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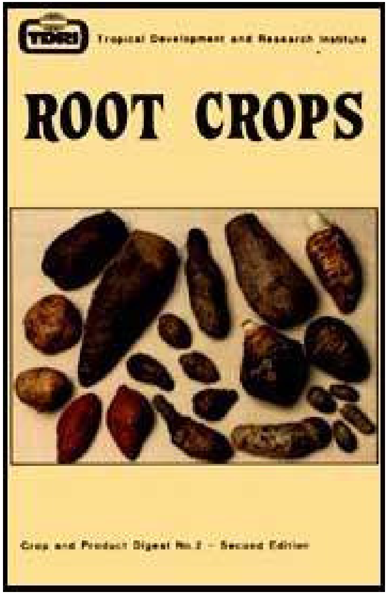

Root Crops (NRI, 1987, 308 p.)

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)**

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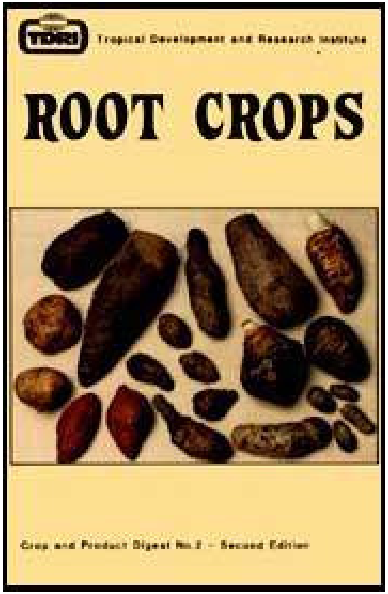
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spp.)

- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
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- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
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- **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**

Daisy E. Kay revised by E. G. B. Gooding

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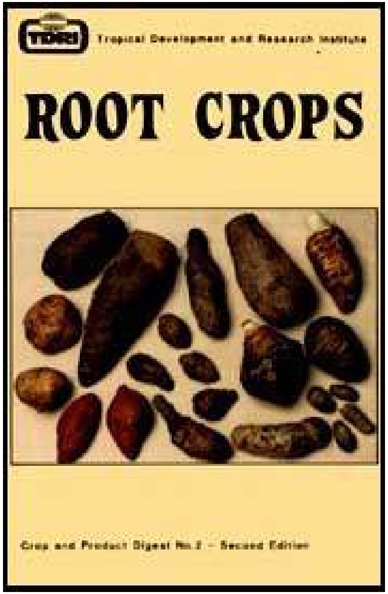
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leontopetaloides)

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Yam bean (Pachyrrhizus erosus)
Appendixes

Arrowroot (Maranta arundinacea)

Common names

ARROWROOT, Bermuda arrowroot, St. Vincent arrowroot, West Indian arrowroot.

Botanical name

Maranta arundinacea L.

Family

Marantaceae.

Other names

Aloro (Philipp.); Amaranta (P. Rico); Araru (Philipp.); Ararut (Beng.); Araruta (Braz.); Aroro (Philipp.); Arraroet (Cur.); Arruruz (Fr.); Aru-aru (Braz.); Car maco (S. Am.); Envers blanco (Ant.); Guate (gallina) (Venez.); Hoangting (Viet.); Kuzuukon (Japan); Marantale (S. Am.); Mouchasse (St. Lucia); Pfeilwurz (Ger.); Pijlwortel (Nether.); Sag (Cur.); Sag belanda (Mal.); Sag bribri (C. Rica); Sal (S. Am.); Uraro (Philipp.); Yuquilla (S. Am.).

Botany

An erect, herbaceous, dichotomously branched perennial, 60-180 cm high, with large, fleshy, cylindrical, obovoid subterranean rhizomes, large lanceolate leaves and white flowers arranged in twin clusters, which very rarely produce red seeds. Two main

cultivars are recognised in St. Vincent: 'Creole', which has long thin rhizomes, which spread more widely and penetrate more deeply into the soil and 'Banana', which has shorter, thicker, less fibrous rhizomes, produced near the soil surface. The latter is more easily adapted to mechanical harvesting. There are, however, many other cultivars, twenty-two of which were reported to be growing in a Philippine germplasm nursery.

Origin and distribution

Arrowroot is indigenous to tropical America and has long been cultivated in the West Indies, particularly St. Vincent, which produces about 95 per cent of the world's commercial supply. Cultivation has spread to many other tropical countries, including Brazil, India, Sri Lanka, Indonesia and the Philippines.

Cultivation conditions

Temperature-arrowroot is a tropical plant that grows best at temperatures of 20-30°C.

Rainfall-a minimum annual rainfall of 95-150 cm is required, but a sufficient water supply in the soil throughout the growing period of the plant is of primary importance, and optimum yields are only obtained where the rainfall is evenly distributed throughout the year or where the dry season is of short duration.

Soil-arrowroot requires deep, well-drained, slightly acid, loam soils for the best results. Badly-drained and heavy clay soils are unsuitable. When grown on light soils, a degree of shade has been found beneficial. The sandy loam soils of St. Vincent, containing minerals of volcanic origin, have proved admirably suitable for

arrowroot cultivation. Fertilising is important. It is recommended that on the St. Vincent soils the crop should receive an 8:5:14 NPK mixture at the rate of 900 kg/ha, 14 weeks after planting.

Altitude-arrowroot normally grows from sea level up to about 900 m but does particularly well near the sea at elevations of 60-90 m.

Planting procedure

Material-arrowroot is normally propagated from 'bits' which are small pieces of rhizomes 4-7 cm in length, with buds on them. In parts of Asia the 'bits' are sometimes treated with smoke to aid germination. Suckers are also used occasionally for propagation.

Method-planting usually starts at the beginning of the

rainy season, after the soil has been thoroughly ploughed and harrowed to obtain a fine filth (forking may be necessary on steep terrain where mechanisation is not possible). Holes about 8 - 15 cm deep are made and the pieces of rhizome are dropped in and covered with soil. The crop must be kept clean-weeded during the first 3 or 4 months and the flowers removed as they appear. Pre-emergence applications of 2,4-D, MCPA, monuron and diuron at the rate of 1.7 kg/ha have been recommended for weed control.

In St. Vincent, where cultivation usually follows a 5-7 year rotation, small pieces of the rhizomes are usually left in the ground at harvest to produce the root crop.

Field spacing-an average spacing of 75 x 37.5 cm is recommended.

Seed rate-approximately 3 000-3 500 kg of 'bits' are required to plant one hectare.

Pests and diseases

Arrowroot is not normally subject to serious attacks by pests or diseases. In St. Vincent the only pest of any importance is the leaf roller, Calopodes ethlius, which has proved resistant to many common insecticides but has been controlled by deltamethrin. In Brazil and Venezuela, the crop is attacked occasionally by Ascia monuste orseis, Neocurtilla hexedactyla and Scapteriscus vicinus. In parts of the Caribbean, particularly in wet districts, arrowroot sometimes suffers from a rot caused by Rosellinia bunodes. Two leaf blights, caused by Rhizoctonia solani and Pellicularia filamentosa, are reported to infect arrowroot in India. A condition known as 'cigar roots', in which the

rhizomes become elongated and very fibrous, has also been reported from the Caribbean but is thought to be due to nutritional deficiencies.

Growth period

The rhizomes mature in 10-11 months.

Harvesting and handling

The rhizomes are ready for harvesting when the leaves begin to wilt and die down. At this stage the plants are usually dug up by hand and the rhizomes separated from the leafy stem. In St. Vincent a modified potato spinner has been used with limited success to harvest 'Banana' arrowroot. The rhizomes are normally left in the ground until required for processing. Once harvested, deterioration is rapid and the 'Banana' cultivar must be

processed within 2 days and the 'Creole' within 7 days.

Primary product

Rhizomes - these are fleshy, cylindrical, covered with regular scales, and grow to approximately 2.5 cm thick and 20-45 cm long.

Yield

Yields of rhizomes normally average about 12.5 t/ha, although under favourable conditions yields as high as 31 t/ha have been recorded. In St. Vincent the normal commercial yield of starch at the factories is 8-16 per cent. Average production of starch per hectare is 2 500 kg, though farmers using improved methods recommended by the St. Vincent Ministry of Agriculture have reported average yields of 3 700 kg (up to 5 600 kg

at the maximum).

Main use

The rhizomes are used for the production of a very fine, easily-digested starch, which appears on world markets as a dry white powder known as arrowroot starch. It is valued as a foodstuff, particularly for infants and invalids, and is used in biscuits, cakes and puddings.

Subsidiary uses

Arrowroot starch possesses demulcent properties and is sometimes used in the treatment of disorders of the intestine. It may also be employed in the preparation of barium meals and in the manufacture of tablets where rapid disintegration is desirable. The starch is also used as a base for face powders, in the preparation of certain

specialised glues and, more recently, in the manufacture of carbonless paper for computers.

Secondary and waste products

(i) The rhizomes are sometimes eaten boiled or roasted.

(ii) In the West Indies the pounded rhizomes may be used for poulticing wounds and ulcers.

(iii) The plant leaves are occasionally used as local packing material.

(iv) The fibrous material, known as 'bittie', which remains after the extraction of the starch can be used as cattle feed or manure. Typical analyses of 'bittie' from 'Creole' rhizomes are: water 12.5 per cent; protein 3.7 per cent; fat 0.3 per cent; starch 64 per cent; fibre 14 per cent; ash 2.2 per cent. Analyses of 'bittie' from

'Banana' rhizomes give: water 11.9 per cent; protein 2.3 per cent; fat 0.3 per cent; starch 50.4 per cent; fibre 14.8 per cent; ash 2.6 per cent.

Special features

Arrowroot starch is one of the purest forms of natural carbohydrate and has a high maximum viscosity, although this is adversely affected by the salinity of the processing water.

Typical analyses of 'Creole' rhizomes are: water 69.1 per cent; protein I per cent; fat 0.1 per cent; starch 21.7 per cent; fibre 1.3 per cent; ash 1.4 per cent.

Typical analyses of 'Banana' rhizomes are: water 72 per cent; protein 2.2 per cent; fat 0.1 per cent; starch 19.4 per cent; fibre 0.6 per cent; ash 1.3 per cent.

Arrowroot starch is composed of simple oval grains 15-70 microns in length; the 'Banana' type has a slightly higher proportion of large grains than 'Creole'. Commercial good-quality arrowroot starch should be pure white, clean and free from specks, and have a moisture content of not more than 18.5 per cent, with low ash and fibre content, an initial pH of 4.5-7 and a maximum viscosity of between 512 and 640 Brabender units, according to the grade.

Processing

Small-scale

(i) The rhizomes are washed and the skin scales carefully peeled from the white fleshy core, otherwise they impart a bitter taste to the final product.

(ii) The peeled rhizomes are washed again and grated into a coarse pulp.

(iii) The pulp is mixed with a large quantity of clean water and the mixture passed over a series of sieves to separate the fibre.

(iv) The liquid is allowed to stand and the starch to settle out on long tables.

(v) The starch is removed from the tables, mixed with more water and resettled overnight.

(vi) The lumps of starch are placed on racks to air-dry, a process which can take from 4 to 14 days according to the weather; slow drying can result in the material becoming discoloured.

(vii) After drying, the lumps of starch are pulverised and

prepared for marketing in different grades according to viscosity ratings. The pulverised starch is packed in moisture-proof bags.

Large-scale

Most of the St. Vincent factories operate on a combination of the small scale and large-scale techniques.

(i) On arrival at the factory the rhizomes are first thoroughly washed in special tanks.

(ii) They are then cut into small pieces, rasped and crushed into a pulp.

(iii) The pulp is passed in a continuous flow of water into a series of three vibratory sieves.

(iv) The starch milk then passes to the separator.

