corn stalks left from an intercrop of maize, or even bushes: there is evidence indicating that such support is necessary for satisfactory plant and tuber development. However, a few cultivars, notably of D. alata and D. esculenta, are adapted to trailing on the ground without support, and in Barbados D. alata is cultivated, without staking, on the plantation scale. Recent work suggests that with close planting other species may also give satisfactory yields without support.

Planting is normally by hand, but a mechanical planter is now being used in Barbados. For optimum yields yams must be kept free from weeds, at least for the first three

months of growth, and the following herbicides have been used successfully: diuron 2.6 kg/ha, together with TCA at 4.4 kg/ha, and atrazine at 1.5-2.9 kg/ha.

Time of planting-yams are not normally grown under irrigation and in areas where the rains last 8-10 months planting normally takes place just before or at the beginning of the rains. Where the rainy season is less than 8 months it has been found that early planting, up to 3 months before the rains, can give a 30 per cent increase in yield.

Field spacing-a wide range of planting distances is used, depending upon the species, the soil type and the water table and whether intercropping is practiced; mounds are often irregularly spaced and planting distances ranging from 0.7 to 2.3 m2 have been reported. Generally, the wider the spacing the lower the yield and

common spacings are 1.2 x 1.2 m, 1.2x0.9 m and 1.8x0.6 m.

Seed rate-the number of setts used obviously varies according to the species and the cultivar, but for most large-tubered yams 10 000-15 000/ha are used, requiring at least 2.5 t/ha of setts.

Pests and diseases

Weeds-can be serious competitors with yams. While hand-weeding is the most common practice, pre-emergence spraying with atrazine or ametryn will control weeds until the plants have sprouted; subsequently paraquat carefully applied with a shielded spray may be used. In due course the foliage should become thick enough to cover the ground and eliminate weeds, especially when the vines are unslaked.

Pests-yam beetles of several species are important, especially in Africa: these include the greater yam beetle (Heteroligus meles), the lesser yam beetle (H. appius), also Heteronychus licas, Prionoryctes rufopiceus, P. caniculus and Lilioceris spp. These attack the tuber setts and may prevent sprouting. Dusting the plant setts with 2 per cent aldrin or 0.5 per cent gamma-HCH will normally prevent attack. In the Caribbean, the yam weevil Palaeopus costicollis causes similar damage and control is as for the yam beetles. The termite, Amitermes evancifer, is occasionally a serious pest of yam tubers in Africa. Yam scale (Aspidiella hartii) attacks stored yams in Africa, Asia and the Pacific; in the Caribbean its principal damage is to young vines which may be destroyed completely. It is important to use scale-free planting material; this, together with the dusting recommended above, should provide adequate control. Mealy bugs, Geococcus coffeae, Phenacoccus

gossypii, Planococcus citri, and (in Papua New Guinea) P. dioscoreae, feed on the tubers and roots of yams, and can multiply to considerable numbers, causing shrivelling of the stored tubers. Only clean and healthy material should be planted (again the dusting treatment recommended for yam beetles should be used), and, if aerial parts of the plant are affected, spraying with malathion or malathion plus an oil emulsion (eg Triona or Albolineum) is recommended.

Several species of nematodes attack yams. The yam nematode, Scutellonema bradys, is widely distributed in both Old and New World tropics and causes 'dry rot' of the tubers. Pratylenchus coffeae, causing rather similar lesions, has been reported to attack yams in Puerto Rico, Jamaica and the Solomon Islands, while the root knot nematodes, Meloidogyne spp. of world-wide distribution, sometimes attack this crop. Chemical

control has not proved entirely satisfactory, though D-D and dibromochloropropane have given some reduction in the infestation rate. Absence of host plants and a fallow period are recommended, and care must be taken to avoid planting infected material.

Diseases-these include anthracnose (caused by Glomerella cingulata), which produces black necrotic lesions on leaves and stems, and can kill the plant by attacking the terminal bud, and leaf spot, caused by various species of Cercospora, Colletotrichum, and Phyllosticta. Control involves sanitation by removal of crop debris, and fungicide treatment: maneb, benomyl, benomyl+ propineb, zineb and mancozeb have all been reported to give reasonably good results. During storage of the tubers, severe losses are caused by rotting due to Botryodiplodia theobromae, Aspergillus spp., Rosellinia bunodes, Lasiodiplodia sp., Fusarium

oxysporum, F. solani and other Fusarium spp. These rots may also affect the growing plant when the setts consist of cut pieces of tuber, but are controlled by simple measures such as the painting of the cut surfaces with limewash or Bordeaux mixture, or coating with wood ash. Rotting during storage may be minimised by treating cut or bruised surfaces of the harvested tubers in the same manner.

Virus diseases have been reported from the Caribbean and West Africa, but are probably world-wide. Most are of the mosaic type causing leaf mottling, and most are serious only when the infection occurs early and is severe, leading to stunting and sometimes causing the production of numerous basal shoots, giving the plant a bushy appearance. In the Lesser Antilles an internal brown spotting (first observed in Barbados) is associated with virus infection; the affected tubers

develop hard brown nodules in the flesh, often surrounded by necrotic areas, and the foliage has (not always easily discernible) mosaic symptoms. Yields of affected plants may be reduced by half. No vector has been identified for any of these viruses, but a meristem culture technique and the production of virus-tested yams has been developed and carried through to the commercial scale in Barbados.

Growth period

Most edible yams normally reach maturity 8-11 months after planting, though in certain species a first harvest may be obtained after 5 months. The growth period usually comes to an end at, or shortly after, the end of the rainy season: neither late planting nor subsequent irrigation will prolong growth beyond the normal annual periodicity for the particular species.

Harvesting and handling

At the start of the dry season yam plants normally die back and the tubers are ready for harvesting, though in most cases they may be left in the ground for several weeks as deterioration is usually not rapid. In some species, eg D. rotundata and D. alata, an early crop may be taken as well as the main harvest; in this case the tuber is carefully cut below the head and removed, leaving the top to grow again and produce another tuber, or tubers. Large yams are usually dug out by hand with wooden spades or digging sticks, or with forks-a laborious task since great care has to be taken to avoid damaging the tubers. Yam species which produce a number of small tubers can be harvested mechanically with a potato spinner, but recent work in the Caribbean has developed a mechanical harvester suitable for the large-tubered D. alata planted on ridges. Aerial tubers

or bulbils are usually plucked by hand from the vine as required.

Yam tubers, if unaffected by pests and diseases, may be stored until their natural period of dormancy is broken. It has already been noted that many species may be stored by leaving them unharvested during part, at least, of the dry season. Normally, however, yams are harvested and stored. The tubers must be clean and undamaged, excessive temperatures must be avoided and good aeration provided. Some varieties will keep in good condition for about 6 months, though the tubers may lose 10-40 per cent or more of their weight, and the storage life differs between different species or even cultivars. Several methods of storage are used: in some parts of Asia and Africa tubers are stacked into heaps which may be small or which may contain several tonnes; these heaps are covered with straw or leafy

branches. In West Africa yam barns are common, consisting of a wooden vertical or nearly vertical framework to which the tubers are individually tied: the frames are usually 1-2 m high and are built in the shade of a tree or under a thatched roof. These frames provide excellent ventilation and the tubers can be protected from termite attack and flooding. In the Pacific Islands specially constructed thatched huts with a raised platform, on which the yams are stacked, are used. In many countries, yams are stored simply in ordinary storerooms, sheds, or under houses that are built on piles or stilts; often the yams are arranged in piles or rows about 1 m high and 1 m broad, allowing for ventilation and access.

Most yams, with the exception of D. trifida, are liable to chilling injury if exposed to temperatures below about 12°C, an important consideration when yams are to be

exported to temperate climates.

Insect damage to yams during storage is usually not serious, though lesions produced by insects (often during the growth of the tubers) may permit entry of fungi or bacteria, as do cuts and bruises received during harvesting. Rots caused by fungi (see Pests and diseases) may be rapid, destroying a tuber within a week or two.

Prolongation of dormancy by chemical methods is not normally successful but recent experiments have achieved a degree of success using gamma irradiation of sound tubers at a dosage of 12.5 head; this treatment has also somewhat reduced weight loss. The method is claimed to be economically and practically superior to storage at 15°C.

Primary product(s)

Tubers-the subterranean tubers consist mainly of starchy tissues covered by a suberised layer forming a skin. There is great variation in the size, form and colour of tubers, in their texture, flavour, thickness of skin, and in storage behaviour.

The principal economic species are the Enantiophyllum yams (see Botany), and these produce few tubers, normally one to three, which may be globular, flattened, cylindrical or elongated and sometimes branched or lobed, under normal conditions weighing from 3 to 15 kg, though specially grown 'giant tubers' can exceed 50 kg. The Lasiophyton yams form several medium-sized tubers, sometimes fused into an irregular cluster. The Asian Combilium yams and the American Macrogynodium yams produce a large number of small

spindle-shaped tubers, similar to sweet potatoes.

Bulbils-many yam species also produce bulbils in the axils of leaves, which may become similar to underground tubers, but smaller. In a few species, eg D. bulbifera (Opsophyton), the bulbils are the main storage organs.

Yield

Under optimal conditions yams are among the most efficient producers of human food: yields of 70 t/ha (D. esculenta) have been recorded from West Irian and 58 t/ha (D. alata) from St. Vincent. Under normal farming conditions, however, yields are considerably lower, the normal range for yams in pure stands being: West Africa 7.5-18 t/ha; South-East Asia 12.5-25 t/ha; the Caribbean 20-30 t/ha. These yields are gross, and

because a substantial quantity is used for propagation, net yields are generally about 2.5 t/ha less.

Main use

Yams are a staple carbohydrate food, commonly eaten as a vegetable, either boiled, baked or fried. In West Africa a major proportion of the yam crop is eaten as 'fufu', a stiff, glutinous dough.

Subsidiary uses

Yams are sometimes dried and made into flour; this is often the case with damaged yams or with yams that are surplus to requirements, essentially as a method of storage. In recent years there have been attempts at more sophisticated processing for export, eg fufu from Nigeria, canned yams and yam soup from Puerto Rico, and yam flakes from Barbados. In general these attempts have not been commercial successes, largely owing to the high cost of the raw material.

Secondary and waste products

Peelings and waste from yams are often used for feeding poultry and livestock. The possibility of using yams for the production of starch or of alcohol has been considered, but not developed, as there are many cheaper sources of both these products in the countries where yams are grown. Poisoned bait for hunting and fishing is sometimes prepared from D. hispida and D. dumetorum in parts of Asia and Africa. Diosgenin (used as a basis for the corticosteroid family of drugs) has been commercially prepared from some species notably D. mexicana, D. floribunda and D. composita. Some species, eg D. cirrhosa, are used as a source of tannin.

Special features

Yams are essentially carbohydrate foods with relatively high protein and ascorbic acid contents. Typical figures for the composition of the edible portion of fresh tuber are: energy 439 kJ/100 g; water 72.4 per cent; protein 2.4 per cent; fat 0.2 per cent; carbohydrate 24.1 per cent; fibre 0.6 per cent; calcium 22 mg/100 g; iron 0.8 mg/100 g; thiamine 0.09 mg/100 g; riboflavin 0.03 mg/100 g; niacin 0.5 mg/100 g; ascorbic acid 10 mg/100 g.

Proximate analyses of different species will be found in the specific chapters.

Many yam cultivars contain substantial amounts of mucilage which affects the culinary properties of the tubers. In addition, several Dioscorea spp. contain

alkaloids, tannin and sapogenins. For example, the toxic alkaloid dioscorine is present in the edible species D. hispida and the presence of diosgenin in D. mexicana and others has already been noted.

Processing

Fufu-is prepared by cutting peeled yams into small pieces and boiling in water until soft, then pounding in a mortar until a sticky dough is formed, which is usually firm enough to be cut into slices.

Yam flour-traditionally a method of long-term storage, in which the tubers are sliced to a thickness of about I cm, peeled and dried in the sun. When dry, the hard slices are ground to give a coarse flour. In a slightly more sophisticated process, washed tubers are cut into slices about 5 cm thick, cooked until soft, then peeled

and mashed into a pulp which is spread out to a depth of about 2 cm and dried for 6-8 hours at a temperature of 50-70°C, until the moisture content is reduced to 10 per cent. The dried material is finely ground and passed through a sieve before being packed into polyethylene bags. When reconstituted the product somewhat resembles fufu.

Yam flakes-have been prepared in the Caribbean from D. alata and in Nigeria from D. rotundata: the process is outlined in the chapter on Greater yam.

Production and trade

Production-despite the increasing consumption of introduced foods such as cassava and rice in the main yam-consuming area of the world (West Africa), it appears that yam production is remaining constant at

about 20 million tonnes per year. Table 1 is taken from FAO statistics (however, the last year for which FAO published separate figures for yams was 1975): it may be seen that some 97 per cent of the world's production derives from Africa (over 90 per cent from West African countries).

	Area harvested ('000 ha)				Production ('000 t)			
	1961–65 average	1973	1974	1975	1961–65 average	1973	1974	1975
World	2 138	2 029	2 073	2 110	16 243	19 380	20 138	20 198
Africa	2 093	1 971	2 012	2 049	15 803	18 749	19 541	19 539
Ghana	146	130	133	160	1 061	777	850	800
Ivory Coast	154	203	198	200	1 228	1 624	1 680	1 700
Nigeria	1 511	1 350	1 350	1 350	11 740	14 500	15 000	15 000
Togo	90	60	100	100	763	639	750	750
Other African countries	192	228	231	239	1 011	1 209	1 261	1 289

Table 1: Yam - Area and production in selected countries

	Area harvested ('000 ha)				Production ('000 t)			
	1961–65 average	1973	1974	1975	1961–65 average	1973	1974	1975
North and Central America	10	21	21	22	134	230	237	243
South America	9	8	10	10	50	47	47	48
Asia	13	14	15	15	104	161	164	168
Oceania	10	14	14	15	151	154	200	200
All developed countries	3	7	7	8	52	130	134	138
All developing countries	2 134	2 021	2 065	2 103	16 181	19 230	20 054	20 000

[1] Discrepancies between world totals and totals for developed and developing countries are due to rounding off of figures

Table 1: Yam - Area and production in selected countries (continued)

World production per hectare increased slightly during the decade 1965-1975 (Table 2), but this was almost entirely due to improvements in Africa (and, to a lesser extent, Asia). Productivity fell slightly in South America.

Table 2: Yam - Average yields (t/ha)

	1961-65	1975
World	7.6	9.37
Africa	7.55	9.54
North and Central America	10.04	11.12
South America	5.7	4.69
Asia	8.29	11.35
Oceania	14.84	13.51
All developed countries	17.91	17.92
All developing countries	7.58	9.54

Trade-accurate figures are not available, but trade sources estimate imports of yams to the UK for 1982 to have been about 10 000 t, made up as follows: Brazil 5 000 t; Jamaica 3 000 t; Barbados 100 t; West Africa 400 t; others 1 500 t. Until 1980 Colombia supplied 5 000 t/a to the UK, but this fell to zero during 1981 and 1982. It

is believed that the Colombian export trade is now entirely to the USA and that the USA also imports about 5 000 t from Brazil and a substantial quantity from Puerto Rico. Canadian trade sources indicate average imports of about 2 000 t/a from Jamaica for the past decade, but expect a slow decline unless there is a reduction in price. It appears that the total quantity of yams entering overseas trade is fairly steady at about 22 000 t/a.

Major influences

Yam in most parts of the tropical world is more costly (mainly because of high labour inputs and relatively low yields) than most of the competing carbohydrate foods, but in spite of this continues to be highly favoured, at least partly for traditional and ethnocultural reasons. It appears to be holding its own in terms of production

and the adoption of full mechanisation as currently being developed (mainly in the Caribbean), along with breeding programmes for high-yielding, shallow-rooting cultivars and elimination of staking, should ensure that yam production will not decrease, but possibly increase. A small export trade seems likely to continue.

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Management, 26, 355-370.

Bitter yam (Dioscorea dumetorum)

Common names

BITTER YAM, Cluster yam.

Botanical name

Dioscorea dumetorum (Kunth) Pax. (Lasiophyton).

Family

Dioscoreaceae.

Other names

Esuri yam, Esur, (W. Afr.); Ikamba (Gab.); Name amargo

(S. Am.); Ono (W. Afr.); Three leaved or Trifoliate yam.

Botany

The stems twine clockwise (to the left), unlike most other yams of economic importance, and are robust, hirsute and spiny. The leaves are trifoliate with tomentose leaflets that have the typical reticulate venation of yams, 12-16 cm long, 6-9 cm broad: the petioles are pubescent and often spiny. The flowers are small dioecious and fertile, forming oblong fruit, about 4 cm in length and 2 cm in diameter. The tubers may be single or (usually) produced in clusters: bulbils are rarely formed. The wild forms are often very poisonous, but the cultivated forms usually have little toxicity. This African species is closely related to the Asian species D. hispida Dennst.