(v) The residues remaining on the sieves are crushed and sieved twice more to effect the maximum extraction of starch. The resultant starch milk is passed to the separator.

(vi) The separator divides the starch from the water within 4 minutes and it is next mixed with fresh water, passed through a fine sieve of 120 mesh wire cloth and re-centrifuged.

(vii) The starch is then mixed with fresh water, treated with sulphurous acid and fed into settling tanks.

(viii) After the starch has settled, the supernatant liquid is run off and the upper layers of sediment are washed away by vigorous hosing to remove as much as possible

of the residual fibrous tissue.

(ix) The starch is then dried in low temperature driers at 55-60°C for 2-3 hours, to a moisture content of approximately 17 per cent or slightly less.

(x) When dry, the starch is pulverised as in the small-scale processing procedure.

Production and trade

Production - St. Vincent accounts for the major proportion of the world's output of arrowroot, but for several years it has been grown to a moderate extent in Brazil, mainly in the Otujai valley, Santa Catarina. Arrowroot starch facilities are known to exist in China. Following an exceptionally heavy crop resulting in 4 000 t of unsold stock, production in St. Vincent declined steadily and might have collapsed entirely, but in recent

years there has been renewed interest, particularly from buyers in the USA where arrowroot starch is used in the manufacture of carbonless paper for computers.

Production in St. Vincent during the period 1960-80 was: 1960, 2 952 1964, 5 400 t; 1968, 1 272 t; 1972, 784 t; 1976, 740 t; 1980, 630 t.

Current production in each of St. Vincent and Brazil is less than I 000 t/a.

Trade - Exports - St. Vincent: 1961-65 average, 2 939 t/a; 1966-69, 2 097 t/a; 1972, 842 t; 1974, 930 t; 1976, 720 t; 1978, 810 t. Brazil: 1961-65 average, 159 t/a; 1966-69, 139 t/a The export market in 1983 was about I 000 t/a.

Imports - most countries do not show arrowroot

separately. Imports of 'arrowroot' starch, which includes sago (ie cassava) starch and flour, into the USA, were reported as: 1961-65 average, 2 158 t/a; 1966-70, 1 492 t/a.

Major influences

The demand for arrowroot starch tends to be limited by its high price compared with other starches and the fact that its manufacture requires large quantities of very pure water. In St. Vincent, recent attempts to increase production to meet the increased demand from the USA for arrowroot starch for use in the manufacture of carbonless paper for computers have been handicapped by the shortage and cost of labour to harvest the crop, and there is an urgent need to mechanise field production. Even so, as arrowroot starch is sold entirely on the basis of its 'special properties', and recent

developments in starch technology have produced cheaper substitutes, eg fractionated wheat starch, market competition is becoming more severe and a decline rather than an increase in demand seems likely.

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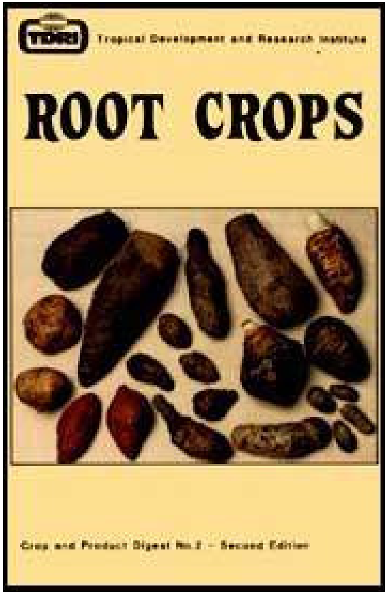
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Cassava (Manihot esculenta)

Common names

CASSAVA, Manihot, Manioc, Tapioca, Tapioka.

Botanical name

Manihot esculenta Crantz syn. M. utilissima Pohl.

Family

Euphorbiaceae.

Other names

Aipi, Aipim ubi (Braz.); Bafifanapaka (Madag.); Brazilian arrowroot, Cassadal (Afr.); Cassave (Nether.); Caxcamot (Guat.); Cu san tau (Viet.); Delhazo (Madag.); Guacamote (Mex.); Kamoteng kahoy (Philipp.); Kasp (Indon.); Kelala (Ind.); Ketalla (Braz.); Khoaimi (Viet.); Kute (agbeli) (Togo); Macaxeira, Mandioca (Braz.); Mandioko (Gam.); Manoco (P. Rico); Mayaca (Zar.); Obikajoe (Indon.); Ramu (Lat. Am.); San (Viet.); Tentu neskok (Philipp.); Ubi kayu (Mal.); Ubi singkong (Indon.); Yautia, Yuca (S. Am.).

Botany

Cassava is a perennial shrub, with latex in all its parts,

which produces enlarged tuberous roots. There are over 100 cultivars and there is great variation in the form of the plant. The height ranges from about 1 to 3 m or more. The stems are usually slender and glabrous, with leaves borne near the apex; the lower parts of the stems have nodes made conspicuous by prominent leaf scars. Branching is variable; some cultivars branch near the base and are spreading in form, others are erect and branch nearer the apex. Stems vary in colour, being grey or silvery, green, greenish-yellow, reddish-brown, or streaked with purple. The leaves, which are spirally arranged with phyllotaxis 2/5, have petioles 5-30 cm long, usually longer than the blades; the blades are deeply palmately divided with 5-7 (occasionally 3-9) lobes, each 4-20 cm long and 1-6 cm wide, obovatelanceolate, pointed and with entire margins. They vary in colour from green to reddish; the petiole and midrib may be deep red. Older leaves are shed

leaving the prominent leaf scars mentioned above. The flowers are borne in axillary racemes near the ends of branches, and are monoecious, pale yellow or red, 1-1.5 cm in diameter. The fruit is a six-winged capsule with 3 ellipsoidal seeds each about 12 mm long. Root tubers develop by a process of secondary thickening as swellings on adventitious roots a short distance from the stem.

Great variation is shown in the number, shape and size of the tubers and the angle at which they penetrate the ground. There are usually 5-10 tubers per plant, cylindrical or tapering, 3-15 cm in diameter and 15-100 cm long, occasionally longer. Hydrocyanic glycoside is present in varying quantity. Cassava clones are often classified by taste as 'sweet' or 'bitter', but - contrary to the commonly stated notion - this does not always reflect a direct relationship with the cyanogenic

glycoside content of the root. The two types have sometimes been regarded as different species, the former being called M. esculenta and the latter M. palmata or M. dulcis. This division is clearly not tenable. Further, the toxicity of a cultivar varies according to environmental growth conditions. However, in any one location it is possible to find some cultivars 'bitter' and some 'sweet', so that a local separation between bitter and sweet can often be made.

Origin and distribution

Manihot esculenta is not known in the wild state. Some 98 species of the genus Manihot have been found in the western hemisphere, and it appears that M. esculenta must have arisen by mutation or hybridisation, the probable centre being southern Mexico/Guatemala or north-eastern Brazil, or both. It was early domesticated

and was cultivated in Peru 4 000 and in Mexico 2 000 years ago. It was subsequently spread throughout Central and tropical South America, and was taken by the Portuguese to Africa in the 16th century. Its spread in Africa was slow until the end of the 19th and first half of the 20th century, but Africa now produces almost 40 per cent of the world's total. The crop has become important throughout the tropics, under a wide range of conditions of climate and soil, with West Africa, Brazil, Indonesia and Thailand being major producers.

Cultivation conditions

Temperature - the optimum temperature range for cassava is 25-30°C, and the approximate boundaries for its culture are latitudes 30°N and 30°S. The minimum temperature for its growth is 18°C and yields are reduced above 30°C. It cannot withstand freezing and

must have a minimum of 300 frost-free days.

Rainfall - a well-distributed annual rainfall of 100-150 cm is regarded as ideal, but the crop can be successfully grown in areas with rainfall ranging from 50 to 250 cm. Occasionally (eg in Kerala, India), with rainfall of less than 75 cm it is irrigated. Except at planting cassava can withstand prolonged periods of drought and is therefore a useful crop in areas of low or uncertain rainfall.

Soil - light sandy loams of medium fertility give the best results, but cultivars can be grown successfully on soils ranging from stiff marine clays with a pH of 8-9, to sands or loose laterites with a pH of 5-5.5. When grown on clay soils, the plant produces stem and leaf growth at the expense of the roots and many cultivars give poor yields. Saline and swampy soils are unsuitable. Cassava can tolerate soils of low fertility, especially if the feeder

roots can penetrate to depths of 40-60 cm; deep cultivation before planting is therefore recommended.

Although it responds well to fertilisation, cassava will grow on relatively infertile soils which are unsuitable for other crops. However, it removes considerable quantities of nutrients from the soil; published figures indicate that for a crop of 25 t/ha of roots the following quantities of nutrients are absorbed: nitrogen 53.5 kg; phosphorus 26.3 kg; potassium 105 kg; calcium 17.2 kg and magnesium 9.75 kg. Thus continuous growing of cassava on improverished soils leads to even more severe soil deficiencies. Potassium is often the limiting factor. Proper fertilising practice will depend upon the soil in question (and on other limiting factors, such as rainfall) but a general basic recommendation is to use about 500 kg/ha of a 12:12:18 complete (NPK) fertiliser. FYM at 20-30 t/ha augmented with 500 kg/ha

of rock phosphate and 300 kg/ha of muriate of potash has given good results in Madagascar with average yield of roots about 40 t/ha.

Altitude - cassava can be grown from sea level up to about 1 000 m in equatorial regions, though at the highest altitudes growth is slow and yields are reduced.

Day-length - cassava is a short-day plant and less productive of tuberous roots in day-lengths greater than 10-12 hours; it is, therefore, most productive when grown in areas between latitudes 15°N and 15°S, though some cultivars will tolerate longer days and extend the limits to 30°N and 30°S.

Planting procedure

Material - seed is difficult to germinate and is used only

for breeding work. In any case it is necessary to use vegetative material to propagate cultivars and stem cuttings (sticks) are used. For hand planting, sticks about 20-30 cm long, 2.5-3.75 cm thick and with at least 5 buds, taken from stems 8-18 months old are recommended. It is essential that virus-free material be selected and treatment of the cuttings with a mixture of fungicides and insecticides (eg maneb + propineb + copper oxychloride + malathion) has been advised. The sticks can be stored for up to 8 weeks in cool, well-ventilated conditions except when harvested under rainy conditions, when storage is normally reduced to 7-10 days. For mechanical planting shorter sticks, 15-20 cm long, are used.

Method - most cassava is still planted by hand, though mechanisation is increasing. Planting is normally at the start of the rainy season, often in flat fields, though

planting on ridges is desirable in wet regions. The sticks may be cut obliquely or at right angles to the axis, and planted vertically or at an angle, with half their length in the soil, or flat below the surface at a depth of about 10 cm. When sticks are planted vertically or inclined, tubers form only at the extreme end of the cut, forming a slanted cluster often of irregular size; when a stick is cut at right angles and planted vertically, the roots are evenly distributed around the circumference and are more uniform in size. Horizontally-planted sticks produce tubers at each node, but lodging of the aerial part is increased and yields reduced. With vertical or inclined planting the roots penetrate more deeply and tubers may be formed at intervals along the planted portion, but in areas of low rainfall desiccation of the cuttings may occur. After 8-12 weeks the plants are usually earthed up to encourage tuber formation.

In smallholdings cassava is frequently grown in mixed cultivations, eg among vegetables, bananas, yams or sweet potatoes, or intercropped with rubber and coconuts: it has been shown that financial gains can be made by certain mixed cultivation systems when compared with monoculture of cassava. When interplanted with coconuts a ground cover of the legume Stylosanthes sp. (stylo) has led to a substantial increase in yield.

Mechanisation of planting (and of the complete production system) is practiced on a large scale in Brazil, parts of Africa and elsewhere. Several types of machine have been developed or modified from vegetable planters: some plant the cuttings vertically or at an angle, others plant the cuttings horizontally in a trench which the machine then covers. The rate of planting can be up to 3-4 ha/day. Sprouting usually

takes place in about a week with only about a 5 per cent failure rate: new cuttings are substituted within a month.

Weed control is extremely important, the timing and frequency depending upon local conditions, but, assuming planting was in a clean field, the first weeding should normally be 2-3 weeks after sprouting, followed by three or four weedings during the following 4-6 months. Chemical control gives excellent results: pre-emergence application of, for example, linuron or diuron with subsequent application of shielded sprays of paraquat, has proved successful.

Field spacing - the plant density preferred varies greatly from country to country and within countries, and is affected by cultivar, soil conditions, local customs, and the use to which the roots will be put: a range of

between 3 000 and 20 000 plants/ha is quoted for cassava for direct eating (the closer spacing is used on the more infertile soils) but 7 000 to 10 000 plants/ha is the more usual range. If other factors remain constant, closer spacing gives higher yields but smaller roots, and is thus favoured for mechanical harvesting of tubers to be used for processing. In parts of Brazil, with certain cultivars, 30 000 plants/ha are used. High densities of planting, however, tend to encourage certain fungal diseases.

Seed rate - planting is usually at 90 cm intervals in rows 90-120 cm apart. With tows 120 cm apart and 90 cm spacing along the row, the plant density would be approximately 9,250/ha.

Pests and diseases

Pests - root knot nematodes (Meloidogyne spp.) are common but seldom of economic importance except when cassava is intercropped with good hosts for the nematode, eg egg plant (Solanum melongena) or Hibiscus sabdariffa. Pratylenchus sp., Helicotylenchus erythrinae, Rotylenchus reniformis and a few other species have been found in cassava but are considered of little importance.

A number of insects may cause defoliation. In Africa the grasshopper Zonocerus variegatus may be serious; control is by destruction of the egglaying sites or by fenitrothion. Cassava hornworm (Erinnyis ello) may attack the crop in the Americas and Caribbean; biological control is best, by Bacillus thuringiensis sprays, by the egg parasite Trichogromma fasciatum, or by the predatory wasp Polistes canadensis. Leaf cutting ants, Atta sp. and Acromyrmex sp., can cause severe

defoliation; poisoned bait is the recommended control. In South America the cassava lacebug (Vatiga manihotae) may cause early defoliation; fenitrothion will control the pest, but will not be economic unless the attack is severe. Among borers in South America, the shootflies, Silba pendula and Carpolonchaea chalybea, burrow into the growing point at the start of the rainy season; resistant cultivars are recommended. Control of larvae may be with diazinon, dimethoate or other chemicals. Stems may be attacked by the weevil borers, Coelosternus spp.; cutting off the infected branches is recommended for control. Scale insects are reported to cause damage especially in areas subject to drought. These include the cassava stem mussel scale (Aonidomytilus albus), the white peach scale (Pseudaulacaspis pentagona), and the black scale (Parasaissetia nigra); oil emulsion plus malathion is recommended for control. Spider mites, Mononychellus

tanajoa and Tetranychus cinnabarinus, sometimes affect the crop; mitetolerant cultivars have been developed and M. tanajoa is attacked by predaceous mites and staphylinid beetles, so that chemical control should not be necessary. However, control can be obtained by a number of acaricides. In some areas rodents, baboons, monkeys and wild pigs are reported to cause severe damage, and smallholders sometimes plant bitter cassava around their areas of sweet cassava to discourage such predators.

Diseases - cassava is subject to several virus diseases. In Africa, the most important is African mosaic or curly leaf disease (manihot virus), transmitted by a white fly (Bemisia sp.). No host plant is known for this virus. A virus producing similar effects, Asian mosaic, occurs in India; Cucumis sativus (cucumber) is reported to be a host. In northern South America another mosaic, also

causing chlorosis and leaf curl, has several hosts, eg other species of Manihot, some Chenopodiaceae and some Malvaceae. Recommended control measures include the removal and destruction of diseased plants, the use of healthy planting material of resistant cultivars, and the control of vectors and host plants where these are known.

Of the fungal diseases the most important are leaf spots caused by Cercospora henningsii and C. caribaea. These may be controlled by copper fungicides, thiophanate or benomyl, but chemical methods are unlikely to be economic and the use of resistant cultivars is recommended, and measures to reduce the humidity in the stand, eg wider spacing. Phyllosticra sp. also causes leaf-spotting; no specific control has been reported except the possible use of resistant material. Uromyces spp. cause rusts of leaves and stems but do not appear

to be of serious economic importance. Stem rots on stored planting material can cause loss of viability. Glomerella sp., Botryodiplodia theobromae and some Basidiomycetes and Ascomycetes are causative agents. Control involves careful selection and handling to avoid wounding, and storage under not excessively humid conditions. 'Seed treatment' fungicides, eg captan+carbendazim, mancozeb and chloroneb, are among those recommended. Root rots include those caused by Phytophthora spp., Rigidoporus lignosus (white rot, white thread), Rosellinia necatrix (black rot), Corticium rolfsii, and a number of others of lesser importance. Control is by cultural practices, including drainage, early harvest, crop rotation, the removal of crop debris, and planting of healthy material. The most important bacterial disease is cassava bacterial blight, caused by Xanthosoma manihotis, which appears as leaf spotting and blight, wilting, die-back, gum exudation

and vascular necrosis throughout the plant; resistant cultivars are available. Other bacterial diseases, but of less importance, are bacterial stem rot (Erwinia cassavae) and Agrobacterium sp. (bacterial stem gall).

A package of integrated pest control has been advocated for cassava. The first objective is to ensure healthy and resistant plants by good soil preparation and good drainage, the use of robust sticks taken from well-lignified stems, free from disease and undamaged, dipped in fungicide (captan + benomyl) before planting, correct planting practices, including wide spacing between plants, good weed control and fertilising. Weed control is important not only to avoid all competition with the crop, but also to avoid the appearance of plants that may be hosts to cassava pests. Disease- and pest-resistant cultivars should be used where possible. As monoculture is the usual practice different cultivars

should be planted together or in adjacent plots, to provide different degrees of susceptibility (or resistance) within the planted areas. Regular inspections should be made so that appropriate pest control may be applied at an early stage when necessary. Natural biological control is important and chemicals should be used only when absolutely necessary. After harvest all plant residues should be removed. Continuous planting of adjacent areas should be avoided as this gives the opportunity for pests to have uninterrupted access to plants at their most susceptible age.

Growth period

Generally cassava reaches maturity in 9-24 months, according to the cultivar, climate and soil conditions. A few quick-growing cultivars can be harvested in 6-7

months, but good yields are normally only obtained after 9-12 months. When used as a vegetable the tubers are normally harvested within 12 months, otherwise they become very fibrous.

Harvesting and handling

The exact time, in terms of months after planting, when the tubers are ready for harvesting depends very much on the cultivar and growth conditions. Delays in harvesting do not seriously affect tuber quality or yield. The plants are normally topped, ie the above ground parts removed by hand, using a machete, or by machine, eg pushed down by a heavy screen mounted on the front of a tractor. The roots may then be dug by hand, but machine harvesting is being increasingly employed. A number of devices are used, from simple 'ridge breakers' which expose the roots and leave them to be

picked up by hand, to relatively sophisticated equipment somewhat resembling potato harvesters. Damage to tubers is still a problem with mechanical harvesting, but smaller tubers are more easily lifted and less liable to damage. For this reason mechanical harvesting is particularly suitable for tubers to be used for processing, where small tubers are satisfactory, and a greater degree of damage can be tolerated.

After harvesting, cassava tubers deteriorate rapidly. There are two distinct types of deterioration which occur during storage, one physiological and the other due to microorganisms. Physiological deterioration, which begins to appear within three days, is essentially a humidity-sensitive wound response with increases in enzyme activity leading to the production of phenols including catechins and leucoanthocyanidins which in the later stages of discoloration polymerise to form

condensed tannins. Visible signs of discoloration are at first blue, becoming brown, and initially generally appear in the peripheral vascular bundles and spread to adjacent parenchyma. Physiological deterioration appears to be connected with enzyme activity and some measure of control has been obtained by holding the roots at low temperature, or storing in air with low oxygen levels or in carbon dioxide. Mechanical damage to the roots also permits the entry of microorganisms, causing rapidly-spreading internal rotting. Storage under conditions that favour wound healing, such as packing in moisture-absorbent material, has been reported to minimise physiological deterioration and invasion by pathogens to give a storage life of 4 or more weeks. Pre-pruning of aerial portions of the plant 2-3 weeks before harvesting has also been shown to minimise physiological deterioration in the tubers Coating with a fungicidal wax is stated to extend the

storage life up to 1-2 months under ambient conditions in the tropics, while holding undamaged tubers at 0-2°C and 85-90 per cent RH is reported as satisfactory for periods of about 4 weeks.

Primary product

Tubers - these are dark coloured, fleshy and cylindrical, varying a great deal in size and form, with a starch content of 20-40 per cent. Each plant normally yields 5-10 tubers, usually 30-45 cm long, with a diameter of 5-15 cm and weighing 0.9-2.3 kg. The peel accounts for 10-20 per cent of the tuber and consists of an outer corky rind and an inner part which separates the peel from the flesh of the roots.

Yield

Yields vary greatly according to cultivar, soil, climate, age at harvesting, etc. Average yields in t/ha for 1984 were quoted as follows: world 9.1; Central America and the Caribbean 5.6; Africa 6.8; Oceania 10.7; South America 11.6; Asia 12. Of the major producers Thailand had the highest average yield, 15 t/ha, though a very minor producer, the Cook Islands, is reported to have averaged 32.5 t/ha. In fact average yields on a world basis changed little during the decade 1974-84; that for 1974-76 was 8.8 t/ha and for 1984 the figure was 9.1. Yields of smallholdings normally range from 5 to 15 t/ha under normal conditions but can drop to 3 t/ha on poor soils without fertilisation. On plantations yields of 30-40 t/ha are normal and with selected high-yielding cultivars can exceed 50 t/ha. Under poor soil conditions appropriate fertilising can triple or quadruple yields.

Main use

Cassava is the staple food of the poorer section of the population of many tropical countries, and has been estimated to provide 37, 12 and 7 per cent of the energy in the diet of the tropical areas of Africa, America and Asia respectively. The fresh peeled tubers are eaten as a vegetable after boiling or roasting. They are often boiled and pounded into a paste and added to soups and stews ('fufu' in Nigeria). As the fresh tubers deteriorate rapidly they are often preserved in the form of sun-dried chips ('kokonte' in West Africa) and consumed after cooking or being ground into a flour. The principal form in which cassava is eaten in West Africa is as a fermented meal known as 'gari', while in Central and South America a product, 'farinha de manioca' which is similar to 'gari' except that much less fermentation occurs during its preparation, is very popular. In the Philippines 'landang' or 'cassava rice' is prepared and retains much of the original small quantity of protein.

Subsidiary uses

Starch - a substantial industrial outlet for cassava is in the manufacture of starch for use in the foodstuff, textile and paper industries, the manufacture of plywood and veneer, adhesives, glucose and dextrin. Minor industrial applications include use in the manufacture of explosives, dyes, drugs, chemicals, carpets and linoleum, the production of alcohol and the coagulation of rubber latex.

Dried cassava roots - increasing quantities of dried cassava roots are being used for livestock feeding, particularly in the EC countries. Formerly, they entered international trade in the form of chips, made by slicing the roots and then sun drying, but these have almost completely been supplanted by pellets made by grinding the dried chips and compressing the powder into

portions approximately 2 cm long and I cm in diameter. These pellets are used as a carbohydrate source in animal feed rations, particularly for pigs

Tapioca - made from cassava starch and used for the preparation of puddings and in infant and invalid foods. In Thailand tapioca is known as sago, which can lead to confusion with true sago starch obtained from the sago palm, Metroxylon sagu.