Origin and distribution

The species is found wild throughout tropical Africa between 15°N and 15°S, and is cultivated in West Africa, especially in Nigeria.

Cultivation conditions

See Yam

Planting procedure

Setts are normally used but satisfactory results have been obtained with vine cuttings.

Pests and diseases

Among other pests of stored yams (see Yam) the insects Araecerus fasciculatus and Lepidobregma minuscula

have been identified in Nigeria as infesting tubers of D. dumetorum.

Growth period

Usually 8-10 months.

Harvesting and handling

D. dumetorum is easily harvested by hand (and could be mechanically harvested were it grown on the large scale). The tubers do not store well, a high proportion becoming hard and inedible within 4 weeks after lifting. Drying of sliced tubers is used as a method of storage.

Primary product

Tubers-which can show great variation in colour, form and quality. The tubers may be single or form a cluster.

The flesh may be white, pale-yellow, or dark-yellow, the last being bitter. The wild forms are usually toxic and the degree of toxicity is generally in inverse proportion to the depth to which the tubers penetrate in the soil.

Yield

No reliable data appears to have been recorded, but yields are generally reported to be higher than for most other edible yam species in Africa.

Main use

Bitter yam is used as a vegetable, but not pounded into 'fufu'. Owing to its soft texture it is favoured by old people with poor teeth. The wild forms are regarded as famine food, and the tubers are detoxified by slicing and soaking and boiling, frequently with the addition of salt;

the slices may be subsequently dried. It is becoming a preferred yam in Cameroon.

Subsidiary uses

The dried tubers can be used to prepare flour. In the Sudan wild detoxified tubers have been ground into a flour which has been used as a base for the preparation of beer.

Secondary and waste products

The tubers of wild varieties mixed with bait are sometimes used for poisoning animals in parts of Africa, and cases of their use for criminal purposes have been recorded. This species is sometimes deliberately planted in fields of other edible yams in order to discourage thieves.

Special features

A typical analysis of the edible portion of the tubers is: water 79 per cent; protein 2.78 per cent; fat 0.28 per cent; carbohydrate 17 per cent; fibre 0.3 per cent; ash 0.72 per cent; calcium 92 mg/100 g; ascorbic acid 6.6 mg/100 g.

The carbohydrate consists mainly of starch, the granules of which are small, rounded or polyhedral, average size 1-4 microns, with a gelatinisation temperature of 77-85.5°C. Analysis of the starch of D. dumetorum has been given as: moisture 13.5 per cent; protein 1.49 per cent; ash 0.39 per cent; amylose 15 per cent; pH 4.4; iod. val. 3.9. Many forms of D. dumetorum contain a convulsant alkaloid which is a mixture of stereoisomers of dihydrodioscorine.

Major influences

D. dumetorum continues to be of importance in Nigeria, Cameroon and several central African nations, and a breeding programme has been started on this species. Further, it has been shown to be less demanding of manpower in its cultivation than D. alata and D. cayenensis.

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Chinese yam (Dioscorea opposita)

Common name

CHINESE YAM

Botanical name

Dioscorea opposita Thunb. (Enantiophyllum).

Family

Dioscoreaceae.

Other names

Chinese potato, Cinnamon vine, Igname de Chine (Fr.); Name (de) Chino (Venez.).

Botany

The vine stems are round, spineless and climb to a height of about 3 m twining anticlockwise (to the right). The leaves are opposite, acuminate, 4-8 cm long. Bulbils are formed in the leaf axils. The flowers are cinnamon-scented, sessile in 1-2 simple raceme-like spikes from the axils.
The tubers are variable in form but are often spindle-shaped and long, reaching I m, descending vertically into the ground; some cultivars have been selected for shorter and thicker tubers.

Origin and distribution

D. opposita is a native of China and widely grown there and in Japan, Korea and the Ryukyu Islands. It is subtropical and can tolerate much colder conditions, including frost, than most yam species. It was grown experimentally in Europe during the 19th century at the time of the potato famine, and is still grown in France to supply the immigrant food market.

Cultivation conditions

Chinese yam requires a good supply of moisture and fertile soil and responds to the application of fertiliser. In Japan it is estimated that for optimum yields 394 kg/ha of nitrogen, 296 kg/ha of phosphorus and 350 kg/ha of potassium are required.

This species requires day-lengths of 10-11 hours for tuberisation.

Planting procedure

In Japan pieces of tuber weighing approximately 280 g are cut into four pieces and after disinfection with formalin are planted in ridges 80 cm apart with 36 cm between the yam setts. Higher yields are obtained if the setts are first germinated in warm seed beds to the stage when the adventitious bud appears as a small knob. The usual planting rate is about 2 750 kg/ha. Bulbils are sometimes used, but these may take 3 years to produce an economic yield of tubers.

Growth period

When setts are used the tubers are ready for harvesting

in about 6 months.

Harvesting and handling

A wooden digging stick is widely used for harvesting the long cylindrical tubers; the shorter, thicker tubers can be lifted by forking. In Japan most of the crop is consumed almost immediately after harvesting, but the tubers can be stored successfully in clamps, and cold storage units are used for storing part of the crop.

Primary product

Tubers-occur in three recognized forms in Japan: thin cylindrical tubers often measuring I m in length, known as Naga-imo; a palmer form known as Icho-imo; and a globular form known as Tsukune-imo. Naga-imo is grown throughout the islands, but the other forms are

grown only in the warmer regions.

Yield

Typical yields from Japan have been reported as 2.25 t/ha.

Main use

The tubers are eaten as a vegetable, usually by slicing or grating and boiling, but sometimes they are ground to make 'tororo', a traditional Japanese dish.

Subsidiary uses

In Japan about 50 per cent of the Chinese yams are used as a raw material in the preparation of various food products, such as pastry, beanjam bun, fish paste and yam flour.

Special features

A typical analysis of the edible portion of the tubers is: water 70-80 per cent; protein 1.11-3.1 per cent; fat 0.06-1.1 per cent; carbohydrate (mainly starch) 16-29 per cent; fibre 0.33-1 per cent; ash 0.69-1.1 per cent.

The starch consists mainly of fairly large granules (5-60 microns) and the gelatinisation temperature is from 65.5° to 75.5°C. Seventeen amino acids have been isolated from the tubers, which have been found to have a high tryptophan and serine content. Stored tubers when cut or grated, rapidly discolour and it has been suggested that field spraying with maleic hydrazide will suppress browning of the tubers which is due to the presence of polyphenolic compounds. Unlike most other yam species grown in Japan, the tubers of D. opposita do not contain any sapogenins.

Major influences

There is a growing demand for yam flour produced by modern freeze-drying methods in Japan and production of D. opposita is reported to be expanding.

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Cush-cush yam (Dioscorea trifida)

Common names

CUSH-CUSH YAM, India yam, Mapuey yam, Yampee.

Botanical name

Dioscorea trifida L. syn. D. brasiliensis Willd. (Macrogynodium).

Family

Dioscoreaceae.

Other names

Ajale (Cuba); Bell yam (Guy.); Car doce, Car mimosa (Braz.); Couche couche (W.I.); Cousse couche blanche (Mart.); Igname Indienne (Ant.); Name de la India (C. Rica); ame morado, ame vino (P. Rico); Name ycampi (C. Am.); Yampi(e) (W.I.).

Botany

Normally, 5-8 stems arise from the base of the plant, each with 2-8 membranous wings (sometimes absent on young stems). Twining is clock wise. The leaves are alternate (rarely opposite), deeply divided into 3-7 lobes, but not into separate leaflets. They are large, measuring about 15-25 cm long and broad. The petiole is long with wings continuous with the leaf blade. The male flowers are small, borne in racemes or panicles

reaching 80 cm in length. The female flowers are in racemes, up to 20 cm in length, and are 12-14 mm long, with a long inferior ovary. Seed sets freely. The tubers are clustered at the base of the plant as the terminal enlargement of (usually) short stolons. These vary in number from 5 to 50 per plant and are commonly spherical to club-shaped but differ consider ably in form and are usually 15-20 cm long.

Origin and distribution

This species is believed to have originated in the Guyana region of South America, and is now cultivated throughout the northern parts of South America and the Caribbean Islands (to which it was taken by the Arawaks), as far north as the Greater Antilles. It is by far the most important of the indigenous American yams. It has not been successfully introduced into other

parts of the tropics except Sri Lanka and New Caledonia, where it is grown on a small scale. In recent years it has received intensive study in Guadeloupe.

Cultivation conditions

D. trifida developed under equatorial conditions where rainy seasons are long and day-length changes minimal, and the growth season of this plant (10-11 months) is not as closely related to annual cycles as is the growth season of many other species. It may therefore be grown not only in equatorial regions but also where there are very distinct wet and dry seasons, if irrigation is provided. Heavy rainfall can be tolerated, but not flooding. A range of soils may be used but, unless they are rich in organic material, fertilising is required: 120-150 kg/ha each of nitrogen, phosphorus and potassium have given high yields in trials in the Caribbean.

Planting procedure

Material-usually small whole tubers are used, but these are more likely to be affected by disease than small cut pieces of whole tubers, which have been treated with benomyl. Seed may also be used. Stem cuttings are not normally successful.

Method-the tubers (or pieces) are planted in hills or ridges, which should be kept moist after planting if rainfall is inadequate. Seed is planted in nurseries with good drainage and aeration, and transplanted when twining stems arise. When the plants have begun to grow, long (2.5-3 m) stakes are normally used for the vines, but recent work in Guadeloupe suggests that staking may not be essential for good yields.

Time of planting-normally at the start of or just before

the rainy season. With year-round rains or supplemental irrigation, year-round planting is possible.

Field spacing-50 x 50 cm-80 x 80 cm (about 40 000-15 000 plants/ha) is recommended.

Pests and diseases

In most cases there are no problems from pests and diseases, but occasionally serious problems may occur. Heavy nematode infestation can cause root damage or cracking, pitting or gall formation on tubers. Meloidogyne incognita and Pratylenchus coffeae have been implicated. Mealy bugs (Planococcus citri and Phenacoccus gossypii) can kill individual stems or the whole plant: clean or treated planting material is important for control. A virus condition, appearing as a leaf mosaic, causes stunting and distortion of the plant

and ultimately reduction or loss of tubers. Destruction of diseased plantings is recommended and planting material should never be taken from affected areas.

Weeds are usually a serious problem: a pre-emergence spray with atrazine at 2.5-3 kg/ha gives good control until emergence; subsequently hand-weeding or shielded sprays of paraquat have been used, though when staking is not used the rapid growth cover formed by the plant minimises weed growth.

Growth period

10-11 months, after which the foliage of the plant dies back.

Harvesting and handling

The tubers are normally dug by hand and care must be

exercised to avoid damage. Mechanical harvesting is being developed with cultivars specially bred for this purpose. Storage life is normally short under tropical conditions, 1-8 weeks before sprouting: loss in weight during storage is rapid (over I per cent per day), and fungal rots and insects may cause severe damage even during such short periods. However, tubers treated against insects and fungi with malathion and benomyl (permitted for grain storage), and stored in a cool dark room, have been maintained in good condition for long periods (up to one year has been claimed). This species appears not to be liable to chilling injury, so refrigerated storage might be a possibility, but this aspect needs further investigation.

Primary product

Tubers-which have relatively thin skins and flesh that

varies in colour from white, yellow, pink to purplish. They have a richer flavour than most yams.

Yield

Commercial yields of about 15 t/ha are normal, although in virus-affected areas they may be as low as 1-2 t/ha. However, recent experimental selection and breeding work in Guadeloupe has produced plants that yielded up to 55 t/ha.

Special features

Few analyses of the tubers have been done but the following composition has been reported: protein 2.54 per cent; (6.4-7.6 per cent on dry weight basis); fat 0.44 per cent; carbohydrate 38 per cent. The carbohydrate con sists mainly of starch of granule size ranging from

10 to 65 microns. The ascorbic acid content is approximately 5.5 mg/100 g edible portion, but it is reported to be rapidly lost during storage.

Major influences

The high acceptability of this species suggests a potential for increasing use, especially where year-round production is possible. The plant's sexual fertility holds potential for improvement that is already being realised.

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Greater yam (Dioscorea alata)

Common names

GREATER YAM, Greater Asiatic yam, Ten months yam, Water yam, Winged yam.

Botanical name

Dioscorea alata L. (Enantiophyllum).

Family
Dioscoreaceae.

Other names

Ambi (N. Guin.); Avase (Togo); Batatilla (Ang.); Bobayassi (W. Afr.); Cabeza de negra (Col.); Car de Angola, Car branco, Car cultivado, Car inhama (Braz.); Couche couche (Lat. Am.); Cucam, Cucui-mo (Viet.); Dandaba (Sen.); Gbara-gu (Guin.); Goradu (Assam); Huwi (Sud.); Igname aile (Gab.); Igname de Chine (Fr.); Kachil, Katula, Khanulu (Ind.); Khoai-mo (Viet.); Kiseba (Ug.); Kuvi (Pacif. Is.); Lisbon yam (W.I.); Name asiatico (Venez.); ame blanco (C. Rica); Name chino (Cuba); Name de ague (Venez.); Name de mine (P. Rico); Name grande (Venez.); Nangate (Mex.); Obbi,

Oewi, Oowi kelapa (Indon.); Ovy (Mal.); Pacala (Fr.); Ratula, Sakourou (Ind.); Tus (C. Rica); Ubi (Philipp.); Ubi kemali (Mal.); Uwi (Indon.); White Manila yam (Philipp.).

Botany

A large climber, which can reach 15 m in height, with quadrangular winged stems, twining is anticlockwise (to the right). Leaves opposite, variable in size and shape, but essentially ovate to cordate with a deep basal sinus, acuminate. The male flowers are borne on panicles, up to 30 cm long; the female flowers are on small axillary spikes. Few cultivars produce fertile seed and most are completely sterile. Bulbils are sometimes formed in leaf axils, but not so freely as with certain other species. The tubers are usually single and show a great deal of variation in size, shape and colour: they are generally

cylindrical but may be long and serpentine to almost globular, and are often branched or lobed, or even flattened and fan-shaped. Their weight is usually 5-10 kg though special cultivation can produce giant tubers of 60 kg or more. The flesh of some cultivars can be pink or even deep reddish-purple and these forms have been classified as D. purpurea Roxb. and D. afropurpurea Roxb. but this is not generally accepted.

Origin and distribution

D. alata is not known in the wild state but appears to have been developed from native species originating in the Assam-Burma region, by selection from deeper-rooting forms. Subsequently, it was spread through Thailand and Vietnam into the Pacific region, westwards and southwards to India and Malaysia and thence apparently to Madagascar and East Africa, later to be

taken by the Portuguese and Spaniards to West Africa, northern South America and the Caribbean; in the eastern Caribbean and in the Pacific it is the most popular species of yam. It is cultivated throughout the tropical world.

Cultivation conditions

Rainfall-for optimum yields rainfall of 150 cm evenly distributed over 6-7 months is required, though it will perform moderately well on 100 cm.

Soil-D. alata will tolerate poorer soils than most other species of yam, but it responds well to fertilising. In India FYM at the rate of 25 t/ha has been recommended. In Barbados, where the crop is frequently grown as a rotation crop with sugar cane which has been fertilised with a 22:0:22 NPK mixture, yields of about 10 t/ha are

normal, but additional fertilising with NPK at the rate of nitrogen 22 kg, phosphorus 25 kg and potassium 57 kg per hectare gave significant and economic increases in yield. Smaller increases were given when phosphorus was omitted Application should be about 10 weeks after planting, when the plant is completing its dependence upon the parent sets.

Altitude-it is usually cultivated at low or medium elevations, but is grown as high as 2 700 m in India.

Day-length - a day-length of less than 12 hours is required for tuberisation.

Planting procedure

Material-normally setts with two or three sprouts, occasionally small whole tubers are used. In Barbados,

small pieces of approximately 100 g are usually cut from stored yams and are often dried for several hours before planting. Owing to the incidence of virus infections, a virus-free planting material has been developed by meristem culture in the West Indies; virus-tested planting material is currently being multiplied and commercially grown in Barbados and is on trial throughout the eastern Caribbean.

Method-the setts are usually planted by hand on mounds or ridges, being placed in holes 5-10 cm deep. Recently, mechanical planting has been developed in Barbados for planting on ridges. It is important to keep the crop weed-free for the first 3 months. The use of pre-emergence herbicides has been suggested: eg atrazine at 1.5-3 kg/ha to which TCA 5 kg/ha may be added on heavy soils to improve grass control, and chloramben at 3-6.5 kg/ha. After emergence, dalapon at 5 kg/ha may

be applied for grass control, provided a shield is used. If the yams are not staked, complete ground cover is attained 3-4 months from sprouting and weeds are virtually eliminated.