Cassava flour - the flour is used in the preparation of bread, biscuits and confectionery and in products such as macaroni, spaghetti and rice substitutes, also as an adulterant of cereal flour and in the production of adhesives.

Glucose - which is produced from cassava in Kerala (southern India).

Secondary and waste products

Cassava meal - about 10-20 per cent residue is left after the extraction of starch and tapioca, and this can be used as a livestock feed, or as a raw material for the production of adhesives. The approximate composition (dry matter) is: protein 5.3 per cent; fat 0.1 per cent; starch 56 per cent; fibre 35.9 per cent; ash 2.7 per cent.

Leaves - young leaves are eaten in some areas of Africa as a vegetable. Mature leaves, which have a protein content of 5-7 per cent, can be used for animal feeding and are sometimes dried and ground into a meal. They have a high lysine content.

Stems - the possibility of utilising cassava stems for the manufacture of particle board has recently been investigated.

Juice - the juice expressed from the tubers during starch production is sometimes concentrated and spices added to obtain a sauce, known as 'cassari po' or 'cassareep' in the West Indies and 'tucupi' in Brazil.
Miscellaneous - the tubers may be stored as silage and used for animal feeding. In some countries fermented beers are prepared on a small scale. In Brazil, alcohol has been produced directly from cassava roots, through malt saccharification and immediate fermentation, but cane sugar alcohol can now be produced more cheaply.

Special features

The typical range of composition for the edible portion of the tubers is: energy 607 kJ/100 g; water 62-65 per cent; protein 0.7-2.6 per cent; fat 0.2-0.5 per cent; total carbohydrate 32-35 per cent; fibre 0.8-1.3 per cent; ash 0.3-1.3 per cent; calcium 33 mg/100 g; iron 0.7 mg/100

g; thiamine 0.06 mg/100 g; riboflavin 0.03 mg/lOOg; niacin 0.6 mg/100 g; ascorbic acid 20-30 mg/100 g; vitamin B 10 IU/100 g.

The principal amino acids present in the protein are arginine, histidine, isoleucine, leucine and Iysine. Owing to the low protein content the disease Kwashiorkor is prevalent in areas where cassava is the main staple item of diet. A method of enriching the protein by innoculation of cassava flour paste with Rhizopus or other suitable fungi has recently been developed and the protein content can be increased to about 3.25 per cent.

Cassava roots contain the glycoside linamarin which is converted into HCN by the enzyme linamarase. HCN contents can vary from 10 to 490 mg/kg, being highest in roots grown on soils of low fertility, particularly if there is a potassium deficiency, and also in the first

year's growth and in the dry season. It is usually highest in the rind and in the fibrous core at the centre, but considerable variation can occur between various parts of the same tuber. For edible purposes cultivars with a high starch and protein content and a low HCN content are preferred. For starch manufacture cultivars with a high starch content are favoured and HCN content is of less importance. As all cultivars contain some cyanogenic glycoside all are toxic in some degree and 'chronic cassava toxicity' is recognised in populations in which cassava is a major portion of the diet, particularly in Africa, as goitre and tropical ataxic neuropathy. In severe cases cassava can cause respiratory difficulties and occasionally death. Detoxification of bitter cassava is normally practiced. Peeling and cooking gives a partial detoxification, but soaking of roots for long periods, repeated boiling in changes of water, soaking after comminution, and fermentation or fermentation

followed by heat treatment, are all used. However, there appears to be no evidence that animals develop toxicity symptoms from continuous intake of cassava or cassava forage.

Cassava starch granules are of various shapes, round, truncated, etc, and vary in size from 5 to 35 microns (average 15-17 microns). The amylose content is about 17 per cent compared with 22 per cent for potato starch and 27 per cent for maize starch. The approximate composition of commercial samples is: moisture 9-18 per cent; protein 0.31-1 per cent; fat 0.1-0.4 per cent; starch (and a little fibre, etc) 81-89 per cent; ash 0.1-0.8 per cent. Good quality starch should be absolutely free from specks and have a pure white colour, a pH of 4.7-5.3, a moisture content of 10-13.5 per cent, and an ash content of less than 0.2 per cent.

Processing

Starch production

(i) The mature roots are first washed to remove dirt and loose soil.

(ii) In small-scale operations the roots are then peeled by hand to remove the skin and cortex; on a factory scale only the outer skin is removed, since when processing large quantities of roots it becomes economic to recover the starch from the cortex although it only contains about 50 per cent of that in the core of the root.

(iii) The roots are next sliced and put through a rasping or grating machine to produce a slurry or pulp.

(iv) The slurry is then sieved to separate the fibrous

tissue from the starch milk; considerable quantities of clean water are used at this stage in order to ensure efficient separation of the starch granules from the slurry.

(v) The starch milk is collected and left in settling tanks for at least 6 hours, when the starch sinks to the bottom and the liquid is drained away.

(vi) The surface layer of the starch mass is usually a yellowish-green colour and contains impurities and is therefore scraped off, leaving a creamy-white mass below, which is stirred vigorously with water and then left to settle. This washing and settling process is repeated once or twice more until the starch is judged to be sufficiently pure.

(vii) The starch cake is dried, either by spreading it out

in trays in the sun or in factories in hot-air driers.

(viii) Finally, the hard lumps of starch are crushed into a powder and sieved.

It should be pointed out that, because the cells of cassava roots are relatively tough, the grinding process must be efficient in order to liberate all the starch granules and to obtain a commercial extraction rate of approximately 20-25 per cent of the raw material.

Tapioca - tapioca consists of pieces of partially-gelatinised cassava starch and can be prepared in the form of flakes, seeds and pearls. In the preparation of tapioca flakes, the moist starch, prepared as above, is rubbed through a sieve of about 8 mesh/cm to give a coarse ground moist flour, and partially gelatinised by cooking for about 2 minutes in iron pans previously

smeared with oil. The flakes of tapioca are then dried at about 50°C to a moisture content of approximately 12 per cent. In the preparation of tapioca seeds or pearls, the sieved damp starch is made into globules by shaking in cloth bags or by the use of mechanically-operated granulators. The globules are then graded according to size and gelatinised by roasting them for about 15 minutes in hot pans smeared with coconut oil. They are finally dried in a hot-air drier at 40-50°C for about 1.5-2 hours; the yield of tapioca from fresh tubers is usually about 25 per cent.

Production and trade

Production - world output increased on average 2 per cent/a for the period 1974-84, reaching nearly 129 million tonnes of roots (corresponding to about 46 million tonnes of grain equivalent). The largest

increases were in Laos, Thailand, the Philippines and Vietnam, but Brazil showed a decline. A slight fall in 1982 was mainly the result of lower production from Thailand. In Africa, supplies still fell short of the food requirements of the population. In the Far East consumption increased in China, Indonesia and the Philippines. World wide, about 65 per cent of the production is consumed direct as human food and about 30 per cent is consumed or processed as animal feed, of which about half is exported (see next section). About 4 per cent is converted into starch and other industrial products and rather less than I per cent into ethanol, mostly in Brazil.

For production data in the more important producing countries see Table 1.

Trade - because fresh cassava deteriorates rapidly only

a very small quantity of fresh roots is traded internationally, mainly to immigrant populations. However, substantial quantities of processed roots (chips and pellets) and cassava starch are traded; world trade in 1981 is estimated to have exceeded 17 million tonnes in root equivalent, compared with 14.7 million tonnes in 1980. Tables 2 and 3 show gross imports and exports for the major cassava trading countries. Exports from China, Indonesia and Thailand rose substantially, with Thailand providing nearly all the 5.5 million tonnes to the EC permitted by a 'voluntary' agreement which reduces this quota to 5 million tonnes for 1983 and 1984, and 4.5 million tonnes for 1985 and 1986. With present EC policies, the market for cassava as animal feed seems unlikely to develop further, nor does there appear to be much likelihood of increased demand elsewhere: 1981 may represent a peak year for trade in this commodity, with relative stability or a slight decline

in the forseeable future.

Only about 4 per cent of world starch production moves in trade and most of this is cassava starch: the major importers are Japan, the USA and Taiwan. However, in the USA home-produced maize starch is taking the place of cassava starch and in Japan the domestic starch industry is highly protected by quotas and tariffs, with the result that there has been a decline in imports of cassava starch in these countries. Only in Taiwan has there been an increase. Table 4 shows production of cassava starch and

Table 5 imports by by the importing countries It is believed that in developed countries the decline in demand will continue and that while, for a time, demand in developing countries may increase, locally-produced starches will eventually reduce imports.

	Area harvested ('000 ha)			Production ('000 t)		
	1974–76 average	1983	1984	1974–75 average	1983	1984
World	12 207	13 489	14 151	107 679	123 048	129 020
Africa	6 438	7 191	7 462	43 300	48 593	51 002
Angola	121	130	130	1 710	1 950	1 950
Ghana	253	210	250	1 773	1 729	1 900
Mozambique	533	500	550	2 600	3 150	3 150
Nigeria	1 043	1 150	1 250	10 467	9 950	11 800
Tanzania	707	450	450	5 053	5 400	5 600
Zaire	1 687	2 086	2 150	11 734	14 600	4 800
South America	2 549	2 500	2 311	30 587	26 873	26 861
Brazil	2 047	2 023	1 817	25 453	21 559	21 275
Colombia	247	207	210	1 998	2 000	2 100
Asia	3 048	3 615	4 171	32 713	46 450	50 000
China	197	252	252	2 416	3 880	4 057
India	383	302	305	6 462	5 341	5 800
Indonesia	1 474	1 247	1 476	12 589	12 229	14 000
Thailand	538	1 018	1 335	7 855	18 989	19 985
All developing countries	12 207	13 489	14 151	107 679	123 048	129 020

Source: FAO Production Yearbook 1984.

Table 1: Cassava: Area and production in selected countries

	1976–78 average	1979	1980	1981
World	13 338	14 612	14 662	17 355
Africa	90	209	183	70
Malawi	6	7	7	7
Tanzania	46	182	156	50
Togo	14	1	1	1
Latin America	31	72	50	35
Brazil	9	49	30	20
Asia	13 211	14 331	14 429	17 250
China	37	250	950	1 050
India	46	na	12	10
Indonesia	564	1 931	1 090	1 200
Malaysia	125	47	47	40
Thailand	12 420	12 071	12 250	14 900

na not available.

Table 2: Cassava: Exports from selected countries ('000 t root equivalent)

	1976–78 average	1979	1980	1981
World	13 108	14 705	14 540	17 357
Africa	1	1	1	1
Latin America	3	4	1	1
Korea	31	na	na	na
Singapore	63	50	62	60
Other Asian countries	252	239	228	440
USA	193	164	139	125
Other North American countries	10	5	7	5
EC	12 058	13 740	12 589	15 100
Other Western European countries	3	28	24	25
Eastern Europe and Soviet Union	na	60	1 100	1 200
Japan	494	414	399	400
All developed countries	12 758	14 411	14 248	16 855
All developing countries	350	294	292	502

Table 3: Cassava: Imports by selected countries ('000 t root equivalent)

North America and Japan take most of their cassava imports in the form of starch and tapioca; pellets for

animal feed predominate in the European and Soviet Union imports. na not available.