Field spacing-when grown under monoculture, plantings on ridges 1.7 m apart, with 0.75-1 m between the plants is recommended, since at these spaces the vines need not be staked. Closer spacing can be used in areas of low rainfall.

Seed rate-in India, approximately 1 400 kg/ha of setts are used, in Barbados 650 kg/ha.

Pests and diseases

In addition to yam beetles and scale insects (see Yam) the larvae of three species of Lepidoptera attack the

greater yam; they are Loxura atymnus, Theretra nessus and Tagiades gana. The first named is the most destructive as, after initially feeding on the leaves, the larvae attack the stems, often causing them to break off. D. alata is also susceptible to attack by the yam nematode, Scutellonema bradys.

One of the most troublesome diseases affecting this species is anthracnose caused by Colletotrichum gloeosporioides, sometimes in association with other fungi, notably Botryodiplodia and Fusarium spp.; crop losses can sometimes amount to 70-80 per cent, but spraying at 10 day intervals with zineb or ferbam is stated to be effective. Leaf spot, due to Cercospora spp., is reported to be serious in Sri Lanka. In Guadeloupe crown-gall, a bacterial condition caused by Agrobacterium tumefaciens, has been observed. An internal brown spot has caused serious losses in yams

exported from Barbados; this has been traced to a virus infection which also leads to considerable reduction in yield (see Yam).

Growth period

Maturity is normally reached in 9-10 months, though some 'early' varieties can be harvested at about 6 months.

Harvesting and handling

Harvesting is normally done manually by forking, though owing to the size and irregular shape of the tubers of many cultivars damage is often high, in the order of 20-25 per cent of the tubers. Recent developments in the Caribbean have led to the production of a mechanical harvester and a reduction in damaged tubers to about 8

per cent.

Storage under ambient tropical conditions is normally for 4-6 months. If the tubers are sound, storage is terminated by the breaking of dormancy: if sprouts are removed as they develop storage may be extended to about 8 months.

Primary product

Tubers-normally large, weighing 5-10 kg, usually basically cylindrical but extremely variable: eg the common 'White Lisbon' of the Caribbean tends to be broad and lobed at the distal end; the 'Coconut Lisbon' is ovoid, the 'Hunt' cultivar is elongated and relatively narrow, much prized for roasting. A great variety of cultivars exists near the South-East Asian centre of origin. The skins are thick and dark and the flesh may be

white, pink or purplish. The tubers of D. alata have a definite period of dormancy of 2-4 months, which may be broken by treatment with ethylene chlorhydrin.

Yield

Yields vary widely, but the following average farm yields have been reported: Malaysia 42.5 t/ha; Trinidad 46.8 t/ha; St. Vincent 57.5 t/ha
Fiji 25.2 t/ha; Barbados 5-6 t/ha.

Main use

Used mainly as a vegetable, similarly to the potato, and some cultivars can be used to make French fries and chips, claimed to be superior to similar potato products. Although it is the preferred yam in many parts of the tropics, especially by those accustomed to European

dietary habits, it is less highly regarded in West Africa, because it is not suitable for the preparation of 'fufu'.

Subsidiary uses

In several countries, eg the Philippines, Barbados and Puerto Rico, attempts are being made to develop processed products such as yam flakes or powder from surplus supplies of D. alata. Coloured cultivars have been utilised as a colouring and flavouring agent for ice cream.

Secondary and waste products

Badly-damaged tubers are often fed to pigs.

Special features

A typical analysis of the edible portion of the tubers is:

water 65-73 per cent; protein 1.12-2.78 per cent; fat 0.03-0.27 per cent; carbohydrate 22-29 per cent; fibre 0.65-1.4 per cent; ash 0.67-2.06 per cent.

The starch contains a high proportion of fairly large granules: sizes ranging from 5 to 50 microns have been reported. The gelatinization temperature ranges from 69° to 88°C and the viscosity from 100 to 200 Brabender units. Unlike most other yam species, starch from D. alata has a high gel strength. Starch from white-fleshed and purple-fleshed cultivars have similar typical composition averaging: moisture 13.6 per cent; protein 0.14 per cent; ash 0.22 per cent; amylose 21.1 per cent; reducing sugars 0.18 per cent; pH 7.1; iod. val. 5.5. Ascorbic acid contents ranging from 4.9 to 8.2 mg/100 g of edible portion have been reported, while certain cultivars in the South Pacific have been found to contain 6 mg/100 g of carotene. Three anthocyanins have been

isolated from D. alata var. atropurpurea and rubella and found to be cyanidin glycosides.

Processing

Yam flakes-dehydrated yam flakes may be prepared from the tubers by Iye or hand peeling (average losses, depending upon condition of yams, 15-35 per cent), slicing into I cm thick pieces, cooking in water or steam until soft, ricing (to avoid breaking the cell walls and so releasing starch which would give a glutinous texture to the reconstituted product), gently mixing to a slurry and dehydrating on a single drum dryer with suitably spaced applicator rolls. The resulting product of about 4 per cent moisture content is packed in plastic bags and has a storage life of 2 years or more under ambient tropical conditions; it reconstitutes to a mashed yam.

Powder-an acceptable yam powder, suitable for blending into food products, can be prepared by cooking unpeeled tubers, then peeling, grating and drying at 50°C to 10 per cent moisture.

Production and trade

No figures are available for the production of D. alata separately from other yams. There has been a small export trade in D. alata from some of the Caribbean islands to the UK since the early 1960s. In 1968 approximately I 000 t of tubers of D. alata were exported from Barbados, but the occurrence of chilling injury at the receiving point, and the incidence of internal black spot (virus), reduced the trade almost to zero. However, the recent production of virus-free yams has allowed the trade to re-start, and in 1982 Barbados exported 116 t (to the UK and other West Indian

territories), and in the first half of 1983, 324 t of which 272 t were to the UK market.

Major influences

D. alata is the world's most popular yam after the D. rotundata/cayenensis complex, and appears to have held its place. Although traditional methods of production (especially in Africa) are more costly in manpower than for other yams, the introduction of complete field mechanisation, which is now a reality, should reduce production costs and make this crop more competitive as a tropical carbohydrate food and also enable it to maintain or improve its position on the export market.

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Intoxicating yam (Dioscorea hispida)

Common names

INTOXICATING YAM, Karukandu, Nam.

Botanical name

Dioscorea hispida Dennst. (Lasiophyton).

Family

Dioscoreaceae.

Other names

Gado(e)ng, Gadong mabok (Mal.); Kalt (Philipp.); Killoi, Koi (Thai.); Maranpash poll (Ind.); amo (Philipp.); Palidumpa, Pashpoli (Ind.).

Botany

D. hispida is a climber usually with a prickly stem, 6-10 mm in diameter, varying from glabrous to pubescent with fine white to brown hairs. Twining is clockwise (to

the left). The leaves are trifoliate with oval to obovate leaflets, about 10 cm long by 8 cm broad, hairy, with small prickles on the underside of the main vein. Male flowers are in large, branched inflorescences; the female inflorescences are unbranched. The tubers are large, weighing 5-15 kg, roughly globose but deeply lobed, pale skinned, but covered with masses of fibrous roots: they are produced near the soil surface and are extremely poisonous.

Origin and distribution

This species grows wild in South-East Asia and Indonesia, and extends to Papua New Guinea and the Philippines and India. It is not cultivated to any great extent, though some cultivation is practiced in Java.

Cultivation conditions

D. hispida thrives in tropical rain forest conditions. It usually grows at relatively low elevations, less than 500 m, though it has been reported growing at altitudes up to 1 200 m in the Himalayas.

Planting procedure

As noted above, the plant is infrequently cultivated. When cultivation is practiced propagation is often by planting pieces of tuber in prepared mounds (see Yam).

Growth period

Maturity is normally reached in about 12 months.

Harvesting and handling

The tubers are usually lifted by hand with a digging stick or fork. It has been reported that if the tubers are

exposed to temperatures below about 10°C, subsequent growth is adversely affected.

Primary product

Tubers-which have white or pale-yellow, starchy, highly toxic flesh.

Yields

In cultivation, yields of about 20 t/ha have been reported.

Main use

As a famine food-the tubers, growing near the surface, are easily accessible. Detoxification is essential and one method is to cut the tubers in pieces, cover the surface with wood ashes for 24 hours, then steep in sea water

for several days, wash with fresh water, and dry. The process is repeated several times. Another method is to dry the slices mixed with ashes. A third is to salt the pieces of tuber and then press under water until no whitish sap remains. After detoxification the yams are usually tested by feeding to dogs or other domestic animals.

Subsidiary uses

The possibility of using the tubers as a source of starch has been considered, but so far appears not to have been commercially developed.

Secondary and waste products

The tubers are sometimes used to prepare poisons. The pounded tubers are also used in parts of Asia in local

medicine for the treatment of open wounds. It has been suggested that the residue left after starch extraction could be used as an insecticide.

Special features

Tubers-an approximate analysis of the tubers has been given as: water 78 per cent; protein 1.81 per cent; fat 0.16 per cent; carbohydrate 18 per cent; fibre 0.93 per cent; ash 0.69 per cent. On a dry weight basis the tubers contained 0.2-0.7 per cent diosgenin and 0.044 per cent of the toxic alkaloid dioscorine.

Flour-the average composition of the flour extracted from the tubers was given as: protein 5.28 per cent; fat 0.23 per cent; starch 88.34 per cent; fibre 5.33 per cent; ash 0.66 per cent. It is suitable for both edible and industrial purposes and can be used for the manufacture

of glucose. Starch granules from Indian tubers are non-stratified and oval-shaped, with an average longitudinal diameter of 35-40 microns and a gelatinisation temperature of 85°C. Starch from D. hispida differs from cassava and potato starches in that its viscosity does not fall appreciably after prolonged heating.

Processing

The following method is suggested for the preparation of flour or starch from D. hispida tubers.

(i) The tubers are thoroughly washed in clean water, either by hand or mechanically, to remove adhering soil, etc.

(ii) The tubers are mashed with water; a potato rasping machine is suitable for the preparation of flour, but for

the production of starch, the tubers must be ground very finely in order to rupture the cell walls and liberate the starch granules.

(iii) In order to detoxify the material, the pulp is treated with lime water containing potassium permanganate; usually lime water equivalent to five times the weight of tubers and containing 0.005 per cent of potassium permanganate, is used. Any excess potassium permanganate is removed by treating the starch milk with sulphur dioxide.

(iv) The starch is allowed to settle out and is then washed and centrifuged as in the manufacture of sweet potato starch.

In the Philippines it has recently been suggested that starch or flour could be produced on a commercial scale

by extracting the tubers with 95 per cent alcohol followed by treatment with 5 per cent sodium chloride or acidified water.

Major influences

Production of D. hispida is normally scattered over a large area so that the large-scale commercial production of starch from this yam is not likely to be economically viable.

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Lesser yam (Dioscorea esculenta)

Common names

LESSER YAM, Asiatic yam, Lesser Asiatic yam.

Botanical name

Dioscorea esculenta (Lour.) Burk. (Combilium).

Family

Dioscoreaceae.

Other names

Apali (Philipp.); Chinese yam (W. Afr. and W.I.); Couche-couche douce (Mart.); Diba (N. Guin.); Hisu (Fiji); Igname des blancs (Fr.); Kangar, Karen potato (Ind.); Kaw(a)i (Fiji); Kizahangu, Kodi (Sri La.); ame asiatico, Name azucar, ame chino, ame papa, ame pequeno (Lat. Am.); Pana (Sol. Is.); Potato yam, Sasniali, Sathni, Silakandom (Ind.); Taitu(kava) (S. Pacif.); Tongo, Trident yam, Tugi, Tungo (Philipp.); Ufi lei (Pacif. Is.); Wale, War (N. Cal.).

Botany

The plant is a vine, seldom climbing to more than 3 m. The stems are thin, usually 1-3 mm in diameter, and vary from smooth to prickly. They twine clockwise (to the left) in climbing. The leaves are alternate, almost round, but pointed at the tips and deeply lobed at the base, finely hairy and about 10 cm in diameter. The petioles are thickened at the base with 4 sharp prickles. Flowers are rare in most cultivars, but when they occur are larger than in most other Dioscorea spp. The roots are fibrous, often more or less prickly, and a former classification based on the presence or absence of prickles (var. spinosa and var. fasciculata) is no longer recognised. The tubers are the swollen ends of stolons arising from the crown of the plant; each stolon bears only one tuber. The stolons vary in length from about 5 to 50 cm; the length is a varietal characteristic. About 5-20 tubers are borne per plant; the number and size of the tubers is related to the cultivar. They resemble

rather long and narrow sweet potatoes, but occasionally may be spindle shaped or branched. Papua New Guinea cultivars produce very large tubers weighing up to 3 kg: the Caribbean cultivars weigh 100-200 g and are usually 8-10 cm long and 2.5-5 cm in diameter.

Origin and distribution

D. esculenta is among the most ancient species of the genus, and its centre of origin is stated by various authorities as India, Vietnam, or Papua New Guinea and the Philippines. It has long been domesticated and is documented as a staple food in southern China from the 2nd and 3rd centuries. Today it is widely distributed throughout the tropics, but is little used except in South-East Asia, where it is grown to such an extent that it ranks third in production and utilisation of yams after D. rotundata/D. cayenensis and D. alata.

Cultivation conditions

Temperature-D. esculenta is a plant of tropical forests and grows best at high temperatures, though this species may be grown up to about 25°N in southern China.

Rainfall-optimum yields have been obtained with moderately high rainfall (175 cm), though satisfactory yields are reported from areas with 87-100 cm, which is well distributed throughout the year. Dry periods of more than about 2 months can lead to death of the plant.

Soil-sandy soils are not suitable, and very heavy clays can lead to misshapen tubers. Good drainage is essential and a high level of organic matter greatly improves growth. There is little information on the use of

fertilisers in the Far East but experiments in Trinidad have shown that nitrogen produces a positive response in the earlier part of the growth cycle, but depresses yield if applied late; potassium is needed especially during tuberisation; phosphate is seldom a limiting factor. A general recommendation is 400 kg/ha of an 11:11:33 NPK mixture applied 6-8 weeks after planting.

Altitude-low or medium altitudes are best, though satisfactory growth at levels of up to 900 m has been reported from northern India.

Planting procedure

Material-small whole tubers of 55-85 g weight are recommended.

Method-the tubers are planted in mounds or in ridges,

8-12 cm below the surface of the ground. Atrazine at 3 kg/ha has been successfully used as a pre-emergence herbicide, and a shielded spray of paraquat at 3 litres/ha is recommended for the later control of weeds. Staking is commonly used and has been shown to double the yield obtained when the vines are unslaked, though the plant is stated to give satisfactory results without staking.

Field spacing-recommended spacings vary, though 90 x 90 cm appears to be the most common for mounds, and from 90 to 130 cm in ridges I m apart: at the latter spacing about 2 000 kg/ha of seed tubers are required.

Pests and diseases

The yam nematode, Scutellonema bradys, and the root knot nematode, Meloidogyne sp., are both reported as

serious pests in some areas. Selection of nematode-free tubers for planting and avoidance of nematode-infested soils are important precautionary measures.

Fungal diseases of the aerial parts are rare, but the tubers may be affected by certain fungi, eg Botryodiplodia theobromae, Lasiodiplodia sp. and Fusarium spp. The foliage often shows virus symptoms; it is thought that virus is always present and is tolerated, though virus-free material might well yield better.

Growth period

In Fiji the crop is reported to mature in 6-7 months, in Malaysia 8-9 months and in the West Indies 10 months.

Harvesting and handling

The tubers are thin-skinned and succulent, and easily damaged during harvesting: lifting is normally done by hand. However, as the tubers are small and near the surface, commercial potato diggers, carefully used, may be used to harvest them when they are planted on ridges. The tubers should be cut from the crown, washed and dried, and packed in well-ventilated boxes, not sacks. Damaged tubers should be used as quickly as possible; even superficial damage permits the entry of fungi which can cause rotting (see Pests and diseases). It is claimed that uninjured tubers can be stored for 4 months or longer in well-ventilated conditions under ambient temperatures in the tropics; larger tubers store better than small ones. Respiration and loss of water continue during storage; there is therefore loss of dry matter and shrivelling of the tubers. Sweetness increases and changes in flavour occur, with a reduction in palatability. Sprouting usually occurs, leading to

further loss of weight. There is no information as to whether low temperature injury occurs below about 13°C as is the case with some other yams.

Primary product

Tubers-which are very thin-skinned and have a yellow flesh, and thus appear pale-yellow even before the skin is removed. The surface is smooth except for some fine adventitious roots and a few depressions like the eyes of a potato; these are not buds, but are local wounds resulting from minor injuries to the tuber during its growth. The flesh is floury to succulent, crisp, with little fibre and a characteristic bland but rather sweet flavour.

Yield

High yields are common when the yams are planted in

pure stands: the following average yields (t/ha) have been reported: Malaysia 25; West Indies 34-38; West Irian 70; Philippines 20 - 30.

Main use

The tubers are cooked and eaten as a carbohydrate foodstuff. They may be boiled in their skins or after peeling (peeling involves only about 5 per cent loss of the tubers); in the latter case they disintegrate badly, though this is minimised by boiling for no more than 10 minutes. They may be baked in their skins, or fried as slices or as chips (french fries).

Special features

The nutritional composition of the edible portion of D. esculenta has been quoted as: water 67-81 per cent;

protein 1.29-1.87 per cent; fat 0.04-0.29 per cent; carbohydrate 17-25 per cent; fibre 0.18-1.51 per cent; ash 0.5-1.24 per cent.

The carbohydrate is mainly starch but with a relatively high content of sugars (7-11 per cent). The starch granules are rounded or polyhedral, very small (1-15 microns in diameter), with a rather low amylose content (14-15 per cent).

Production and trade

Although considerable quantities are grown in the Far East, the delicate and perishable nature of the tubers makes any external trade difficult and the tubers are normally traded only within a community or village.

Major influences

D. esculenta is both high yielding and easily adapted to mechanical cultivation, as well as being palatable and easily prepared in the kitchen; it therefore could become more popular than at present.

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Potato yam (Dioscorea bulbifera)

Common names

POTATO YAM, Aerial yam, Air potato, Bulbil bearing yam, Turkey liver yam.

Botanical name

Dioscorea bulbifera L. (Osophyton).

Family

Dioscoreaceae.

Other names

Acom (W.I.); Agbanio (Togo); Akam or Akom (W. Afr.); Banalu (Philipp.); Batata de rama (Braz.); Bayag-toro (Philipp.); Cambar marron (Maur.); Car de aire, Car de espinho, Car de Sao Thom, Car de sapateiro (Braz.); Cu mei (Viet.); Danda yam (W. Afr.); Dimoa (N. Cal.); Gaithi (Ind.); Hoi (Tah.); Huwi blichik (Sud.); Igname bois (Ant.); Igname pousse debout (Zar.); Irga (Gab.); Kaile (Fiji); Kasiena (S. Pacif.); Kattala (Sri La.), Khoing (China), Man nok (Thai.); Name del aire (Col.); Name congo, Name criollo, Name de mate (Venez.); Numwe (N. Cal.); Oobi Singapore (Mal.); Otaheite potato (W.I.); Papa caribe, Papa del aire, Papa voladora (C. Rica); Pousse en l'air (Fr.); Ratulu (Ind.); Soi (Polyn.); Ubi atas (Mal.); Ubi-ubihan (Philipp.); Ycam.

Botany

A strongly climbing vine, reaching 6 metres or more, with smooth stems ranging from I to 8 mm in diameter; twining is clockwise (to the left). The leaves are cordate-orbicular to ovate-orbicular, strongly acuminate, 15-30 cm long and broad; the petioles are thickened at the base with ear like projections that often encircle the stem. The flowers are small (though larger than those of many cultivated yams), about 3 mm long, closely appressed to the pedicel in long axillary or terminal racemes. Winged seeds are produced freely from the trilocular capsules which are 2-5 cm long: the seeds germinate readily. Tubers are produced underground and tuberous bulbils in leaf axils and on terminal racemes. In African races of the plant these bulbils are sharply angled, while those of Asian races are spherical to ellipsoid. The bulbils are grey or brown

in colour with white or yellow mucilaginous flesh; they range from about 3 to 10 cm in diameter and usually weigh about 0.5 kg, but can be as heavy as 2 kg. Some varieties may need detoxification by soaking or boiling before they are eaten. The underground tubers arise from a swelling of the young stem and enlarge rapidly as storage organs. Both bulbils and tubers are edible, although tubers are usually hard, bitter and unpalatable, and selection for bulbils appears to have taken place in early times, as some varieties, both Asian and African, lack significant underground tubers. Tuber size ranges from small up to about 25 cm in length.

The species occurs in a wide variety of forms and many synonyms have appeared in the literature, including D. crispata Roxb., D. heterophylla Roxb., D. oppositifolia Campbell, D. papilaris Blanco, D. pulchella Roxb., D. sativa Thunb., D. tamnifolia Salisbury, D. tunga

Hamilton, D. Iatifolia Benth., and D. anthropophagum Chev.

Origin and distribution

The African and Asian varieties are so distinct that evolution must have taken place in prehistoric times, and there is disagreement as to whether the original source was in South-East Asia or whether there was also a centre of origin in Africa. The species is now pan-tropical.

Cultivation conditions

Potato yam grows in a wide range of soils and most varieties require long rainy seasons; this plant can be grown at elevations up to 1 800 m.

Planting procedure

Material-bulbils or tubers, either whole or small pieces. The tubers produced by plants grown from bulbils are usually very small in the first year and are often themselves used as setts for planting the following year to produce edible bulbils (and tubers) of a reasonable size.

Method-see Yam. Staking is necessary.

Field spacing-information is scant. In Puerto Rico satisfactory results have been obtained with rows at 160 cm spacing and the plants 70 cm apart in the row (about 9 000 plants/ha).

Pests and diseases

Leaf spot (due to Cercospora spp.) sometimes occurs and the nematode

Scutellonema bradys has been reported to attack the subterranean tubers.

Growth period

Immature bulbils may be harvested 3-4 months after planting, and picking may continue for the life of the plant, up to 24 months. Underground tubers are normally harvested when the vine dies back, after about 15-24 months.

Harvesting and handling

Immature bulbils are hand picked: mature bulbils fall to the ground. The tubers are lifted by fork or other digging tool or may be left for several months in the soil until needed. Both bulbils and tubers are resistant to fungal infections and harvest wounds heal quickly;

storage under dry, cool conditions, away from sunlight, appears to give moderate storage life.

Primary products

Bulbils-usually weighing 0.5-2 kg. The flesh is yellow or white and is harder in the African varieties than in the Asian varieties.

Tubers-which also have white or yellow flesh. The African varieties are harder than the Asian.

Yield

This species is seldom grown commercially, but field trials in Puerto Rico of sixteen varieties from all over the tropics gave yields ranging from 0.05 to 19.5 t/ha for bulbils, and from zero to 25.34 t/ha for tubers. Some varieties gave high yields of both bulbils and tubers, eg

10.6 t bulbils and 22.09 t tubers, and 16.9 t bulbils and 13.35 t tubers. There is clearly potential for high productivity but unfortunately the time span of the experiment was not stated.

Main use

The bulbils are normally cooked and eaten in a manner similar to other starchy root crops, though many African forms require detoxification by soaking in water or prolonged boiling before they are safe to consume. A few are very succulent and may be eaten raw. The flavour is reported to be inferior to that of most common yams and some are bitter. Some yellow fleshed varieties darken during cooking. However, these yams have some popularity because of the convenient size of the bulbils for kitchen use.

Subsidiary uses

The bulbils and tubers are occasionally used for the production of flour. In Indonesia a fish poison is made from the bulbils of toxic varieties, and in Africa poisonous varieties may be planted among safe varieties to discourage thieves. In folk medicine in India a paste from the tuber is used as a cure for snakebite and in Jamaica for treatment of scorpion and centipede stings.

Secondary and waste products

Tubers-are used as food in times of scarcity, detoxification is usually necessary.

Special features

Bulbils-the proximate composition of the bulbils, in terms of the fresh weight, has been given as: water 63-

67 per cent; protein 1.12-1.5 per cent; fat 0.04 per cent; carbohydrate 27-33 per cent; fibre 0.7-0.73 per cent; ash 1.08-1.51 per cent.

Tubers-the fresh weight composition of the tubers has been given as: water 69.1 per cent; protein 0.89 per cent; fat 0.1 per cent; carbohydrate 26.5 per cent; fibre 6.74 per cent.

Considerably higher values of protein have been found in other analyses, up to 10 per cent of the dry matter, but the sulphur-bearing amino acids are low, limiting the nutritive value. The yellow pigments of D. bulbifera are xanthophylls of no nutritional importance: beta-carotene is absent.

The toxic element found in many varieties is apparently dioscorine, and in some varieties the saponin dioscin

has been reported.

Major influences

D. bulbifera has not been thoroughly investigated and its full potential may still be undiscovered. Currently, it seems that it should have a future in the home plot or gardens rather than commercial production. In its favour is the fact that a crop can be harvested for a period of perhaps 20 months starting at only 4 months from planting; in addition, the non-toxic varieties are easy to prepare for consumption.

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White yam (Dioscorea rotundata)

Common names

WHITE YAM, Guinea yam, White Guinea yam.

Botanical name

Dioscorea rotundata Poir. (Enantiophyllum).

Family

Dioscoreaceae.

Other names

Common yam, Eboe yam (W. Afr.); Eight months yam, Name blanco, ame Guineo blanco (S. and C. Am.); Negro yam (Jam.); Portuguese yam (Mart.); Proper yam.

Yellow yam (Dioscorea cayenensis)

Common names

YELLOW YAM, Guinea yam, Yellow Guinea yam.

Botanical name

Dioscorea cayenensis Lam. (Enantiophyllum).

Family

Dioscoreaceae.

Other names

Afoo (Jam.); Affou (Trin.); Affun yam (W. Afr.); Atous temps (Ant.); Attoto yam (Afr.); Balugu (Ug.); Car de Par (Braz.); Congo amarillo (P. Rico); Cut and come again yam, Dye yam (Guy.); Fusaka (Mali); Hard yam (Guy.); Igname Guine, Igname jaune, Igname pays negre (Fr.); Mapuey morado (P. Rico); ame amarillo (Sp.); Name chomo (Pan.); Name negro (C. Rica); Negro yam (W.I.); Niame (Cuba); Ovihazo (Madag.); Twelve months yam, Yam a tout tan (W.I.).

Botany

The classification of these yams is confused. In the older literature they are usually separated but most taxonomists now regard them as the same species. Both show considerable variation: at the extremes the differences seem clear, but many intermediate forms occur, possibly as a result of hybridisation, and many current workers are grouping the two under the term Dioscorea rotundata/cayenensis complex, and this approach is taken here. Much of what follows is common to both 'species'; differences between the extremes of the complex will be noted under the 'specific' names.

The plants grow vigorously and can climb to a height of 10-12 m. The stems are cylindrical or slightly striated and are usually spiny, though sometimes completely smooth. The leaves are extremely varied, from deeply cordate to almost orbicular, 4-20 cm long, opposite or alternate. Some varieties have purplish leaf veins and

stems. Male flowers are small (1-3 mm in diameter), borne on spikes; female flowers are much less frequently borne and the production of seeds is somewhat rare. Tubers are large (commonly 2-5 kg in weight, sometimes up to 25 kg or more), generally cylindrical but sometimes distorted, and thick skinned. The flesh ranges from white to yellow. More than 200 cultivars are known. The commonest differences between the two extreme types are:

	D. rotundata	**D. cayenensis**
Tuber colour (flesh)	White	Yellow
Leaf shape	Narrowly ovate	Broadly ovate
Climatic preference	Intermediate rainfall	High rainfall
Growing season	7-8 months	10-12 months
Number of harvests	2	1

Number of harvests	2	1
Possible time of harvest	Limited: late summer to	Almost year round winter

(Source: Martin and Sadik, 1977.)

Origin and distribution

West Africa appears to be the centre of origin, with initial domestication from the Ivory Coast to Cameroon, and in this African 'yam belt' these are the most important of all the yams. From West Africa they spread to Brazil and the Caribbean (presumably by way of the slave ships), and are important in Jamaica, Puerto Rico and the French West Indies, but not in the other islands. They were introduced into New Caledonia by the French.

Cultivation conditions

A warm tropical climate is required, but while D. cayenensis needs a long rainy season (about 10 months), D. rotundata cultivars can be grown with only 6-7 months of rainfall (100-150 cm evenly distributed) and thus can be grown further away from the equator where dry seasons are longer; also, because of its greater tolerance of drought, this type is adapted to the Caribbean region, though D. cayenensis is also grown there. D. cayenensis is relatively tolerant of sandy soils: D. rotundata thrives best on heavy soils even with a high clay content. Responses to organic matter (FYM or heavy mulch) are good. Nitrogen appears to be especially important (in Ghana 67 kg nitrogen applied after tuber reserves were exhausted gave a 22 per cent increase in yield; phosphorus gave a small response but potassium none), but fertiliser requirements vary from place to place.

Planting procedure

Material-usually small whole tubers, crowns or mid-section cuttings of large tubers (in 100-150 g pieces), dried for a few days before planting and preferably treated with wood ash to protect the pieces from fungal infection. Propagation of D. rotundata by stem cuttings is possible but does not yet appear to be commercially developed. Planting material must be disease-free.

Method-in Africa, yams are normally planted in land freshly-prepared by 'slash and burn', in mounds which are usually large enough for one plant, but sometimes for several. The pieces are planted at a depth of 5-15 cm, sometimes with the stem end down. The mound may be mulched with dried grass. In the Caribbean, planting in ridges 30-50 cm high is the usual practice, the seed tubers being placed 10-15 cm deep, by hand or

by machine. In some areas, where soil drainage is naturally good, planting on the flat is practiced. Staking appears to be essential.

Field spacing-mounds are 1-2 m apart, and ridges also 1-2 m apart. Maximum yields are obtained by spacings of 1 x 1 m (10 000 ha).

Pests and diseases

Weeds-control is as described for Yam.

Pests-there seem to be few serous insect pests, but nematodes, especially Pratylenchus spp., Meloidogyne spp. and Scutellonema spp. are common, affecting not only the growing tuber but being associated with dry rot in the stored tuber. It has been stated that seed pieces can be treated with hot water at 50- 60°C for 30- 60

minutes; treatment of the soil with dibromochloropropane has been effective. In Africa, the greater yam beetle Heteroligus meres may attack the tubers and termites can cause severe damage. In the Caribbean, the white grub, Lachnosterna sp., and the sugar cane root borer, Diaprepes abbreviatus, often damage tubers. Field sanitation and avoidance of infected planting material are important aspects of control.

Diseases-fungal diseases are seldom serious, but anthracnose (due to Colletotrichum gloeosporioides) can be sporadically severe; resistant cultivars are available. More serious is the green banding virus (called mosaic in Puerto Rico, and shoestring disease in Africa) which, when severe, decreases yields significantly. Again, the use of planting material from healthy plants is essential.

Growth period

D. cayenensis types mature in 10-12 months and D. rotundata in 7-8 months. The early maturing of the latter permits double harvesting, as the early tuberisation results in large, though immature, tubers being present after 4 months. Some may be harvested then (and stored if so wished) while the remainder are harvested after 7-8 months. This practice is quite common in Africa where the mound permits tubers to be removed with little disturbance to the other tubers.

Harvesting and handling

Normally harvesting is by hand, though recent developments suggest that there may be possibilities for mechanically harvesting material planted in high ridges. Storage is as described for Yam. D rotundata tubers

store better than those of D. cayenensis: under tropical conditions the storage life of sound tubers can be up to 4 months and 2 months respectively, although sprouting and excessive desiccation could be a problem.

Primary product

Tubers-usually only one large tuber per plant, though sometimes more are produced. A single tuber normally weighs 2-5 kg (but can be 25 kg or more). The skins are brown and thick, the flesh white in D. rotundata types to yellow in D. cayenensis.

Yield

In Africa, 8-18 t/ha and in the Caribbean, 15-25 t/ha are typical yields.
Over 67 t/ha has been reported from Puerto Rico.

Main use

Both types are eaten boiled, mashed, fried, etc. In Africa D. rotundata types are used in large quantities for the preparation of 'fufu'.

Subsidiary uses

Instant yam flakes can be made from suitable cultivars, though D. cayenensis yams are not favoured because of their yellow colour. Yam flour is also prepared.

Special features

Approximate composition of the edible portion of mature tubers has been quoted as: energy 439 kJ/100 g; water 58-33 per cent; protein 1.02-1.99 per cent; fat 0.05-0.12 per cent; carbohydrate 15-23 per cent; fibre 0.35-0.79 per cent; ash 0.53-2.56 per cent.

Higher moisture contents occur in immature tubers. Ascorbic acid is quoted as 6.5-11.6 mg/100 g in D. rotundata and 4.5-8.2 mg/100 g in D. cayenensis. Differences in the nature of the starch are reported: D. rotundata granules are large (10-70 microns) but those of D. cayenensis are smaller (3-25 microns). No commercial use has been made of the processed starch.