Latin America and Caribbean	Early 1970s	111
Argentina		3
Brazil	Early 1970s	75
Colombia		6
Costa Rica	Early 1970s	5
Dominican Republic	Early 1970s	5
Mexico	Early 1970s	3
Paraguay	Early 1970s	8
Venezuela	Early 1970s	10
Africa		
Kenya		<1
Asia		
Indonesia	1979	661
Malaysia	1978	70
Philippines	1977	17
Taiwan	1980	15
Thailand	Late 1970s	400

Source: Jones, 1983.
< less than

Table 4: Cassava starch: Production in selected areas ('000 t)

	1976	1977	1978	1979	1980	1981
Japan	82	94	91	69	67	79
USA	40	38	35	30	28	36
Taiwan	11	33	62	43	76	na

Source: Walters, 1983.
na = not available.

Table 5: Cassava starch: Imports to major markets ('000 t)

Major influences

Cassava produces more starch per hectare under relatively dry conditions than any other known crop. Production is likely to increase in semi-arid areas of the tropics, especially where the land is level and machinery can be used, and it may replace to some extent yams, aroids and sweet potatoes in local diets. Increasing urbanisation in the tropics is likely to lead to an increase in plantation production particularly where there is a need to supply local processing units. This will result in

the increasing mechanisation of crop production, although mechanical harvesting still poses problems.

The overall prospects for any significant increase in international trade in cassava products is limited at present price levels. Any future increase in cassava production will therefore need to be utilised primarily in the producing countries themselves.

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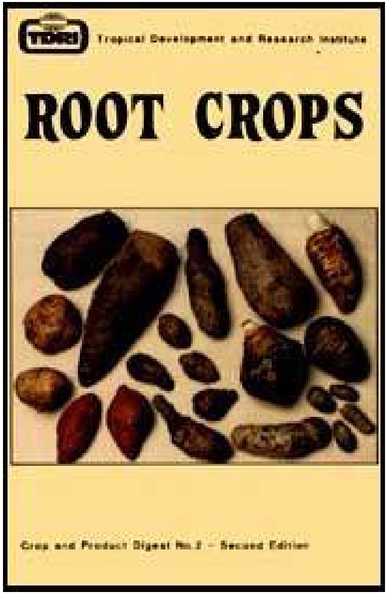
TDRI
Tropical Development and Research Institute
ROOT CROPS
Crop and Product Digest No.2 – Second Edition

- **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)**
- **Topee tambo (Calathea allouia)**
- **Ullucu (Ullucus tuberosus)**

Chavar (Hitchenia caulina)

Common name

CHAVAR

Botanical name

Hitchenia caulina (Grah.) Baker syn. Curcuma caulina (Grah.).

Family

Zingiberaceae.

Other names

Arrowroot lily, Chowar, Indian arrowroot'.

Botany

A tuberous herb with a leafy stem, 0.9-1.2 m high, with oblong-lanceolate, fibrous leaves 30-50 cm long and 7.5-10 cm broad. The yellow flowers, which possess a long peduncle, are borne on a central spike.

Origin and distribution

The plant is native to India and is found mainly growing wild on the table land of the Mahabaleshwar plateau and

neighbouring regions in forest areas with high annual rainfall.

Cultivation conditions

Hot moist conditions are essential: rainfall of upwards of 500 cm per annum characterises its natural habitat, though it may be grown on the banks of irrigation canals.

Planting procedure

Chavar is easily propagated by tuber cuttings, which are planted in raked soil at the beginning of the monsoon, frequently in arecanut plantations and on the banks of rivers and irrigation channels. It is often planted very densely to prevent soil erosion, in some areas up to 50 000 plants per hectare.

Growth period

For maximum yields of starch a 2 year rotation should be practiced and the tubers harvested when they are 20-24 months old.

Harvesting and handling

The tubers are dug by hand.

Primary product

Tubers - these are normally the size of an orange with white flesh and covered with fibrous roots.

Main use

The tubers yield a white edible starch, which has sometimes been used as a substitute for arrowroot

starch.

Secondary and waste products

It has been suggested that the leaves could be used for papermaking.

Special features

The tubers have a starch content of 10.9-18.3 per cent (fresh weight basis). On average the tubers yield about 13 per cent of starch, 60 per cent of which is of superior quality and very similar to that of arrowroot.

Processing

The harvested tubers are washed and the fibrous roots removed, after which the cleaned tubers are grated and the resultant pulp washed thoroughly, sieved and then

re-washed, and the starch allowed to settle out. It is then sun-dried.

Major influences

Although formerly used locally as a source of 'arrowroot starch', nowadays it is not normally economic to prepare starch commercially from chavar, but the crop can yield a high quality starch, and it could be of value in high rainforest areas to prevent soil erosion.

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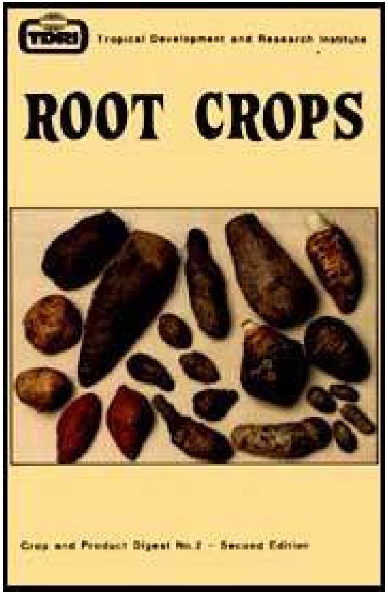

macrorrhiza)

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

Chinese water chestnut (Eleocharis dulcis)

Common names

CHINESE WATER CHESTNUT, Matai, Waternut.

Botanical name

Eleocharis dulcis (Burm. f.) Trin. Ex Hensch. var. tuberosa (Schult.) Koyama syn. E. tuberosa Schult.

Family

Cyperaceae.

Other names

Aplid, Buslig (Philipp.); Cabezas de negrito (Sp.); Chtaigne d'eau (Fr.); Chikai, Dekang (Indon.); Kalangub (Philipp.); Kohekohe (Haw.); Mati (China); Nilaga (Philipp.); O-kuroguwai (Japan); O-yu, Peci (China);

Pipi-wai (Haw.); Pi't'si (China); Potok (Philipp.); Po-tsai (China); Sibosibolasan (Philipp.); Tek, Teki-tik (Indon.); Wu-yu (China).

Botany

A variable, annual, stout, tufted, aquatic, sedge plant, characterised by its lack of leaves, their photosynthetic activity having been transferred to the numerous upright tubular septate stems, 50-100 per plant, which normally reach a height of 0.9-1.5 m. Inflorescences containing about 50 insignificant flowers are produced at the top of these stems. The female (pistillate) flowers appear when the stem tips reach 15 cm above the water and are followed later by the male (staminate) flowers. Tiny 'seeds', in fact achenes, are produced but are of no economic importance. Two types of subterranean rhizomes are produced. Rhizomes spread from the base

of the plant: the first appear 6-8 weeks after planting, grow horizontally under the surface of the soil, and then turn upwards to form suckers and ultimately daughter plants; others, starting somewhat later, bend down and produce corms at the tip (one per rhizome), about 12 cm below the soil surface. The young corms are white, becoming scaly and brown when mature, subglobose, somewhat flattened, 1-4 cm across.

Two very distinct forms of E. dulcis are recognised. One is a wild form, which generally grows in stagnant water, produces very small, very dark skinned, almost black secondary corms and is sometimes referred to in the literature as E. plantaginea or E. plantaginoides. The second form occurs only under cultivation and produces larger, sweeter, secondary corms and was originally described as a separate species. E. tuberosa.

Origin and distribution

Eleocharis dulcis grows wild in many parts of India, South-East Asia and Polynesia. It was first cultivated in South-East China in humid monsoon areas and is now also grown commercially in Japan, Hong Kong, the Philippines, Hawaii and other Pacific islands, India and the southern USA.

Cultivation conditions

Temperature - a long warm growing season is required, with at least 220 frost-free days, and a soil temperature of 14-15.5°C is necessary for germination of the corms.

Rainfall - the plant is aquatic and thrives in areas where there are well-controlled irrigation facilities giving a continuous supply of water throughout the year.

Soils - for optimum yields a rich clay or peaty soil with a pH of 6.9-7.3 is required; slightly more acid soils may be successfully neutralised with limestone. It has been shown that this crop has a high uptake of certain nutrients; in experiments in which corm production was approximately 4 700 kg/ha the uptake in kg/ha was nitrogen 108, calcium 6.9, magnesium 37.5, though requirements for phosphorus and potassium are relatively low. In the USA the application of a high grade complete fertiliser (including magnesium) at a total rate of 2.5 t/ha, one third or one half before planting, another third 8-10 weeks after planting, and the balance just prior to the development of the corms, has been recommended.

Altitude - the crop may be grown at altitudes from sea level up to 1 200 m.

Planting procedure

Material - small corms are used.

Method - the corms may be planted directly into the field or, usually in the more temperate climates, started in protected nursery beds and hand transplanted when the top growth is 20-30 cm high. If planted direct in the field, the corms are planted in rows in holes 10-12.5 cm deep. This is often done manually with a hand trowel, but in larger plantings in the USA, the furrows are opened with a plough or courter and the corms dropped in at intervals of 75 cm and then covered with a covering plough or hiller. After planting the fields are flooded for 24 hours and then allowed to drain naturally; as soon as top growth reaches 20-30 cm the fields are again flooded and the water level kept to at least 10-12.5 cm throughout the growing season. Weeds are not

usually a problem provided the soil has been well-tilled just before planting. In the USA the use of preemergence herbicides has been tried with success: 2,4-D amine at 1.9 kg/ha gave good weed control and was effective for 3 months.

Field spacing - in the USA a spacing of 75 x 75 cm has been recommended. In China a triangular spacing of 45-60 cm and 45 cm between plants is common practice.

Seed rate - approximately 500 kg of corms are used to plant one hectare.

Pests and diseases

Chinese water chestnuts are not normally subject to serious attacks from pests and diseases, though when grown on acid soils, ph 5.5, the plants may be attacked

by a stem fungus, Cylindrosporium spp. In Florida, the most serious insect pest is the billbug, Calendra cariosa, and the crop is also attacked by a stem nematode, Ditylenchus spp. and by the awl nematode, Dolichodorus heterocephalus. In the Philippines, the crop is sometimes attacked by a grasshopper, Aiolopus thalassinus, but this pest has been effectively controlled by spraying with 2 per cent aldrin. Rodents, especially rats, can cause considerable crop losses at harvest, unless effectively controlled.

Growth period

Chinese water chestnuts require a long warm growing season and the corms usually reach maturity in about 7-8 months; in many areas of China this is after the first frost has killed the green culms.

Harvesting and handling

Harvesting normally takes place after the culms have turned brown or been killed off by frost and by this time the corms have acquired a characteristic deep chestnut-brown colour. In most areas irrigation is stopped at least 3-4 weeks before harvest so that the ground dries, and the corms are carefully dug out by hand to avoid bruising. In the USA, in the harvesting of small plots, the soil is carefully lifted on to a 0.9 cm wire mesh screen and worked over with rubber pads or paddles, when about 98 per cent of the corms are left on the screen. These are picked off and dropped into water to clean them. In larger plantings a small plough is used which turns a furrow to a depth of approximately 15 cm. The furrow is then raked with a potato rake having rubber-covered prongs. The corms are carefully picked out by hand, washed thoroughly, and all damaged ones

removed before they are air-dried, preferably in the shade. Harvesting may be delayed, since the corms do not deteriorate in the soil provided that there are no severe frosts.

In the USA commercial supplies of the dried corms are usually packed in 64-litre moisture-proof containers, which are sealed but not airtight. They can be kept satisfactorily at temperatures between -1 and 4°C for up to 6 months; at a temperature of about 14°C sprouting occurs.

Primary product

Corms - the edible starchy corms have a dark chestnut-brown coloured outer skin and are usually rounded or onion-shaped and from I to 4 cm in diameter. The wild forms are usually the smallest and in general only corms

3 cm or more in diameter are commercially acceptable. The flesh is crisp and white with a characteristic flavour.

Yield

Yields in China are reported to average 20-40 t/ha and in the USA 28 t/ha.

Main use

Chinese water chestnuts are eaten as a vegetable either fresh or cooked and are an important ingredient of many Chinese food dishes. They are said to smell like sweet corn when boiled.

Subsidiary uses

Certain cultivars are sometimes used for the preparation of starch, while very small corms are useful for poultry

feed.

Secondary and waste products

In China the corms are used in traditional medicine. The dry stems can be used for cattle feed, mulching, as a packing material for horticultural products and for making baskets, mats, etc.

Special features

The corms show considerable variation in composition; an approximate analysis of the edible portion of fresh Chinese corms has been given as: moisture 77.29 per cent; protein 1.53 per cent; fat 0.15 per cent; nitrogen-free extract 18.9 per cent; reducing sugars 1.94 per cent; sucrose 6.35 per cent; starch 7.34 per cent; fibre 0.94 per cent; ash 1.19 per cent; calcium 2-10 mg/100

g; iron 0.43-0.6 mg/100 g; phosphorus 52.2-65 mg/100 g; thiamine 0.24 mg/100 g; riboflavin 0.007 mg/100 g; niacin 0.94 mg/100 g; ascorbic acid 9.2 mg/100 g.

The starch is similar to that obtained from sweet potatoes or cassava and has large grains up to 27 microns in length which may be rounded, have regular geometric shapes or be completely irregular. The juice extracted from the corms has been shown to contain an antibiotic principle, designated puchiin.

Processing

Canning - the corms are first washed and peeled, usually by hand, and then processed in a manner similar to potatoes. The recommended processing times are 30 minutes for No. 2 cans, 35 minutes for No. 2 1/2 and 45 minutes for No. 10 at 115°C, after an initial heating

before sealing to 60°C.

Quick freezing - the washed, peeled corms are blanched for 4 minutes in steam at 99-100°C in single layers on wire mesh trays; they are then cooled immediately in an air-blast, packed into cans and frozen in a blast freezer at - 32°C then held at - 18°C for periods up to 12 months.

Starch - in China starch is sometimes extracted from the corms by a very primitive method. The corms are washed, then crushed, and the resultant starchy mass put in a fine bamboo basket which is set in a filter cloth and hung over a wood fire. The basket is then placed in a pan, water added, and the contents thoroughly stirred for 15 minutes. Three parts of starch milk are collected; the first contains the largest proportion of starch and is set aside to allow the starch to separate out, the rest of

the starch milk being re-used to wash more pulp. After about 5 hours the starch has separated out and is collected and dried in the sun on bamboo trays.

Production and trade

There is considerable trade in Chinese water chestnuts in Asia, and prior to the embargo on imports from China into the USA shipments averaged about I 000 tonnes a year. These have been partially replaced by domestic production in the southern states, eg Florida, but the demand is reported to be increasing.

Major influences

There is a growing demand for this speciality foodstuff, particularly in the USA, but the high cost of manual harvesting and the fact that the corms must be stored at

low temperature to suppress sprouting are factors handicapping the commercial development of the Chinese water chestnut. It has been stated to be one of the more important crops that will thrive under Philippine conditions and is cultivated on a large scale in Laguna and Mindro (Luzon) and in Davon (Mindanao).

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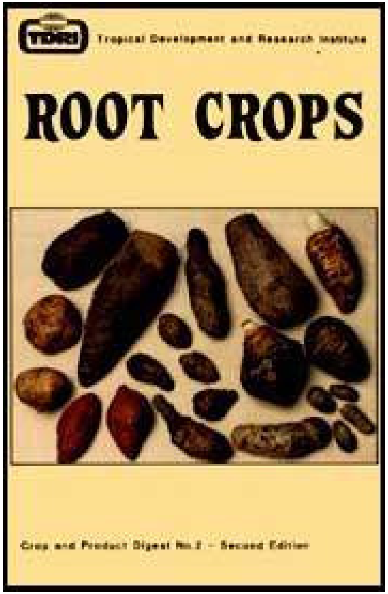
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spp.)

- **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

Chufa (Cyperus esculentus)

Common names

CHUFA, Earth nut, Tiger nut, Yellow nutsedge

Botanical name

Cyperus esculentus L.

Family

Cyperaceae.

Other names

Amande de terre (Fr.); Aya (Nig.); Chichoda (Ind.);

Earth or ground almond, Enensa (Nig.); Erdmandel (Ger.); Imumu (Nig.); Kaseru (Ind.); Motha (Beng.); Omu (Nig.); Rush nut; Souchet comestible (Fr.); Zulu nut.

Botany

An erect perennial, grass-like sedge, usually 30-90 cm high, with long narrow dark-green leaves arranged in three rows around the triangular stem. The plant develops as a series of shoots, bulbs and stem tubers connected by brown wiry rhizomes which are strengthened by lignification of the inner cortex. Tubers are small, 1-2 cm in diameter, and are borne at intervals along the rhizomes. Basal bulbs grow from rhizome tips, producing shoot growth and new plants. The plant, when growing wild, is extremely difficult to eradicate and is stated to be the fifteenth worst weed in the

world.

Origin and distribution

Chufa is thought to have originated in the Mediterranean area and western Asia but has spread (mainly as a weed) to many parts of the world. It will grow in a very wide range of climatic conditions, and occurs in the tropics, subtropics and warm temperate regions and is cultivated in several countries.

Cultivation conditions

Temperature - although the plant can be grown in relatively cool climates, optimum yields are obtained with moderately high temperatures throughout the growing season.

Rainfall - a moderate well-distributed rainfall is required

for optimum yields. Although chufas are fairly drought resistant, commercial crops receive copious and repeated irrigation during the dry summer season (eg in Valencia, Spain) in order to ensure maximum yields.

Soil - maximum yield is obtained in light sandy loams of pH 5.5-6.5, but chufas can be grown on any well-drained soil. Alluvial sands containing relatively high quantities of manganese, sulphur, calcium, magnesium and boron are particularly suitable. They can be grown on saline soils in coastal areas and are of use in reclaiming such areas. There is little information on the precise fertiliser requirements of chufas but nitrogen is often limiting under natural conditions. The application of a 6:6:8 complete (NPK) fertiliser at the rate of I 000 kg/ha has been recommended. In many areas growers give a heavy dressing of FYM, if available, and wood ash, before or immediately after planting. In Florida,

however, the crop has been found to respond very erratically to applications of fertilisers.

Planting procedure

Material - tubers are used for propagation.

Method - the tubers are soaked in water for 24-36 hours and then planted, either by hand or drill. Sprouting can be stimulated by treatment with ethylene at 3-10 ppm in air or by ethephon (ethrel) at 10-100 ppm in water.

Field spacing - spacing is extremely variable according to the soil conditions, local cultural methods and the purpose for which the crop is grown. Reports from Florida indicate that when grown for pig feed, chufas are usually drilled in rows 60-90 cm apart, with either 30 cm or 15 cm between the plants. Reports from other

countries refer to tubers frequently being planted at 10 cm intervals along rows 60 cm apart. With spacing in the row of 10x60 cm a single tuber is placed in a hole and covered with 2.5-4 cm of soil, with IS x 60 cm spacing two tubers are used and at 30 x 60 cm, four tubers are used.

Seed rate - chufa tubers vary in size so that it is difficult to give even an approximate seeding rate; 16-22 kg/ha has been reported but calculations suggest that over 500 kg may be required when spacing is close and medium-sized tubers are used.

Pests and diseases

In Florida the negro bug, Thyreocoris pulicaria, has been reported to damage the crop; the larvae develop inside the tubers. Proper crop rotation is the best means of

control. Chufas are seldom seriously affected by diseases.

Growth period

Chufas normally take 3-4 months to reach maturity.

Harvesting and handling

The tubers are ready for harvesting when the plants begin to die back; they are usually dug by hand or by running a small lifting plough under them. In Florida groundnut harvesters are sometimes used. The entire plant is laid on the soil and allowed to dry for 1-3 days before the tubers are separated for storage in thin layers in sheds. Tubers for human consumption are washed in running water and then dried either in the sun or artificially, after which they are graded and

stored.

Primary product

Tubers - tubers are normally 1.5-2 cm in length, with a maximum diameter of approximately 1-2 cm. They have very thin skins and the flesh is slightly yellowish-white in newly-formed tubers, but darkens with increasing maturity; the flavour is sweet and nutty.

Yield

**On sandy soils the yields of tubers are reported to average 800-900 kg/ha, although in Spain, with large-scale cultivation, yields as high as 8 000
14 000 kg/ha are reported.**

Main use

The tubers are used as a foodstuff, particularly in Africa, where they are an important food crop with certain tribes. They may be eaten raw, baked as a vegetable, roasted like groundnuts or grated and used to make icecream, sherbets or a milky beverage which is known as 'horchata' in Spain and Latin American countries. In Spain the major proportion of the crop (approximately 1000 t) is used in this manner, and horchata continues to be a popular beverage, in spite of severe competition from carbonated drinks.

Subsidiary uses

Animal feeding - chufas can be used for animal feed and are grown as pig feed in parts of the southern USA.

Confectionery - chufas are sometimes used in certain types of confectionery, often as a substitute for

almonds.

Coffee and cocoa adulterant - the ground tubers are sometimes used as a substitute or adulterant of coffee and cocoa.

Secondary and waste products

Oil - the tubers contain 20-28 per cent of a yellow non-drying pleasantly flavoured oil, similar to olive or sweet almond oil. It is used in Spain and Italy for culinary purposes and for the manufacture of soap.

Starch - chufa tubers are potentially a rich source of starch which may be extracted after the oil has been removed from the tubers.

Flour - the tubers can be ground to produce a nutritious flour, which can be used mixed with wheat flour in

baking. It has the following composition: protein 3.4 per cent; fat 27 per cent; starch 38 per cent; ash 2.5 per cent.

Alcohol - chufa tubers can be used for the production of alcohol by fermentation. In Sicily, a cultivar with a very high sucrose content is grown and used commercially for this purpose.

Leaves - it has been suggested that the leaves of the chufa could be utilised for papermaking; simple digestion with soda lye will give a yield of 35-40 per cent of a deep-yellow coloured pulp.

Special features

Tubers - chufa tubers are rich in both starch and oil. They are variable in composition: the dry matter of fresh

tubers is from about 70 per cent to about 90 per cent. Average analytical figures of the dry matter have been quoted as: residual moisture 9.3 per cent; protein 8.6 per cent; fat 21.8 per cent; carbohydrate 48 per cent; ash 1.7 per cent; magnesium 0.1 mg/100 g; phosphorus 211.5 mg/100 g; potassium 0.5 mg/100 g.

The carbohydrate consists of 33.4 g starch and 14.6 g total sugars. Quinones occur and have been used as an aid to the classification of the genus Cyperus.

Starch - chufa starch has the following approximate composition: moisture 9 per cent; nitrogenous material 0.3 per cent, fat traces; starch 89.8 per cent; cellulose 0.3 per cent; ash 0.5 per cent. It is a white flavourless product and when heated in water forms a transparent gelatinous paste.

Oil - the oil has the following characteristics: SG (15°C) 0.917-0.924; ND (20°C) 1.4680; sap. val. 190-194; iod. val. 74-89; acetyl val. 4.5-12; RM val. 0.2; Poll val. 0.3; unsap. 0.6 per cent. The oil consists of 17-18 per cent saturated acids of which 12 per cent is palmitic and 5 per cent stearic; of the unsaturated fatty acids present, 75 per cent is oleic acid and 6 per cent linoleic, though this varies to some extent with growing conditions and from cooler areas the proportions have been reported as 67.5 per cent and 15.2 per cent respectively, with a corresponding increase in the iodine value. Chufa oil is resistant to oxidative changes and it has been suggested that it could be added to oils such as coconut oil to retard rancidity.