Processing

See Yam.

Production and trade

The major part of the total African production of yams (19 million t) is of the D. rotundata/cayenensis complex, and there is substantial production (though small by comparison with Africa) in Brazil and the

Greater Antilles. There is a small trade from Brazil and Jamaica (estimated at about 9 000 t annually) to the UK, which also imports a small quantity from West Africa.

Major influences

Although apparently threatened by less labour-intensive and therefore cheaper carbohydrate crops, such as cassava, and by imported rice, African yam production appears to be holding its own. There seems to be little scope for expansion of exports or of processed products, mainly because of the high cost of the raw material.

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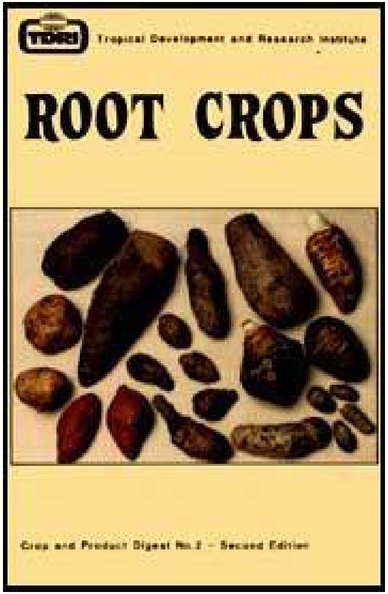
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ROOT CROPS
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leontopetaloides)

- **Elephant yam (Amorphophallus spp.)**
- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**

- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma chamissonis)**
- **Sweet potato (Ipomaea batatas)**
- **Tannia (Xanthosoma spp.)**
- **Taro (Colocasia esculenta)**
- **Topee tambo (Calathea allouia)**
- **Ullucu (Ullucus tuberosus)**
- **Winged bean (Psophocarpus tetragonolobus)**
- **Yacn (Polymnia sonchifolia)**
- **Yam (Dioscorea spp.)**

Yam bean (Pachyrrhizus erosus)
Appendixes

Yam bean (Pachyrrhizus erosus)

Common names

YAM BEAN, Potato bean.

Botanical name

Pachyrrhizus erosus (L.) Urban syn. P. angulatus L. C. Rich. ex DC.

Family

Leguminosae.

Other names

Ahipa, Ajipa (S. Am.); Bangkoewang (Indon.); Bunga (Philipp.); Carota de caballo (Venez.); Chopsui potato (Haw.); Dolique bulbeux (Fr.); Fan-ko (China); Frijol de jicama (Salv.); Frijol ame (Philipp.); Jicama, Jiquima (Mex., Peru); Mishrikand (Ind.); Nupe(ra) (Venez.); Patate-cochon (Ant.); Pois cachou, Pois manioc (Guin.); Poroto batata (Arg.); Ram-kaseru, Sankalu, Sankeh alu (Ind.); Sengkuang (Mal.); Sincamas (Philipp.); Ubi sengkuang (Mal.); (W)yaka (Asia); Yuco de bejuco (Venez.).

Botany

A hairy twining herbaceous plant, woody at the base, trailing or climbing to about 6 m. The leaves are alternate, trifoliate, with petioles 3-18 cm long and

ovate or rhomboidal leaflets which are toothed or lobed, about as broad as long, usually large, in the range 4-20 cm. The flowers are in long axillary racemes, 1-5 borne in each of several clusters along the peduncle; the petals are violet or white, 1.5-2 cm long and broad. The pods are 7.5-15 cm long and about 1.5 cm broad, flattened, almost smooth at maturity, containing 4-12 seeds which are yellow, brown or red, almost square and flattened, 5-10 mm in diameter. Tuberous roots, frequently turnip-shaped, are borne at the base of the stem, and may be solitary or several, simple or compound; normally they are about 10-15 cm in diameter. This species shows considerable genetic variability, and phenotypic studies have shown significant negative correlation in some genotypes between root yield and days to flowering, days to pod maturity and length of main stem.

A closely related species is P. tuberosus (Lam.) Spreng.,

which has entire leaflets, white flowers and longer pods, usually 25-30 cm in length, with irritant hairs; the seeds are kidney-shaped.

Origin and distribution

The yam bean appears to have originated in Mexico and northern South America, in the head-water region of the River Amazon, and was cultivated there in pre-Columbian days The Spaniards took it to the Philippines and it is now cultivated and naturalised in the Philippines, Cambodia, China, Indonesia, northern India as well as in western and northern South America and the Caribbean.

Cultivation conditions

The yam bean is tolerant of various climates, but for

optimum yields it requires fairly high temperatures and a moderate to high rainfall: it grows well in the hot, wet tropics. In Mexico, it is grown under irrigation and in the cooler areas has a longer vegetative cycle. It is normally grown at altitudes below I 000 m.

Soil-a well-cultivated sandy loam soil with adequate drainage is essential; it will tolerate well-drained clay soils, but not heavy soils liable to become waterlogged. For high yields, the application of a 12: 24: 12 NPK fertiliser at the rate of 300-400 kg/ha before planting has been recommended, followed by 200 kg/ha of ammonium sulphate when the plants begin to climb. In addition, if the soil has been heavily cropped it is suggested that it should receive 10 t/ha of compost or FYM, about one month before planting.

Day-length-short days are necessary for tuberisation.

When grown under a 14-15 hour photoperiod the vegetative growth is good, but there is little production of tuberous roots: short day-length gives smaller, more bushy plants and good tuberisation.

Planting procedure

Material-the yam bean is grown principally from seed, but it can be grown from sprouted roots saved from the previous crop. It has been recommended that this practice be followed to maintain desirable characteristics in the plants.

Method-the seeds are normally sown at the beginning of the rains, either on the flat or in ridges; the latter gives better results. Usually 2-3 seeds are placed in each hole and the plants thinned out as necessary, or the seeds may be planted singly by drill. The provision of bamboo

trellises about 2.5 m high to support the vines has been found beneficial, but is not essential. The crop is kept free from weeds and is often mulched to help conserve soil moisture and prevent weed growth. Sometimes the plants are stopped or pruned in order to encourage vegetative growth and the removal of the flowers is reported to increase tuber yields and improve their flavour.

Field spacing-recommended seed spacing for India is 15 cm along rows 50 cm apart; in the Philippines, a spacing of 10 cm in rows 15-20 cm apart is common practice, although it has been shown experimentally that the yield of roots doubled when a spacing of 15 x 15 cm was used.

Seed rate-in the Philippines, 20-25 kg/ha of seed is used for planting, assuming a germination rate of 90-95

per cent. In India, a higher seed rate, 50-70 kg/ha, is preferred.

Pests and diseases

In Central America, the yam bean is reported to be subject to attacks from the larvae of Thecla jebus and Ferrisia virgata. In Mexico, the seeds are often attacked by weevils. In the Philippines, a mosaic disease has been noted, which is caused by a systemic virus, transmitted through the seed or root. A slight mottling or chlorosis and blistering of the leaves, together with the production of very small tubers are characteristic symptoms. A bacterial leaf spot caused by Pseudomonas syringae has also been reported.

Growth period

The crop normally reaches maturity in 5-8 months, although in the warmer parts of Mexico a commercial crop is obtained in about 3 months. If a seed crop is required, the growing period is approximately 10 months.

Harvesting and handling

The roots are usually dug manually, though with large-scale production they are sometimes ploughed out. The tops are trimmed or removed entirely and the roots washed and packed in baskets for market. Within 24 hours the creamy colour of the skin changes to a purplish-brown, but this can be arrested if the roots are stored in the dark at 9-10°C. They can be stored successfully for at least 2 months at temperatures just above 0°C; older roots tend to store better than tender immature ones. They can also be 'field-stored'; in

Mexico, the normal practice is to withhold irrigation water thus stopping growth and the roots remain in good condition in the soil for 2-3 months. Just prior to lifting they are irrigated and absorb water, and can be marketed in the usual way.

Primary product

Tuberous roots-which, as normally harvested, are 10-15 cm in diameter and weigh up to 2-2.5 kg: they have a creamy surface and white, rather watery flesh. At this stage they are crisp and succulent, with a pleasant, sweet flavour. If left to grow they increase in size and can reach 30 cm in diameter and weigh 5-18 kg, but they become tough and unappetising. The tubers of P. tuberosus are rather larger.

Yield

Average yields of tuberous roots are about 7.5-20 t/ha, although yields as high as 95 t/ha have been reported from the Philippines and Indonesia.
Recent trials have shown considerable differences from cultivar to cultivar and cv. Rajendra Mishrikand-l has been reported from India to average 40 t/ha (twice the normal yield).

Main use

The young tubers are eaten raw in salads, or cooked as a vegetable, or in pickles and chutney. They are popular among the lower income groups in parts of Latin America and the Caribbean. In the USA they are becoming increasingly used, both for eating in their own right and as a substitute for Chinese water chestnut.

Subsidiary uses

As the roots mature their starch content increases and older roots are sometimes used as a source of starch or for animal feeding. In China, the dried roots are reported to be used as a cooling food for people with fever.

Secondary and waste products

Seed pods-the young seed pods of P. erosus are sometimes eaten as a cooked vegetable, similarly to French beans, but cannot so be used as the seeds develop. The crushed pod of P. tuberosus, mixed with lard, is used in China to cure itch.

Seeds-the powdered seeds are sometimes used as an insecticide or fish poison. In Indonesia, the pulverised seeds mixed with sulphur are applied to certain types of skin eruption. One half seed may be taken as a laxative,

though it is stated that if poisoning occurs coconut water will counteract it.

It is, however, reported that the oil in the seeds resembles cottonseed oil and may be used for cooking.

Stems-the stems yield a tough fibre, which is sometimes used for making fishing nets in Fiji.

Animal feed-it has been reported that the whole plant is sometimes used as fodder, and is best for this purpose when harvested at the 50 per cent flowering stage; however, the leaves and seeds are both toxic (the leaves less so than the seeds) and grazing among mature plants can be fatal to animals.

Green manure-the whole plant is sometimes ploughed into the soil as a green manure.

Special features

Roots-the tuberous roots contain both starch and sugar and are a moderately good source of ascorbic acid. Average figures for the edible portion have been published as: energy 186-264 kJ/100 g; water 82.4-87.8 per cent; protein 1.5-2.4 per cent; fat 0.09-1.3 per cent; carbohydrate 10.6-14.9 per cent; fibre 0.6-0.7 per cent; ash 0.5 per cent; calcium 16-18 mg/100 g; iron 0.8-1.1 mg/100 g; thiamine 0.05-0.1 mg/100 g; riboflavin 0.02-0.03 mg/100 g; niacin 0.2-0.3 mg/100 g; ascorbic acid 14-21 mg/100 g.

Approximately 65 per cent of the carbohydrate is starch, 20 per cent non-reducing sugars and 15 per cent reducing sugars. Mature tubers yield a grayish-white starch, consisting of polyhedral or semi-polyhedral grains of 8-35 microns diameter. Non-protein nitrogen

may be as high as 80 per cent of the total nitrogen as indicated by the crude protein figure given.

Pods-analysis of the edible portion of the young seed pods (Philippines) has given the following figures: water 86.4 per cent; protein 2.6 per cent; fat 0.3 per cent; carbohydrate 10 per cent; fibre 2.9 per cent; ash 0.7 per cent; calcium 121 mg/100 g; iron 1.3 mg/100 g; phosphorus 39 mg/100 g; vitamin A 575 IU/100 g; thiamine 0.11 mg/100 g; riboflavin 0.09 mg/100 g; niacin 0.8 mg/100 g.

As the pods become mature toxicity develops.

Seeds-analysis of the seeds gives the following figures: water 6.7 per cent; protein 26.2 per cent; fat (oil) 27.3 per cent; carbohydrate 20 per cent; fibre 7 per cent; ash 3.64 per cent.

The seeds are toxic and have been studied as a possible commercial source of a vegetable insecticide, since they contain 0.12-0.43 per cent of rotenone, pachyrrhizone and pachyrrhizonic acid. (The toxic principles of the seeds can be eliminated by boiling them with alcohol.) The seeds could be used as a source of an edible oil which has the following characteristics: SG (31°C) 0.914; ND (26°C) 1.4673; sap. val. 196.7; iod. val. 85.3; acid val. 1.1; RM val. 2.71; unsap. 2.3 per cent; saturated fatty acids 37.6 per cent; unsaturated fatty acids (oleic and linoleic) 62.4 per cent.

Stem-fungicidal compounds have been isolated from the stem: four pterocarpan derivates were isolated, neodunal was the major component.

Processing

The use of processed (mainly canned) roots is increasing, both as a starchy food in its own right, and as a substitute for Chinese water chestnut (Eleocharis dulcis). Very large tubers are woody and unsuitable; roots of about 10 cm diameter and weighing about I kg are preferable. The inner layers of the rind contain thick layers of fibrous material which are difficult to remove mechanically, but Iye peeling by immersion for about 10 minutes in 18 per cent sodium hydroxide solution at 95-99°C appears to be practicable. Discoloration of the surface of the peeled roots resulting from this treatment may be removed by bleaching with hydrogen peroxide.

Production and trade

There is little information about production and trade in yam beans, despite their popularity in parts of Latin America and the Caribbean. There is some demand from

the USA, mainly California, for yam bean roots from Mexico, as they are used as a substitute for the Chinese water chestnut.

Major influences

There appears to be increasing interest in this plant, both as a root crop for local consumption and export (albeit on a small scale), but also as a possible source of 'natural' pesticidal principles.

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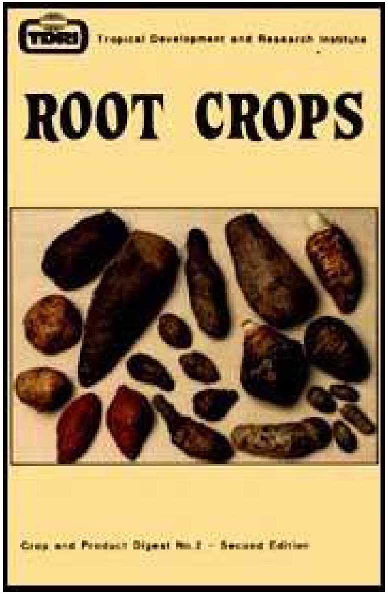
Root Crops (NRI, 1987, 308 p.)

Appendixes

A. Root crop distribution on a climatic basis



Root Crops (NRI, 1987, 308 p.)

Appendixes

A. Root crop distribution on a climatic basis

Climatic type	1	2	3	4	5	6	7
African yam bean		x	x				
Ahipa					xH	xH	
Arracacha			(x)H			x	
Arrowhead	x	x			x		
Arrowroot	x	(x)					
Cassava	x	x	x				
Chavai	x						
Chinese water chestnut		xA			xA		
Chufa	x	x	x		x	x	
East Indian arrowroot	x	x	x				
Elephant yam	x	x	x		(x)		
False yam			x				
Giant taro	x	x					
Hausa potato	(x)	x	x				
Jerusalem artichoke		x	x	(x)I	x	x	x
Kudzu		x		x	x	x	
Lotus root	xA	xA			xA		
Maca							xH
Oca							xH
Potato		(x)	(x)		x	x	x
Queensland arrowroot		x	x		x	x	
Radish		x	x	(x)I	x	x	
Shoti	x	x			x		
Swamp taro	x	x					
Sweet potato	x	x	x	(x)I	x	x	
Tannia	x	x	xI		(x)		
Taro	x	(x)I	(x)I		(x)		
Topee tambo	x	(x)					
Ulluco					xH	xH	
Winged bean	x	x	xI				
Yacon			xH		xH	xH	
Yam	(x)	x	x				

Yam bean	x	A	x	(x)

( ) Limited cultivation.
A Aquatic conditions required.
I Irrigation required.
H High altitude

1 Tropical rainforest.
2 Tropical monsoon.
3 Tropical savanna
4 Dry tropical, ie steppe and desert.
5 Humid subtropical.
6 Subtropical (Mediterranean).
7 Humid intermediate

Table

B. Estimated world production figures for the major root crops ('000 t/a)

	1961-65	1969-71	1980-82
	average	average	average
Cassava	75 048	96 700	124 761
Potato	282 959	277 286	247 719
Sweet potato	na	142 141	141 285
Yam	18 080	16 243	19 898'

Sources: 1961-65 from Kay, 1973. TPI Crop and Product

Digest No. 2.

1969-71 and 1980-82 calculated from FAO Production Yearbook 19X2.

Yams are for 1979-81: they are not quoted separately in subsequent Yearbooks. na not available.