Processing

Horchata, the milky white beverage, is prepared as

follows:

(i) The tubers are left to soak in water for 12 hours and then thoroughly washed to remove adhering soil, etc.

(ii) The clean swollen tubers are ground in a crusher and the resultant paste stirred with water and passed through a 25 mesh sieve.

(iii) The residues left on the sieve are stirred with water twice more and the milky liquid obtained added to that from (ii).

(iv) The liquids from (ii) and (iii) are passed through a 100 mesh sieve and the residues pressed to obtain maximum extraction.

(v) Sucrose is then added to the extract at the rate of 150 g/litre and the product is bottled and kept at 0-5°C.

In general, about I kg of chufas will produce 5.5 litres of horchata.

A typical analysis of horchata is: total solids 22.8 per cent; fat 2.6 per cent; starch 2.4 per cent; sucrose 2.1 per cent; reducing sugars 0.03 per cent; ash 0.24 per cent; vitamin B 0.02 mg/100 g; ascorbic acid 0.27 mg/100 g. The pH is approximately 7 and Brix 18.3°.

When prepared on a commercial scale and stored at 0.5°C horchata quickly ferments and has a storage life of only 48 hours; for this reason attempts have been made to produce a more stable commercial product, eg by the production of frozen concentrates or using infra-red radiation. Pasteurisation before bottling is stated to extend the storage life of the chilled product to about four weeks without adverse effect on flavour.

Freeze drying is a promising (though costly) technique, which, with the incorporation of the antioxidant EDTA (ethylenediaminetetracetate) and packaging in nitrogen, gives a product of excellent quality with a storage life of four months at 37°C or about one year at 25°C. Spray drying has also been investigated.

Major influences

Although most of the literature on chufa is concerned with its eradication as a weed, there is continuing interest in the plant as a food and as a drink in the form of horchata. Certain vegetarian organisations have promoted chufa tubers as a complete food, in spite of the fact that their protein content is relatively low and their high cellulose content is nutritionally detrimental.

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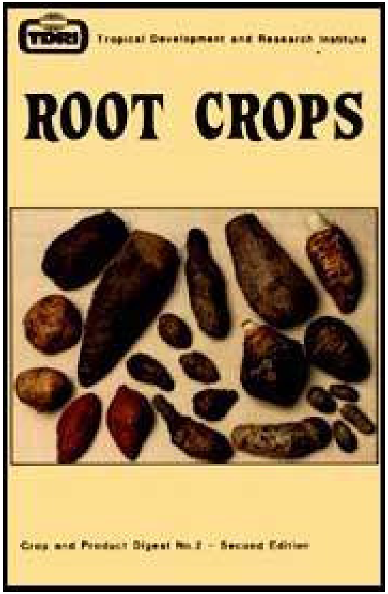
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- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis tuberosa)**
- **Potato (Solanum tuberosum)**
- **Queensland arrowroot (Canna indica)**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

East Indian arrowroot (Tacca leontopetaloides)

Common names

EAST INDIAN ARROWROOT, Fiji arrowroot, Indian arrowroot', Polynesian arrowroot, Tacca, Tahiti arrowroot, Williams arrowroot.

Botanical name

Tacca leontopetaloides (L.) Kuntze syn. T. pinnatifida Forst., T. involucrata Schum. and Thonn.

Family

Taccaceae.

Other names

Kabitsa (Madag.); Katjandong (Indon.); Loki (Polyn.); Lukeh (Mal.); Makmok, Mokmok (Mar. Is.); Masoa (Sam.); Pia (Haw.); Tavolo(s), Tavolo-kabija (Madag.); Vitian (Tah.); Yabia, Yabyaban (Philipp.).

Botany

East Indian arrowroot is a perennial herb with a tuberous rhizome, from which a single petiole, 60-90 cm long arises, bearing deeply lobed leaf blades consisting of three main segments, each further divided in a pinnate manner; the blades are about 30 cm across. The inflorescence is borne on a long stalk, also arising from the basal tuber, and is terminated by an umber of small green flowers surrounded by six or more bracts each about 3-4 cm long and numerous thread-like purplish inner bracts. The fruit is an ovoid, smooth, yellowish berry, about 3.5 cm long, with six ribs. Two distinct

types have been reported from the Pacific Islands, one producing a single large tuber, the other with a number of smaller (potato-sized) tubers.

Origin and distribution

East Indian arrowroot was introduced into the Pacific Islands from its origin in South-East Asia very early, and was subsequently introduced throughout tropical Asia, tropical Africa and tropical Australia. Its importance has declined; it is not cultivated in Africa and only sporadically elsewhere, though it has persisted throughout its range of early distribution in a wild state.

Cultivation conditions

Tacca leontopetaloides is a tropical plant but there is little precise information on its cultural requirements,

though it appears to thrive best on low-lying (up to 200 m), friable soils, particularly near the seashore; weeding is important and partial shade is beneficial.

Planting procedure

Material - propagation is by division of the small tuberous rhizomes which form at the base of the plant and often remain in the soil when the larger ones are harvested.

Field spacing - the tubers are often planted about 15 cm deep at a distance of 45 cm in rows 75-90 cm apart.

Pests and diseases

Few diseases or insect attacks have been recorded from cultivations of East Indian arrowroot as a reserve food crop in the Pacific.

Growth period

In Hawaii, the leaves appear in the early spring and the crop is mature by the end of the summer, approximately 8 months from planting, though under some conditions the crop can take up to 10 1/2 months to reach maturity.

Harvesting and handling

The tuberous rhizomes are ready for harvesting when the leaves begin to wither and fall. They are dug and sometimes stored in pits, but are liable to sprout.

Primary product

Tuberous rhizomes - most plants produce many starchy tubers, similar in appearance to potatoes, usually 10-15 cm in diameter, but they can reach 30 cm on rich soils.

They normally weigh from 70 to 340 g but can reach 1 kg. The tubers have eyes, a pale-yellow skin and dull-whitish flesh, and are usually bitter and almost inedible when raw.

Main use

The tubers were in the past a staple foodstuff in Polynesia, and in the 19th century were used as a source of starch rather similar to that of arrowroot, often given in the treatment of dysentery and for feeding infants. In Tahiti, they are used to make 'poi' ('poke' in the Cook Islands), a traditional food which consists of a mixture of fruit pulp and starch, flavoured with vanilla and lemon and cooked in an oven.

Subsidiary uses

Wild plants are regarded as a famine food in parts of West Africa.

Secondary and waste products

In the 19th century the leaves were marketed in Europe for the manufacture of hats.

Special features

The tubers contain 20-30 per cent of starch which can be easily extracted in a pure state and was formerly marketed in Europe and used in the Philippines for breadmaking. An analysis of Tahitian tubers has been given as: water 60.59 per cent; skin 2.5 per cent; starch 30.6 per cent; fibre 6.3 per cent.

An analysis of African tubers on a dry weight basis has been given as: protein 5.1 per cent; ether extract 0.2 per

cent; carbohydrate 89.4 per cent; cellulose 2.1 per cent; fibre 8.8 per cent; ash 3.2 per cent; calcium 0.27 per cent; phosphorus 0.2 per cent.

The principal amino acids present in the protein are arginine, glutamic and aspartic acids, leucine, Iysine and valine.
The starch obtained from the tubers is very white and similar in many respects to that of cassava or arrowroot; the grains are simple polyhedrons or semi-hemispheres, with diameters ranging from 8 to 40 microns, average 20 microns. In addition, the tubers contain about 2.2 per cent of a bitter extract, and a bitter principle taccalin has been isolated from the dried tubers.

Processing

Starch - the tubers are peeled, grated, and the resultant pulp washed in water several times, finally in a sieve or cloth. The aqueous starch solution is collected and the starch grains allowed to settle out, collected and dried in the sun.

Major influences

The demand for East Indian arrowroot starch has never been high and there seems no prospect of its expansion in the future. In Tahiti it has been largely replaced by cassava starch in the preparation of 'poi'.

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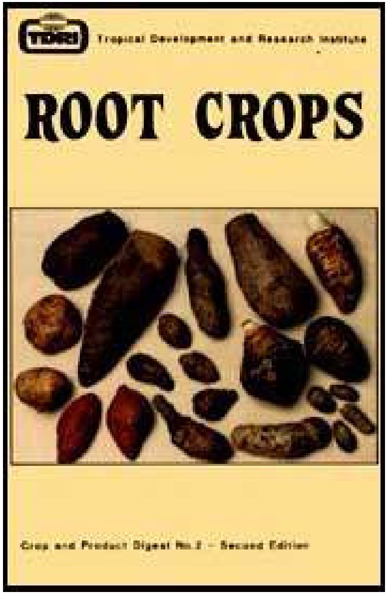
TDRI
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ROOT CROPS
Crop and Product Digest No.2 – Second Edition

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)
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- **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

Elephant yam (Amorphophallus spp.)

Common names

ELEPHANT YAM, Elephant bread, Elephant foot yam, Suran, Sweet yam.

Botanical name

Amorphophallus spp.

Family

Araceae.

Other names

Anto (Philipp.); Arsaghna, Balukund (Ind.); Chena (Mal.); Daga (Fiji); Ilis-ilis, Kand godda (Indon.); Karak-kavanai (Tamil); Karnai kilangu (Mal.); Kidaran (Ind.); Koe (Polyn.); Konjac, Konniaku, Konnyaku (Japan); Mo-yu (China); Ol (Assam); Ol kuchu (Bangl.); Oroy, Pogapong, Pugapung (Philipp.); Sooweg (Indon.); Suron (Fiji); Tamari (Sol. Is.); Telinga potato (Ind.); Teve (Tah.); Tigi (Philipp.); Waloor (Indon.); Zaminkund (Ind.).

Botany

A robust herbaceous plant, with an erect solitary stem usually 1-2.5 m in height and bearing at the top one or two tripartite leaves, each part of which is deeply dissected into numerous segments. Towards the end of

the plant's cycle (usually 4-6 years) a large terminal inflorescence is produced, consisting of a short stalk and spathe and a spadix, which emits a malodorous smell, reminiscent of rotten meat. The corms are large globose depressed tubers, usually dull-yellow or brownish-yellow in colour, and these produce 5-10 cormels at the end of each growing season.

The genus Amorphophallus consists of about 90 species, but the most important and widespread in the tropics is Amorphophallus paeoniifolius (Dennst.) Nicolson (syn. A. campanulatus Decne) and according to some authorities this exists in two forms, the wild one, var. sylvestris, recognisable by its rough petioles, while the cultivated form, var. hortensis, has much smoother petioles. In Indonesia two closely related species A. oncophyllus Prain and A. variabilis Bl. occur and are utilised. In addition, A. konjac C. Koch (syn. A. rivieri

Durien var. konjac (C. Koch) Engler) is cultivated and utilised in Japan and the warmer parts of China, and is also referred to as elephant yam in these areas.

Origin and distribution

The genus is indigenous to tropical Asia and Africa and A. paeoniifolius is found widely distributed in thickets and secondary growth forests at low and medium altitudes in the Philippines, Malaysia, Indonesia, Sri Lanka and the South-East Asia subcontinent. A. konjac originated in the Vietnam-southern China region and was introduced into Japan in the 10th century.

Cultivation conditions

A. poeoniifolius is a tropical and subtropical crop and requires an average temperature of 25-35°C, preferably

fairly equable during its growing period. The rainfall should be evenly distributed and between 100 and 150 cm, although the plant can be grown with a rainfall as low as 65 cm provided irrigation facilities are available. Warm humid conditions favour leaf growth and dry conditions favour the development of the corms. A. konjac requires cooler conditions with temperatures in the range 18-30°C, and is normally grown between latitudes 34°N and 43°N.