C. Pesticides mentioned in the text

The word pesticides refers to chemicals used to combat insects, arachnids, nematodes, diseases and weeds. The following table lists the International Organization for Standardization common names of pesticides mentioned in the text, and other common names, along with their more commonly known trade names and notes on their use. The use of italics for a common name denotes that it is no longer used, or in the case of a trade name, that

it is no longer manufactured.

All pesticides are hazardous and should be used strictly as recommended by the manufacturer and the local agricultural advisory service. Many countries place restrictions on the use of certain pesticides, including several listed here: some may not be permitted at all, others only if stated conditions are adhered to. Therefore mention of a particular pesticide in this digest does not necessarily imply endorsement by TDRI. There are also internationally approved recommendations and often legal limits on the level of residual pesticide permitted on fresh foods for consumption (whether home produced or imported). The legal limits vary between crops and countries and the regulations are changed from time to time. It will therefore be necessary to check the permitted pesticides and the recommended levels of application with the local

agricultural advisory service, and to check the permitted residue levels with the appropriate consumer authority (particularly where there may be exports to countries with possibly different regulations).

Reference to trade names implies no endorsement of the efficacy of these products nor any criticism of competing products not mentioned.

Abbreviations:	
ec	emulsifiable concentrate
sc	suspension concentrate
ULV	ultra-low volume formulation
wp	wettable powder

ISO common name Other common names	Trade names	Uses and comments

aldicarb aldicarbe	Temik	Systemic insecticide, acaricide and nematicide with contact action. Applied to soil, absorbed through roots. Control of biting and sucking insects, spider mites and free-living nematodes. Formulated as granules.
aldrin[1] aldrine HHDN	Octalene	Contact, stomach and respiratory insecticide. Control of soil-dwelling insects Formulated as wp, ec, dust, granules, oil solution, seed dressing.
allidochlor CDAA	Randox	Selective pre-emergence herbicide. Also used post-emergence. Control of annual grasses and broad-leaved weeds. Formulated as ec, granules.
ametryn ametryne	Ametrex Duroplant Evik Gesapax	Selective pre- and post-emergence herbicide. Absorbed through foliage and roots. Control of annual broad-leaved and grassy weeds. Formulated as wp, sc. Also in mixed formulations.
atrazine	AAtrex Atranex	Selective pre- and post-emergence soil and foliar

	Aatred Gesaprim Primatol Vectal	herbicide. Absorbed predominantly through roots but also through foliage. Control of germinating weeds and grasses.

[1] Used for pure HHDN 95 per cent minimum.

Table part I

ISO common name Other common names	Trade names	Uses and comments
		Formulated as wp, granules, sc, water dispersible granules, liquid. Also in mixed formulations.
benomyl[1]	**Benlate**	Broad spectrum protective and eradicant systemic fungicide with secondary acaricidal activity. Absorbed through foliage and roots. Also used as pre- or post-harvest spray or dip. Control of wide range of plant diseases. Formulated as wp. Also in mixed formulations.
captan	**Merpan**	Curative foliar fungicide. Also

captane	Orthocide Pillarcap	used as protective spray, root dip or seed treatment Control of diseases of many crops. Formulated as wp, dust, sc, seed dressing. Also in mixed formulations.
carbaryl NAC NMC sevin	Denapon Dicarbam Murvin Patrin Ravyon Sevin	Contact and stomach insecticide with slight systemic activity. Control of insects in various crops. Formulated as wp, granules, dust, bait pellets, ec, micronised suspensions in molasses, non-phytotoxic oils or aqueous media, true solutions in organic media. Also in mixed formulations.

[1] Withdrawn by the licensee (United Nations Secretariat. 1984. *Consolidated list of products whose consumption and/or sale have been banned, withdrawn, severely restricted or not approved by governments, 1st issue revised*.)

Table part II

ISO common name Other common names	Trade names	Uses and comments
carbendazim carbendazime	Bavistan Custos	Systemic foliar and soil fungicide. Absorbed through

carbendazol	Delsene Derosal Pillarstin Stempor Triticol	roots and green tissues. Control of wide range of pathogens. Formulated as wp, sc, oil and aqueous liquid, suspensions, seed treatment, water-soluble liquid, powder. Also in mixed formulations.
carbofuran	Curaterr Furadan Pillarfuran Yaltox	Systemic acaricide, insecticide and nematicide with contact and stomach action. Applied to foliage or soil. Control of soil- or foliar-dwelling or foliar-feeding mites, insects and nematodes. Formulated as wp, ec, granules.
chloramben *amben* chlorambene	Amiben *Amoben* Vegiben	Selective pre-planting and pre-emergence herbicide. Applied to soil. Control of grasses and broad-leaved weeds. Formulated as granules, liquid, dry soluble, aqueous solution.
chlorfenvinphos CVP	Apachlor Birlane Haptarax Haptasol Sapecron Steladone	Soil and foliar insecticide with contact and respiratory action. Some acaricidal ovicidal activity. Control of many insects and mites.

	Supona Vinylphate	Formulated as wp, ec, dust, granules, emulsifiable citrus spray oil liquid seed treatments.

Table part III

ISO common name Other common names	Trade names	Uses and comments
chloroneb chloronebe	Demosan Tersan	Systemic fungicide. Absorbed through roots. Also used as supplemental seed treatment. Control of *Rhizoctonia* spp. Less effective for *Pythium* spp. and *Fusarium* spp. Formulated as wp.
chlorpropham chlor-IPC chlorprophame IPC	Furloe Pommetrol Sprout Nip Triherbide-CIPC	Pre-emergence herbicide with post-emergence activity. Also used as sprout inhibitor in stored potatoes. Control of many weeds. Formulated as ec, liquid (solution), granules. Also in mixed formulations as ec, liquid (solution).
chlorpyrifos chlorpyrifos-ethyl chlorpyriphos	Detmol Dursban Lorsban Loxiran	Broad spectrum non-systemic insecticide with contact, stomach and respiratory action. Absorbed through foliage and

	Pyrinex Zidil	roots. Control of many soil and foliar crop pests. Formulated as wp, dust, ec, ULV, granules. Also in mixed formulations
copper oxychloride	Cupravit *Fernacol* *Fere*-col Recop	Protective fungicide. Formulated as wp, water-dispersible granules, paste. Also in mixed formulations.
2,4-D 2, 4-PA		Systemic post emergence herbicide. Control of broad-leaved weeds. Most grasses are immune.

Table part IV

ISO common name Other common names	Trade names	Uses and comments
		Formulated as aqueous solutions (amine salts), ec (esters), ULV. Also in mixed formulations as wp, solution, ec, spray, granules.
dalapon (BSI) **DPA** proprop	Basfapon (sodium salt) Dowpon	Selective herbicide. Absorbed through foliage and roots. Control of annual and

	(sodium salt) Gramevin (sodium salt) Radapon (sodium salt)	perennial grasses. Formulated as water-soluble powder. Also in mixed formulations as wp, soluble powder.
D-D[2]	D-D Vidden D	Pre-plant nematicide. Applied to soil. Control of soil nematodes. Used without formulation.
DDT (draft ISO) **chlorophenothane** **dicophane**	Dedelane Didimac *Gesapon* *Gesarol* Neocid	Non-systemic insecticide with contact and stomach action. High persistence in fatty tissues. In UK, permitted only for certain specified uses. Formulated as wp, ec, dust.
deltamethrin (draft ISO) *decamethrin*	Butoflin Butox Decis K—othrin	Contact and stomach insecticide. Control of many insect pests. Formulated as wp, ec, ULV, sc, dust.
diazinon	Basudin Diagran Diazitol	Non-systemic insecticide and acaricide with contact, stomach and respiratory action.

* Common name approved by the British Standards Organisation. An ISO common name has not been agreed.

[2] Common name used in the Agrochemicals Handbook for the reaction mixture of 1,2-dichloropropane and 1,3-dichloropropene.

Table part V

ISO common name Other common names	Trade names	Uses and comments
	Diazol Exodin Neocidol Nucidol Sarolex Spectracide	Control of wide range of sucking and foliar-feeding insects and mites. Formulated as wp, ULV, granules, dust, ec, emulsifiable solution, oil solution. Also in mixed formulations as emulsifiable solution.
dibromochloro-propane DBCP	Fumazone Nemagon	Nematicide and soil sterilant. Has now been superseded.
dicloran (BSI)[1] CNA DCNA dichloran dichlorane ditranil	Allisan Botran Resisan	Protective fungicide. Control of fungal pathogens. Formulated as wp, dust, ec, smoke generators. Also in mixed formulations.
dimethoate fosfamid	Cygon Daphene Devigon Dimetate Fostion MM Perfekthion	Broad spectrum systemic insecticide and acaricide with contact and stomach action. Control of wide range of pests. Formulated as wp, ec, ULV, granules, dust. Also in mixed

[illegible] Rebelate Regim Resion Telmetlon	granules, dust. Also in mixed formulations.	
diphenamid difénamid difenamide	Dymid Enide	Selective pre-emergence herbicide. Absorbed through roots. Control of annual grasses and some broad-leaved weeds. Formulated as wp, liquid dispersion, granules.

[1] Common name approved by the British Standards Organisation. An ISO common name has not been agreed.

Table part VI

ISO common name Other common names	Trade names	Uses and comments
diuron DCMU dichlorfenidim DMU	Dialer Diurex Diurol Dynex Karmex Unidron Vonduron	Pre-emergence root herbicide. Control of all weeds in non-cropped land. Used selectively on some crops. Formulated as wp, sc, granules. Also in mixed formulations as wp, ec, sc, granules.
endosulfan benzoepin	Beosit Chlorthiepin	Non-systemic insecticide and acaricide with contact and

benzoepin thiodan	Chlorthiepin Cyclodan Malix Thifor Thimul Thiodan Thionex Tiovel	acaricide with contact and stomach action. Control of wide range of insects and some mites. Formulated as wp, ec, ULV, dust, granules. Also in mixed formulations.
fenitrothion MEP	Accothion Agrothion Cyfen Cytel Folithion Novathion Sumithion	Potent insecticide and acaricide with contact, stomach and respiratory action. Control of wide range of pests. Formulated as wp, ec, ULV, dust, aerosol concentrates. Also in mixed formulations.
ferbam ferbame	Carbamate Ferbam Ferberk *Fermate* Hexaferb Knockmate Trifungol	Protective foliar fungicide. Control of fungal pathogens. Formulated as wp.

Table part VII

ISO common name Other common names	Trade names	Uses and comments
gamma-HCH[1]	BHC	Contact and stomach insecticide

benzene hexachloride BHC *gamma-BHC* HCH hexachloran hexaklor	Gamma-HCH Gammexane	with some fumigant activity. Applied as foliar spray, to soil, and as seed treatment. Control of wide range of soil-dwelling and phytophagous insects. Formulated as wp, ec, dust, smoke generators. Also in mixed formulations.
linuron	Afalon Linorox Linurex Lorox	Selective pre- and post-emergence herbicide. Absorbed through foliage and roots. Control of weeds in various crops. Formulated as wp, ec, sc. Also in mixed formulations.
malathion carbofos malathon maldison mercaptothion mercaptotion	Calmathion Celthion Cythion Fyfanon Malaphele Malathion Malmed MLT Sumitox Zithiol	Broad spectrum non-systemic insecticide and acaricide with predominantly contact but some stomach and respiratory action. Control of wide range of sucking and chewing pests. Formulated as wp, ec, ULV, dust. Also in mixed formulations.
mancozeb mancozèbe manzeb	Dithane M-45 Dithane ultra Manzate 200	Protective foliar fungicide. Also used as seed treatment. Control of wide range of foliar

	Nemispor Pernneozeb Vondozeb Plus	fungal diseases. Formulated as wp, ec, sc. Also in mixed formulations as wp.

[1] ISO approved common name lindane is used for grades where the gamma-isomer content is 99 per cent minimum.

Table part VIII

ISO common name Other common names	Trade names	Uses and comments
maneb manèbe	Dithane M-22 Manesan Manzate Nespor Trimangol	Protective foliar fungicide. Control of many fungal plant diseases. Formulated as wp, sc. Also in mixed formulations as wp, dry seed dressing.
MCPA MCP 2,4-MCPA metaxon	Agritox Agroxone Chiptox *Cornox M* Empal Hedonal M Phenoxylene Plus Rhomene Rhonox Shamrox Vacate	Selective systemic post-emergence hormone-type herbicide. Absorbed through foliage and roots. Control of annual and perennial broad-leaved weeds. Formulated as solution. Also in mixed formulations as wp, ec, solution, water-dispersible grains, soluble powder.

	Vacate	
methomyl	Lannate Nudrin	Systemic and stomach insecticide and acaricide. Control of wide range of pests. Formulated as ec, water-soluble liquid, water-soluble powder, bait. Also in mixed formulations.
monuron chlorfenidim CMU	Monurex *Telvar*	Pre-emergence root herbicide. Control of all weeds in non-cropped areas. Formulated as wp. Also in mixed formulations.

Table part IX

ISO common name Other common names	Trade names	Uses and comments
naptalam alanap naptalame NPA (sodium salt)	Alanap (sodium salt) Cratutin	Selective pre-emergence herbicide. Absorbed predominantly through roots but also through foliage. Also used post-emergence. Control of broad-leaved weeds. Formulated as granules, liquid. Also in mixed formulations.
nitrofen	TOK E-25	Selective, predominantly pre-

nitrofen NIP nitrofène **nitrophen**	Tokkorn Trizilin	emergence contact herbicide. Control of wide range of weeds. Formulated as wp, ec, granules.
paraquat	Dextrone X Esgram Gramoxone Gribe Paraquat CL Pillarxone	Broad spectrum contact herbicide. Absorbed rapidly through foliage. Control of wide range of weeds and grasses. Formulated as liquid (solution), soluble concentrate, water-soluble granules. Also in mixed formulations.
pirimicarb pyrimicarbe	Abol Aficida Aphox Fernos Pirimor Rapid	Selective systemic aphicide with contact and respiratory action. Absorbed through foliage and roots. Also some fumigant activity. Control of aphids in various crops. Formulated as wp, ec, ULV, water-soluble powder or grains, aerosol, smoke generators. Also in mixed formulations.

Table part X

ISO common name	Trade names	Uses and comments

Other common names

prometryn *prometryne*	Caparol Gesagard Primatol Q Prometrex Uvon	Pre- and post-emergence foliar and root herbicide. Selective in certain crops. Control of most annual grasses and broad-leaved weeds. Formulated as wp, sc. Also in mixed formulations.
propham *IPC* IFC prophame	Chem-Hoe Premalox Triherbide IPC Tuberite	Selective pre-emergence herbicide. Absorbed through roots. Also used as sprout inhibitor in stored potatoes. Control of annual grassy weeds. Formulated as wp, ec, granules. Also in mixed formulations as ec, sc, liquid (solution).
propineb mezineb propinèbe	Airone Antracol Taifen	Protective foliar fungicide with secondary acaricidal activity. Control of several plant diseases. Formulated as wp, dust. Also in mixed formulations.
quintozene PCNB PKhNB terrachlor	Avicol Botrilex Brassicol Folosan Kobuto Pentagen	Specific soil fungicide. Also used as seed treatment. Control of various plant diseases. Formulated as wp, ec, dust, granules. Also in mixed

	Terrachlor Tritisan	formulations.
TCA	NaTa (sodium salt) Tecane (sodium salt)	Selective pre-emergence herbicide. Absorbed through roots. Control of certain grasses. Formulated as water-soluble granules (sodium salt), powder

Table part XI

ISO common name Other common names	Trade names	Uses and comments
		(sodium salt). Also in mixed formulations.
thiabendazole *benzimidazole*	Arbotect Comfuval Mertect Mycozol Storite Tecto Thibenzole Tobaz	Systemic fungicide. Absorbed through foliage and roots. Also used as post-harvest treatment. Control of fungal pathogenic diseases. Formulated as wp, sc, liquid, smoke generator. Also in mixed formulations.
thiophanate	Cercobin Enovit Nemafax Topsin	Preventive and curative systemic fungicide with secondary acaricidal activity. Control of wide range of

		fungal pathogens. Formulated as wp, sc. Also in mixed formulations.
vernolate	Surpass Vernam	Selective pre-emergence soil herbicide. Control of broad-leaved and grassy weeds. Formulated as ec, granules, liquid. Also in mixed formulations.
zineb zinèbe	Aspor Dithane Z78 Lonacol *Parzate* Phytox Tiezene Tritoftorol Zinosan	Protective foliar and fruit fungicide. Control of various plant diseases. Formulated as wp, dust. Also in mixed formulations.

Sources: Hartley, D. and Kidd, H. (eds). 1983. *The agrochemicals handbook*. Nottingham, UK: The Royal Society of Chemistry.
Worthing, C. R. and Walker, S. B. (eds). 1983. *The pesticide manual*, 7th edn. Croydon, Surrey, UK: The British Crop Protection Council.

Table part XII

D. Index of trivial names

(Other than the common name used for the title of

entries)

Aardpeer	— Jerusalem artichoke	Apio	— Arracacha
Aardappel	Potato	Apio blanco	— Oca
Abalong	— Taro	Apio criollo	— Arracacha
Achera	— Queensland arrowroot	Apulic	— Chinese water chestnut
Achira	— Queensland arrowroot	Araru	— Arrowroot
Acom	— Potato yam	Ararut	Arrowroot
Aerial yam	— Potato yam	Araruta	— Arrowroot
Affo/u	Yellow yam	Araruta bastarda	— Queensland arrowroot
Affun yam	— Yellow yam	Arboloso	— Yacon
Aghario	— Potato yam	Arié	— Topee tambo
Agua bendita	— Topee tambo	Aricoma	— Yacón
Aguaturma	— Jerusalem artichoke	Aricuma	— Yacón
Agyptische bohne	Lotus root	Aroro	Arrowroot
Ahipa	— Yam bean	Arraroot	— Arrowroot
Aipi	— Cassava	Arrecate	— Arracacha
Aipim ubi	Cassava	Arrowroot lily	Chavar
Air potato	— Potato yam	Arrowroot vine	— Kudzu
Ajaze	— Cush-cush yam	Arruruz	— Arrowroot
Ajipa	Yam bean	Arsaghna	— Elephant yam
Akam	— Potato yam	Artichaut des Indes	— Sweet potato
Akidereku	— African yam bean	Aru-aru	— Arrowroot
Akom	Potato yam	Arvi	— Taro
Alavu	— Giant taro	Asiatic yam	— Lesser yam
Aloro	— Arrowroot	Asparagus bean	— Winged bean
Alléluia	— Topee tambo	Asparagus pea	— Winged bean
Allouya	— Topee tambo	Atous tomns	— Yellow yam
Alooku	— Giant taro		

Index part I

Index part II

Cassave — Cassava
Coxcamote — Cassava
Chaca — Sweet potato
Chara-konsem — Winged bean
Châtaigne d'eau — Chinese water chestnut
Chaudhaari phali — Winged bean
Chavdhari-ghevda — Winged bean
Chee-koo — Arrowhead
Chena — Elephant yam
Chich pi — Winged bean
Chipin — Winged bean
Chichoda — Chufa
Chigua — Ulluco
Chika — Chinese water chestnut
Chinese eddoe — Taro
Chinese potato — Chinese yam
Chinese radish — Radish
Chinese taro — Taro
Chinese water lily — Lotus root
Chinese yam — Lesser yam
Chisgua — Queensland arrowroot
Chonque — Taro
Chopsui potato — Yam bean
Chotaskir — Arrowhead
Chou — Tannia
Chou bouton — Taro
Common yam — White yam
Congo amarillo — Yellow yam
Cotufa — Jerusalem artichoke
Couche couche — Cush-cush yam/Greater yam
Couche couche douce — Lesser yam
Country potato — Hausa potato
Cousse couche blanche — Cush cush yam
Cubio — Añu
Cuenin — Greater yam
Cuepimo — Greater yam
Cuiba — Oca
Cuiva — Oca
Cumar — Sweet potato
Cu mei — Potato yam
Curcuma d'Amerique — Topee tambo
Cu san fau — Cassava
Cut and come again yam — Yellow yam
Daga — Elephant yam
Dagmay — Taro
Daikon — Radish
Dalo — Taro
Dalo ni tana — Tannia
Dam long — Sweet potato
Danchin — Taro
Danda yam — Potato yam
Dandaba — Greater yam

Index part III

Elephant bread	— Elephant yam	Giant swamp taro	— Swamp taro
Elephant foot yam	Elephant yam	Giglio de Nilo	— Lotus root
Elephant's ear	— Taro	Girasole	— Jerusalem artichoke
Elianto tuberoso	Jerusalem artichoke	Girigiri	— African yam bean
Enensa	— Chufa	Gyeepara	— Sweet potato
English potato	— Potato	Gonadhi hulu	— Kudzu
Envera blanco	Arrowroot	Gname	— Yam
Erdartischocke	— Jerusalem artichoke	Goa bean	— Winged bean
Erdmandel	— Chufa	Goradu	— Greater yam
Esuri yam	— Bitter yam	Greater Asiatic yam	— Greater yam
Esuru	— Bitter yam	Ground almond	Chufa
Fan-ko	— Yam bean	Guacamote	— Cassava
Fava de cavallo	— Winged bean	Guagui	— Taro
Fen-ko	— Kudzu	Guate (gallina)	— Arrowroot
Figal	— Radish	Guinea arrowroot	— Topee tambo
Figeli	— Radish	Guinea yam	White yam
Fiji arrowroot	— East Indian arrowroot	Gumbili	— Sweet potato
Flèche d'eau	— Arrowhead	Hard yam	— Yellow yam
Fléchière	— Arrowhead	Haricot dragon	— Winged bean
Flügelbohne	— Winged bean	Haricot igname	— African yam bean
Four-angled bean	— Winged bean	Hasu-n-ne	— Lotus root
		Hathipich	— Jerusalem artichoke
		Hatichuk	— Jerusalem artichoke

Index part IV

Hatsuka daikon	Radish	Irish potato	Potato
Hisu	— Lesser yam	Iriga	— Potato yam
Hoangting	— Arrowroot	Isaño/u	— Añu

Hog taro — Giant taro
Hoi — Potato yam
Hubas — Ulluco
Huisisai — Oca
Huwi — Greater yam
Huwi blichik — Potato yam
Iáraj — Swamp taro
Ibias — Oca
Ighnam — Yam
Igname — Taro/Yam
Igname ailée — Greater yam
Igname bois — Potato yam
Igname de Chine — Chinese yam/Greater yam
Igname des blancs — Lesser yam
Igname Guinée — Yellow yam
Igname Indienne — Cush-cush yam
Igname jaune — Yellow yam
Ignamekolle — Yam
Igname pays negre — Yellow yam
Igname pousse debout — Potato yam
Ikamba — Bitter yam
Ilis-ilis — Elephant yam
Imbirg — Queensland arrowroot
Imo — Sweet potato/Taro
Imumu — Chufa
India yam — Cush-cush yam
Indian

Jagg-kand — Potato
Jamaica water lily — Lotus root
Japanese arrowroot — Kudzu
Japanese radish — Radish
Jetica — Sweet potato
Jicama — Yam bean
Jiquima — Yacon/Yam bean
Jiquimilla — Yacón
Kabitsa — East Indian arrowroot
Kachang bélimbing — Winged bean
Kachang botol — Winged bean
Kachang boter — Winged bean
Kachang embing — Winged bean
Kachang kelisah — Winged bean
Kachang kotor — Winged bean
Kachil — Greater yam
Kachoor — Shoti
Kachora — Shoti
Kalamismis — Winged bean
Kaile — Potato yam
Kakake — Swamp taro
Kalanguh — Chinese water chestnut
Kalut — Intoxicating yam
Kamal — Lotus root
Kamote — Sweet potato
Kamoteng kahoy — Cassava
Kand godda — Elephant yam

arrowroot	— Chavar/East Indian arrowroot/Shoti	Kangar	— Lesser yam
Indian lotus	— Lotus root	Kanwal	— Lotus root
Inhame	Taro/Yam	Kape	— Giant taro
Inhame gigante	— Giant taro	Kara imo	Sweet potato
Inhames	Yam	Karal-kavanai	— Elephant yam
Innala	— Hausa potato	Karake	— Swamp taro
		Karen potato	Lesser yam
		Karunai kilangu	— Elephant yam

Index part V

Kartoffel	— Potato	Ko hwo	— Kudzu
Karukandu	— Intoxicating yam	Ko t'eng	— Kudzu
Kaseru	— Chufa	Kohekohe	— Chinese water chestnut
Kasiena	— Potato yam	Koi	Intoxicating yam
Kaspé	Cassava	Koko	— Taro
Katchang botor	— Winged bean	Kolkas	— Taro
Katjeradong	East Indian arrowroot	Kolokasi	Taro
Katjeper	— Winged bean	Kong Kong taro	— Tannia
Kattala	— Potato yam	Konjac	— Elephant yam
Katula	— Greater yam	Konniaku	— Elephant yam
Kaw(a)i	— Lesser yam	Konnyaku	— Elephant yam
Kechipir	— Winged bean	Koorka	— Hausa potato
Keladi	— Taro	Kopfförmige marante	— Topee tambo
Kelala	— Cassava	Kotonoou	— African yam bean
Kembili	Hausa potato	Kourahan	— False yam
Ketala rambat	— Sweet potato	Kudazinila teiga	— Kudzu
Ketalla	— Cassava	Kulege	— African yam bean
Ketang	— Hausa potato	Kumala	— Lotus root/Sweet
Kétjeepir			

Index part VI

arrowroot

Mabi(y) — Sweet potato
Macabo — Tannia
Macachin — Oca
Macaxeira — Cassava
Madagascar potato — Hausa potato
Madère — Taro
Madumba — Tannia
Mafaffa — Tannia
Magnagna — Kudzu
Makmok — East Indian arrowroot
Malanga(y) — Tannia/Taro
Malangu — Taro
Mamusa — Cassava
Manaka — Giant taro
Manankaso — False yam
Mandiova — Cassava
Mandioke — Cassava
Mandioquinha-salsa — Arracacha
Mangareto — Tannia
Manihot — Cassava
Manila bean — Winged bean
Manioc — Cassava
Mankachu — Giant taro
Mankanda — Giant taro
Man nok — Potato yam
Mañoco — Cassava
Maota — Swamp taro
Mapuey morado — Yellow yam
Mapuey yam — Cush-cush yam

Mauritius bean — Winged bean
Mayaca — Cassava
Melloco — Ulluco
Michirui — Ulluco
Miguri — Ulluco
Miquichi — Oca
Mishrikand — Yam bean
Mita-alu — Sweet potato
Mokmok — East Indian arrowroot
Moniato — Sweet potato
Moola — Radish
Moriscaverai — Winged bean
Motha — Chufa
Mouchasse — Arrowroot
Mourai — Radish
Mo-yu — Elephant yam
Mulluculi — Ulluco
Muiang — Swamp taro
Mulle — Radish
Mullangi — Radish
Mullanki — Radish
Muli — Radish
Mullong — Radish
Murukavari — Winged bean
Muyá-muyá — Arrowhead
Mwong — Swamp taro
Myonk-ni — Sweet potato
Ñame — Yam
Ñame amargo — Bitter yam
Ñame amarillo — Yellow yam
Ñame asiatico — Lesser yam/Greater yam
Ñame [illegible] — Lesser yam

[illegible]	[illegible]	[illegible]	[illegible]
Marampash pasi	— Intoxicating yam	Ñame blanco	— Greater yam/White yam
Maranta/s	— Arrowroot	Ñame chino	— Greater yam/Lesser yam
Mashua	— Añu		

Index part VII

Ñame chomo	— Yellow yam	Ocumo cuman	— Tannia
Ñame congo	— Potato yam	Oewi	Greater yam
Ñame criollo	— Potato yam	Ola	— Giant taro
Ñame de agua	— Greater yam	O-kuroguwai	— Chinese water chestnut
Ñame (de) chino	— Chinese yam	Okpu duda	— African yam bean
Ñame de la India	— Cush-cush yam	Ol	— Elephant yam
Ñame del aire	— Potato yam	Ol kachu	— Elephant yam
Ñame de mata	— Potato yam	Old cocoyam	— Taro
Ñame de mina	— Greater yam	Olloco	— Ulluco
Ñame grande	— Greater yam	Omu	Chufa
Ñame Guineo blanco	— White yam	Ona	— Bitter yam
Ñame morado	— Cush-cush yam	Oobi	— Greater yam
Ñame negro	— Yellow yam	Oobi Singapore	— Potato yam
Ñame papa	— Lesser yam	Oowi kelapa	— Greater yam
Ñame pequeño	— Lesser yam	Oriental radish	— Radish
Ñame vino	Cush cush yam	Oroy	— Elephant yam
Ñame yeampi	— Cush-cush yam	Otaheite potato	— Potato yam
Namí	— Intoxicating yam	Ovihazo	— Yellow yam
Ñame	Intoxicating yam	Ovy	— Greater yam
Nangale	— Greater yam	O-yu	— Chinese water chestnut
Navios	— Añu	Pacala	— Greater yam
Navo	— Añu	Padma	— Lotus root
		Palacunda	Shoti

Index part VIII

Peruvian carrot — Arracacha
Peruvian parsnip — Arracacha
Pè-saung-sa-(ya or za) — Winged bean
Pfeilkraut — Arrowhead
Pfeilwurz — Arrowroot
Pia — East Indian arrowroot
Pijlkruid — Arrowhead
Pijlwortel — Arrowroot
Pindu — Giant taro
Pipi-wai — Chinese water chestnut
Pising — Taro
Pi't'si — Chinese water chestnut
Poire de terre cochet — Yacón
Pois ailé — Winged bean
Pois cachou — Yam bean
Pois carré — Winged bean
Pois manioc — Yam bean
Polynesian arrowroot — East Indian arrowroot
Pomme de terre — Potato
Pomme de terre céleri — Arracacha
Pomme de terre du Mossi — African yam bean
Pseudokolokasia — Jerusalem artichoke
Pulaka — Giant taro
Puna — Swamp taro
Puñgapung — Elephant yam
Pura(ka) — Swamp taro
Purple arrowroot — Queensland arrowroot
Pwolok — Swamp taro
Quequeque — Tannia
Quiba — Oca
Quiquisque — Taro
Quiq(u)as — Taro
Racacha — Arracacha
Radis — Radish
Ram-Kaseru — Yam bean
Ramu — Cassava
Rascadera — Tannia
Ratala — Hausa potato
Ratula — Greater yam
Ratula — Potato yam
Rettich — Radish
Rheru — Kudzu
Ripani — Radish
Root artichoke — Jerusalem artichoke
Roya — African yam bean
Ruba(s) — Ulluco
Rush nut — Chufa
Sabidokong — Winged bean
Sacred lotus — Lotus root
Sagittaire — Arrowhead
Sagu — Arrowroot
Sagu belanda — Arrowroot

Pongaporis — Elephant yam
Poroto batata — Yam bean
Portuguese yam — White yam
Sagu bribri — Arrowroot
Sakoureu — Greater yam
Sali — Arrowroot

Index part IX

Saluga — Hausa potato
San — Cassava
Sankalu — Yam bean
Sankeh alu — Yam bean
Sasniali — Lesser yam
Sathui — Lesser yam
Satoimo — Taro
Satsuma imo — Sweet potato
See-kok-tau — Winged bean
Segidilla — Winged bean
Seguidilla Winged bean
Sembu — Queensland arrowroot
Sengkuang Yam bean
Sénté — Giant taro
Sequidilla — Winged bean
Sererella — Winged bean
Sese — African yam bean
Sesquidilla — Winged bean
Shambe kayi — Winged bean
Sihosibolasan — Chinese water chestnut
Sigarilya — Winged bean
Silakandom — Lesser yam
Simindou Swamp taro
Sincamas — Yam bean
Skirrets — Sweet potato
Sweet yam — Elephant yam
Tacca — East Indian arrowroot
Tahiti arrowroot — East Indian arrowroot
Taioba — Tannia/Taro
Tamu(zava) — Lesser yam
Tajer Tannia
Takwara — False yam
Talanu — Giant taro
Talo papalagi — Tannia
Tamani — Elephant yam
Tan(n)ier — Tannia
Tanyove — Tannia
Tao Kape — Swamp taro
Tapioca — Cassava
Tapioka — Cassava
Tarate — Lotus root
Taro de Chine Taro
Taru kalo — Taro
Taiaze — Tannia
Taro Taro
Tavolo(s) — East Indian arrowroot
Tavolo-kabija — East Indian arrowroot
Tavoba — Taro

Skurar-konde	— Sweet potato	Tayobe	— Tannia
Soi	— Potato yam	Tayonne	— Tannia
Sooweg	— Elephant yam	Tayo tyo	— Tannia
Souchet comestible	— Chufa	Teké	— Chinese water chestnut
Spanish potato	— Sweet potato	Teki téké	— Chinese water chestnut
St. Vincent arrowroot	— Arrowroot	Telinga potato	— Elephant yam
Sudan potato	— Hausa potato	Temu kuning	— Shoti
Sugú	— Queensland arrowroot	Temu puteh	— Shoti
Sunroot	Jerusalem artichoke	Ten months yam	— Greater yam
Suran	— Elephant yam	Tenu reskok	— Cassava
Suron	— Elephant yam	Tapuraka	— Swamp taro
Swamp potato	Arrowhead	Teve	— Elephant yam
Swan potato	— Arrowhead	Three leaved yam	Bitter yam
Sweet corn root	— Topee tambo	Tiger nut	— Chufa

Index part X

Tigi	— Elephant yam	Uta	— Swamp taro
Timbos	— Ulluco	Ulloco(s)	— Ulluco
Tiquino	— Ulluco	Umala	— Sweet potato
Tiquisque	— Tannia	Umara	— Sweet potato
Tjeepir bee-bas	— Winged bean	Uraro	— Arrowroot
Tjeepir we-loo	— Winged bean	Uvea	— Giant taro
Tjeetjeepir	— Winged bean	Uwi	— Greater yam
Tongo	— Lesser yam	Vaaga	— Giant taro
Too-a-poo	— Winged bean	Vatke	— Hausa potato
Topinambour	— Jerusalem artichoke	Va yaka	— Kudzu
		Veeazee	— Sweet potato

Tupinambour (blanca) — Topee tambo
Topitambo/u — Topee tambo
Toupie nambours — Topee tambo
Tous les mois — Queensland arrowroot
Toyoen — Giant taro
Trident yam — Lesser yam
Trifoliate yam — Bitter yam
Trouffe douce — Sweet potato
Tua pu — Winged bean
Tugi — Lesser yam
Tumpinambou — Topee tambo
Tumuku — Hausa potato
Tungo — Lesser yam
Turkey liver yam — Potato yam
Tus — Greater yam
Twelve months yam — Yellow yam
Tzu ku — Arrowhead
Uala — Sweet potato
Uara — Sweet potato
Uarifi — Topee tambo
Ubi — Greater yam/Sweet potato
Ubi atas — Potato yam
Ubi kayu — Cassava
Ubi kemali — Greater yam
Ubi sengkuang — Yam bean
Ubi singkong — Cassava
Ubi-ubihan — Potato yam
Via (gaga) — Giant taro
Via kana — Swamp taro
Viamiko — Giant taro
Viazi — Potato
Virraca — Arracacha
Vitian — East Indian arrowroot
Vomanga — Sweet potato
Wale — Lesser yam
Waloor — Elephant yam
Wari — Lesser yam
Waswar — Swamp taro
Watalu — Potato
Waternut — Chinese water chestnut
Water yam — Greater yam
West Indian arrowroot — Arrowroot
White eddoe — Taro
White Guinea yam — White yam
White Manila yam — Greater yam
White potato — Potato
Wild yam bean — African yam bean
Williams arrowroot — East Indian arrowroot
Winged pea — Winged bean
Winged yam — Greater yam
Wu yu — Chinese water chestnut
(W)yaka — Yam bean
Ya — Taro

Index part XI

Index part XII

Printed for Her Majesty's Stationery Office by Hobbs the

Printers of Southampton
(3202/85) Dd8304964 3/87 G3371

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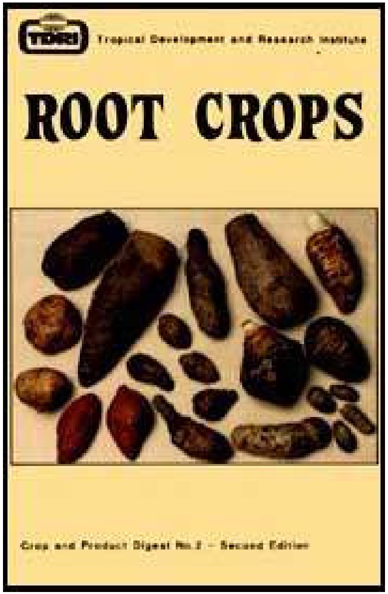


- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma**

Introduction

The term 'root crops' is applied to plants which produce subterranean structures that may be used for human or animal food. They are normally perennating organs, storing plant nutrients through a resting period (dry season or winter) which are used in the regrowth of the plant when growing conditions are again favourable. The word 'root' is often a misnomer, as in many cases the storage organ may be morphologically a modified stem, eg a swollen rhizome or corm, or a tuber such as a potato, rather than a swollen root as in carrot or sweet potato. All these swollen underground organs are commonly spoken of as 'tubers'.

Root crops are the second most important source of carbohydrates in the world's food: FAO figures for world production in 1981 showed 1,661 million tonnes of cereals and 561 million tonnes of root crops. The tropical world, however, where root crops are

proportionally much more important, produced 82 million tonnes of root crops and only 42 million tonnes of cereals. In many tropical countries where rice is not grown they are the staple diet. In general, protein content is low, but some, for example Solanum tuberosum (potato) and Dioscorea spp. (yam), provide significant amounts of certain vitamins.

The following pages briefly describe 42 root crops, the most important of which are Manihot esculenta (cassava), Solanum tuberosum (potato), Ipomoea batatas (sweet potato), Colocasia esculenta (taro), Xanthosoma spp. (tannia) and Dioscorea spp. (yam). Many others are of only minor or local importance, but have been included to make this compilation as comprehensive as possible.

Each crop is listed alphabetically under its first common

name, followed by local names. In the index of 'trivial' names (Appendix E) these local names are cross-referenced to the first common name. Selected literature references are given, but are not exhaustive; some crops, eg Manihot esculenta (cassava) have been the subject of so much study that lengthy bibliographies for them have been published, and such bibliographies are included in the relevant lists of references.

Data about each crop are arranged under the following headings:

Common names

Widely used English names are given, the first being printed in capitals and being used for the alphabetical arrangement of the entries and for cross-referencing.

Botanical name; Family

Nomenclature closely follows the Index Kewensis and its Supplements

Other names

Most plants have a wide range of local names, and many of these are listed, with the country or language to which they normally apply being appended in parentheses. Less common English names are given without the country being indicated.

Botany

A short description of the plant, its form and habit, varietal differences and systematics where appropriate is given.

Origin and distribution

Brief particulars of the origin and distribution of the crop are given.

Cultivation conditions

The main climatic regions in which it is possible to cultivate the plant are given in accordance with van Royen and Bengtson. The climates of the world are divisible into tropical, subtropical, intermediate or temperate and polar types.

Tropical climates have an average annual temperature of above 25°C, no month having an average temperature below 18°C. Subtropical climates have short, mild winters and long growing seasons. There is a period of 1-2 months when freezing temperatures may occur,

though the average temperature of the coldest month is above 6°C. The summer temperatures may be as high as those of the tropical climate. Intermediate or temperate climates, ie those between subtropical and polar, have cold winters and warm to hot summers. They vary from areas where the winters are short to those where they are long and severe. All intermediate climates have a season of frost as well as a frost-free season.

The humid tropical climates are tropical rainforest, tropical monsoon, and tropical savanna. The tropical rainforest has no pronounced or prolonged dry season, an annual rainfall of 200-400 cm or more, a relative humidity of around 80 per cent and a high and uniform temperature with annual means ranging from 25 to 26.5°C with little seasonal variation. The tropical monsoon climate exhibits marked daily and seasonal temperature changes, has an annual rainfall of 100-200

cm with abundant rainfall during the wet season, alternating with a period of drought lasting 4-6 months or longer. The tropical savanna climate has a rainfall often exceeding 100 cm annually, well spread over 120-190 days, with a prolonged drought often lasting 6-7 months. The climate is hot with a moderate range of temperature. The dry tropical climates are subdivided into semi-arid or steppe type and arid or desert type. In the areas of tropical steppe climate the rainfall is occasional, though seasonal and commonly averages 20-50 cm or more annually; the temperature is variable but high at all seasons. The desert climate has a rainfall usually averaging less than 20 cm per annum, and a daytime relative humidity (RH) commonly less than 50 per cent.

The subtropical climate is subdivided into dry subtropical or Mediterranean and humid subtropical. The

former has an average annual rainfall generally below 75 cm, in some places below 50 cm, with most of the rainfall occurring during the cool season. In some regions there is a moderate amount of summer rainfall, while others may be nearly rainless during this period. There are about 6-8 months with an average temperature below 18°C. In humid subtropical regions the rainfall averages above 75 cm per annum, with no pronounced dry season. There are generally 4-6 months with an average temperature below 18°C. In both types of subtropical climate frost may occur during the coldest period.

Humid intermediate climate has an annual rainfall which ranges from 50 cm in the drier parts to 200 cm in the more rainy sections. Dry intermediate climates have an annual rainfall which is commonly less than 50 cm. They may be subdivided into middle latitude steppe and

middle latitude desert; the former having an annual rainfall of 15-50 cm and the latter less than 15 cm per annum.

Plant growth requirements are arranged under the main headings of temperature, rainfall and soil, with additional factors such as altitude and day-length noted where they are crucial. The possibility of growth under irrigation is mentioned when describing rainfall requirements and any positive evidence concerning the effects of fertilisers is included in the information on soil. The main climatic zones in which the root crops listed are generally grown are shown in Appendix A.

Planting procedures

Information concerning the type or types of planting material is given, with brief mention of their relative

merits, and with special emphasis on the preferred type, where more than one type of planting material is available. The usual methods of planting are given, together with details of field spacing and, where applicable, seed rate.

Pests and diseases

The most serious pests and diseases attacking the crop in various growing regions are noted, along with methods of control. (A list of the pesticides referred to in the digest is given in Appendix C.)

Growth period

An approximate average or range of time lengths from planting to harvesting is quoted.

Harvesting and handling

The most common and best methods of harvesting, handling and storage are briefly indicated.

Primary product

The part of the plant for which the crop is primarily grown and the form in which it is commonly marketed are given. Normally one form only has been selected and this is shown at the beginning of the heading; this form will be used as the basis for quantitative data given in subsequent headings, unless otherwise stated. In some cases where there are other main products, eg seeds or pods, these are noted separately.

Yield

A good average yield of the primary product is given. Yields obtained in different regions or circumstances

may be separately quoted.

Main use

The main use or uses of the primary product are given.

Subsidiary uses

Additional uses of the primary product are entered under this heading.

Secondary and waste products

Useful by-products resulting from the processing of the primary product or prepared from other parts of the plant are listed, together with their uses, etc. Major waste products which result from primary or secondary product processing are noted, with possible outlets where applicable.

Special features

Information is given on the chemical components of importance in the plant, and the main nutrients of the edible portion are listed wherever possible. The percentage composition often varies widely according to the variety, locality, conditions of growth, etc. so 'typical' figures are quoted, taken from the most reliable source available, eg FAO Food Composition Tables, recent papers, etc. Only a few publications quote ranges of high and low values; workers in the nutritional field are advised to seek local information for the food in question. Fibre and protein represent 'crude' fibre and 'crude' protein (N x6.25) respectively, unless otherwise stated.

In addition, the presence of constituents that may call for special treatments, eg toxins, are indicated, and also

of those that may have value as drugs, antibiotics, etc.

Processing

The main processing operations through which the primary product may have to pass in order to produce a final marketable commodity, are listed. In certain circumstances, similar information may also be given for secondary products.

Production and trade

There is very little statistical information available regarding the production and trade of many of the individual root crops included in this digest, largely because most root crop production in the tropics is in smallholder units. Moreover, the major part of the production is consumed locally, since tropical root

crops, owing to their high water content and perishability, have not assumed any great significance in international trade. Where information is available, details are provided of: (i) the estimated average world production of the crop; (ii) the output of the major producing countries; (iii) shipments from the major exporting countries; and (iv) shipments to the major importing countries. In some cases only very fragmentary information is available, in others none. In view of the extreme variations in exchange rates, commodity prices and general economic instability of recent years, prices have not been included as any such figures could be misleading.

Major influences

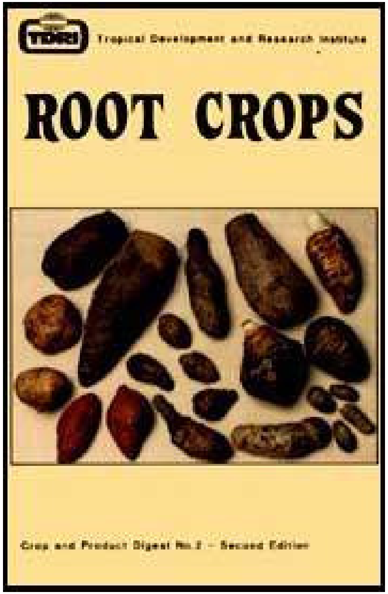
Any factors which might have a significant influence on the future supply of and demand for the commodity are

mentioned under this heading.

Particular attention is paid to possible competition from synthetic materials and other substitutes.

Bibliography

Textbooks, technical bulletins, research reports, papers given at recent symposia, articles in technical periodicals and bibliographies are cited. For some root crops literature is scant, but for many it is extensive, and the bibliographies for each individual crop are selective and by no means exhaustive. Emphasis has been given to material published between 1972 and 1982.



Root Crops (NRI, 1987, 308 p.)

arundinacea)

- **Cassava (Manihot esculenta)**
- **Chavar (Hitchenia caulina)**
- **Chinese water chestnut (Eleocharis dulcis)**
- **Chufa (Cyperus esculentus)**
- **East Indian arrowroot (Tacca leontopetaloides)**
- **Elephant yam (Amorphophallus spp.)**
- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke**

(Helianthus tuberosus)

- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma chamissonis)**
- **Sweet potato (Ipomaea batatas)**
- **Tannia (Xanthosoma spp.)**
- **Taro (Colocasia esculenta)**

Abbreviations

a	annum
Abs.	Abstract acet.
val.	acetyl value
°C	degrees Celsius

cm	centimetre
cm2	square centimetre
cv.	cultivar
eg	for example
etc	and so on
°F	degrees Fahrenheit
FAO	Food and Agriculture Organization of the United Nations
FYM	farmyard manure
g	gram
ha	hectare
HCN	hydrogen cyanide
ie	that is
iod. val.	iodine value

IU	international unit
Jr.	Junior
K	potassium
kg	kilogram
km	kilometre
krad	kilorad
I	litre
m	metre
m2	square metre
m3	cubic metre
mg	milligram
mm	millimetre
N	nitrogen
na	not available

ND	refractive index
No.	number
NPK	nitrogen: phosphorus: potassium
P	phosphorus
pH	hydrogen ion concentration
Poll val.	Polenske value
pp.	pages
ppm	parts per million
RH	relative humidity
RM val.	Reichert-Meissl value
S	sulphur
sap. val.	saponification value
SG	specific gravity
sp./spp.	Species .

ssp.	Subspecies
syn.	Synonym
t	tonne
TPS	true potato seed
TS	total solids
unsap.	unsaponifiable matter
val.	Value
var.	variety
wt	weight
Geographic and langauge abbreviations used	
Afr.	Africa
Am.	America
Ang.	Angola
Ant.	Antilles
Ar.	Arabic

Arg.	Argentina
Bangl.	Bangladesh
Barb.	Barbados
Beng.	Bengal
Boll	Bolivia
Bom.	Bombay
Braz.	Brazil
C.	Central
Cam.	Cameroon
Camb.	Cambodia
Carib.	Caribbean
Col.	Colombia
C. Rica	Costa Rica
Cur.	Curacao

Cy.	Cyprus
E.	East
EC	European Community
Ecu.	Ecuador
Eth.	Ethiopia
Fr.	France
Gab.	Gabon
Gam.	Gambia
Ger.	Germany
Gh.	Ghana
Gren.	Grenada
Guat.	Guatemala
Guin.	Guinea
Guy.	Guyana
Haw.	Hawaii

Hind.	Hindustani
Ind.	India
Indon.	Indonesia
Ir.	Iran
Is.	Island(s)
It.	Italy
Jam.	Jamaica
Kiri.	Kiribati
Lat. Am.	Latin America
Madag.	Madagascar
Mall	Malaysia
Mar. Is.	Marshall Islands
Mart.	Martinique

Maur.	Mauritius
Mex.	Mexico
Mol.	Moluccas
N.	North or New
N. Guin.	New Guinea
Nether.	Netherlands
N. Cal.	New Caledonia
Nig.	Nigeria
N.Z.	New Zealand
P. Rico	Puerto Rico
Pacif.	Pacific
Pak.	Pakistan
Philipp.	Philippines

Polyn.	Polynesia
Pon.	Ponape
Port.	Portugal
Salv.	El Salvador
S.	South
Sam.	Samoa
Sen.	Senegal
Sol. Is.	Solomon Islands
Sp.	Spain
Sri. La.	Sri Lanka
St.	Saint
Sud.	Sudan
Sur.	Surinam
Swah.	Swahili
Tah.	Tahiti

Tah.	Tahiti
Tam.	Tamil
Tanz.	Tanzania
Thai.	Thailand
Trin.	Trinidad
Tuv.	Tuvalu
Ug.	Uganda
USA	United States of America
Venez.	Venezuela
Viet.	Vietnam
W.	West
W.I.	West Indies
Zar.	Zaire