For optimum yields, deep loamy soils worked to a fine filth are necessary, preferably not alkaline. Good drainage is essential as the crop cannot stand waterlogging and heavy clays are therefore unsuitable. In India, it has been recommended that the crop should receive 25 t/ha of FYM, in addition to nitrogen 40 kg/ha, phosphorus 40 kg/ha and potassium 80 kg/ha. If no FYM is used additional nitrogen is advised, about 50

kg/ha in July and again in August for a fourth year crop.

Planting procedure

Material - both A. paeoniifolius and A. konjac are propagated from small corms (cormels) or buds produced below ground from the base of the shoot; in A. paeoniifolius the cormels appear during the fourth year but in A. konjac they appear in the second or third year. A weight of 100-120 g per piece is usual for planting. Both species have a dormancy period of 2-3 months. A crop may be obtained in one year from A. paeoniifolius if a four year old corm is cut into sections, each of which weighs 1-1.2 kg and carries at least one cormel and planted. Viable seeds have been produced experimentally and may be used for breeding work.

Method - the soil should be well tilled. Frequently

planting is on the flat, after paddy culture, but planting on ridges is also common. The corms are usually planted 10-15 cm deep. The crop often receives little cultural atten tion, although mulching or shading during the first 3-5 weeks of growth, followed by weeding and earthing up, is recommended. In India it is often grown mixed with other crops, such as arecanuts (Areca catechu), ginger (Zingiber officinale), methi (Trigonella foenum-graecum), cluster bean (Cyamopsis tetragonoloba) and bananas (Musa sp.). In parts of India, eg Bombay, the corms are usually dug at the end of each growing season, stored and then replanted, but in other areas, such as Japan, where A. konjac is grown, the corms are left in the ground for the whole growth cycle. It is essential for the corms of both species of Amorphophallus to be allowed a period of natural dormancy of 2-3 months. Amorphophallus has been recommended for intercropping with coconuts.

Field spacing - trials in India using cut pieces of four year old corms gave the highest yield per hectare when planted at 90x 120 cm. With seed pieces a spacing of 60x 120 cm has been recommended if accompanied by fertilisers.

Seed rate - approximately 1 600-2 000 kg/ha of corms or buds are required: when cut pieces of four year old corms are used the rate is about 10 000 kg/ha.

Pests and diseases

Reports from India indicate foot rot (caused by Rhizoctonia solani) as a serious problem. Drenching the soil around affected plants at monthly intervals with 0.2 per cent captan or 0.1 per cent quintozene was highly effective and led to almost double the tuber yields of untreated plants. Little has been reported from

elsewhere.

Growth period

The growth cycle of the corms normally takes about 8-12 months but the tubers are small and unmarketable after only one season and 3-4 seasons are required for an economic crop, except when planted from four year old corms as described.

Harvesting and handling

The corms are dug by hand when the leaves begin to wither and die, and weigh from 3 to 9 kg, depending upon the number of growing seasons. They are usually carefully cleaned and are stored in heaps preferably in well-ventilated sheds. Corms of A. paeoniifolius can lose as much as 25 per cent of their initial weight in the first

month of storage, but can be successfully stored at 10°C for several months. Alternatively, they may be left in the ground until required, with a little irrigation if necessary. Corms dipped for I minute in a 4 per cent fungicidal emulsion can be stored at room temperature for about 2 months with minimal loss of weight or sprouting. In Japan corms of A. konjac that are to be replanted must be protected in store from low winter temperatures, since it has been found that if they are subjected to temperatures of - 5°C germination is affected.

Primary product

Corms - the depressed globose corms often have a diameter of 30 cm or more, and under good cultural conditions can weigh 7-9 kg by the fourth season.

Yield

In India the average yield ranges between 12 and 22 t/ha; as an intercrop with coconuts 13 t/ha. However, under experimental conditions over 60 t/ha has been reported, and 36 t/ha in mixed cropping.

Main use

The corms and cormels of A. paeoniifolius are usually boiled or baked and eaten as a vegetable: in Japan A. konjac is mainly eaten as konnyaku, a gel-like food with an elastic texture made from konjac mannan flour (see Processing). The small one year old corms of A. konjac are considered to be a delicacy. Wild forms must be soaked in water for some time before cooking, and boiled for a lengthy period in order to remove the bitterness.

Subsidiary uses

In the Philippines, the corms are sometimes boiled and fed to pigs. They may be used as a source of starch and alcohol and have been used to prepare a flour for breadmaking. In Indonesia, the species A. onchophyllus is used to produce flour for industrial purposes, and the Japanese species A. konjac is used as a commercial source of mannose. A glucomannan from species of Amorphophallus has been proposed for thickening food products such as ice cream or mayonnaise.

The konjac mannan flour from A. konjac is used to make paste that does not separate when frozen and thawed, and is not eaten by insects. It is also employed in the manufacture of paper, and in textiles it is used in the same manner as starch. Cotton and other fabrics are waterproofed by coatings based on konjac mannan

flour. Cosmetics such as those for chapped skin, beauty creams and hair pomades may contain the flour.

Secondary and waste products

The young petioles and leaf blades may be boiled and eaten as a vegetable which is reported to resemble asparagus. Older, tougher petioles are used for livestock feeding, while the corms are reported to be used for medicinal purposes in parts of India.

Special features

The composition of the edible portion of the corms of A. paeoniifolius has been reported as: energy 330 kJ/100 g (approx); water 72-79 per cent; protein 1.7-5.1 per cent; fat 0.2-0.4 per cent; carbohydrate 18-24 per cent; fibre 0.-0.8 per cent; ash 0.7-1.3 per cent; calcium 50-56

mg/100 g; iron 0.6-1.4 mg/100 g; phosphorus 20-53 mg/100 g; vitamin A 434 IU/100 g; thiamine 0.04-0.06 mg/100 g; riboflavin 0.05-0.08 mg/100 g; niacin 0.07-0.075 mg/100 g; ascorbic acid trace-3 mg/100 g. Most of the carbohydrate is starch (75-80 per cent); the starch granules vary in shape and size (about 5.5-19 microns).

A. konjac is reported to have a higher water content (80-90 per cent), with only about 10 per cent of the carbohydrate as starch but up to 65 per cent as glucomannan.

A. paeoniifolius and A. konjac contain calcium oxalate crystals; the wild forms of A. paeoniifolius contain more than the cultivated and are strongly acrid.

Processing

No processing methods for A. paeoniifolius have been described, but A. konjac corms are commonly air-dried in the sun; the dried corms may be stored for long periods, or made into flour. The following procedures apply only to A. konjac.

Flour (konako or konjac mannan flour) - the corms are peeled, sliced and skewered onto bamboo sticks 60 - 90 cm long, 2 or 3 cm apart, and placed in the sun. After about one week the slices are crushed and then ground in a mortar and pestle run by a waterwheel. During the grinding a flap attached to the mortar blows away the fibre and cell debris (and some of the flour). The flour is known as konako: about 12 kg of konako is obtained from 100 kg of fresh tubers. The proximate composition of konako has been given as: water 17 per cent; fat 0.6 per cent; carbohydrate 68 per cent; fibre 2.3 per cent; ash 4.5 per cent. The flour is used in many recipes.

Konnyaku - konako flour is made into konnyaku by the following process:

(i) Water is stirred into the flour until it becomes uniformly soft and gelatinous.

(ii) The paste is allowed to stand, stirred, and allowed to stand for a further period of time.

(iii) A dilute, strained suspension of slaked lime is stirred into the gel, and mixed thoroughly until it thickens.

(iv) The mass is poured into shallow trays, allowed to stand until further thickening has developed, then cut into squares (often with about 10 cm sides).

(v) The squares are boiled in water for about 20 minutes, allowed to cool in the cooking water and then

stored, refrigerated, in the same water. Konnyaku is reported to last indefinitely if the water is not changed.

Shirataki - the lime-treated gelatinous mass (step (iii) in the production of konnyaku) is pressed through a die (or sieve) before cooking, forming noodles called shirataki.

Konnyaku and shirataki are an important part of the Japanese diet and may be eaten fresh (or refrigerated), or canned. Published analytical figures for Hawaiian and Japanese konnyaku are:

Hawaiian konnyaku (fresh): energy 50 kJ/100 g; water 96.6 per cent; protein 0.09 per cent; carbohydrate 3.07 per cent; fibre 0.06 per cent; ash 0.24 per cent; calcium 63 mg/100 g; iron 0.3 mg/100 g; magnesium 7 mg/100 g; phosphorus 7 mg/100 g; potassium 10 mg/100 g;

sodium 38 mg/100 g; thiamine 0.021 mg/100 g; niacin 0.02 mg/100 g; ascorbic acid 0.5 mg/100 g.

Japanese konnyaku (fresh): water 97.4 per cent; protein 0.1 per cent; carbohydrate 2.3 per cent; fibre 0.1 per cent, ash 0.2 per cent; calcium 43 mg/100 g; iron 0.4 mg/100 g; phosphorus 5 mg/100 g; sodium 10 mg/100 g.

Japanese konnyaku (canned): energy 54 kJ/100 g; water 96.48 per cent; protein 0.04 per cent; fat 0.01 per cent; carbohydrate 3.28 per cent; fibre 0.37 per cent, ash 0.19 per cent; calcium 63 mg/100 g; iron 0.28 mg/100 g; magnesium 3 mg/100 g; phosphorus 3 mg/100 g; potassium 18 mg/100 g; sodium 2 mg/100 g; ascorbic acid 0.1 mg/100 g.

The figures for shirataki would be similar.

Konnyaku in the diet is reported to lower plasma cholesterol.

Production and trade

Very little information is available: in Japan the area under A. konjac was estimated to be about 15 000 ha in 1979, with production of 90 000 t, and in India about 800 ha of A. paeoniifolius is reported.

Major influences

Although the elephant yam continues to be a popular root crop in parts of India and eastern Asia, production is limited mainly because of the four year crop cycle. However, in Japan, breeding and selection aimed at improved disease resistance, higher yields, earlier maturity and higher mannan contents, are in progress.

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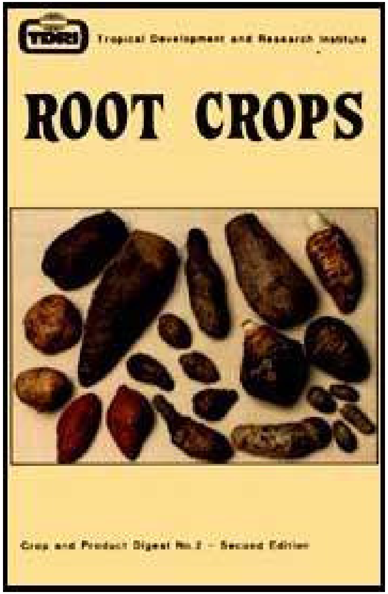
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- **Chufa (Cyperus esculentus)**
- **East Indian arrowroot (Tacca leontopetaloides)**
- **Elephant yam (Amorphophallus spp.)**
- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**

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- **Tannia (Xanthosoma spp.)**
- **Taro (Colocasia esculenta)**
- **Topee tambo (Calathea allouia)**
- **Ullucu (Ullucus tuberosus)**
- **Winged bean (Psophocarpus tetragonolobus)**

False yam (Icacina senegalensis)

Common name

FALSE YAM.

Botanical name

Icacina senegalensis A. Juss.

Family

Icacinaceae.

Other names

Bankanas (Sen.); Basouna (W. Afr.); Kouraban (Sen.); Manankaso (Gam.); Pan (Sud.); Takwara (Gh.).

Botany

False yam is a shrubby perennial, variable in form, which sends up glabrous or pubescent erect leafy shoots from a large, underground fleshy tuber. The aerial stems are light green, and may reach about I m in height. The leaves are simple, ovate or obovate, pointed or rounded at the apex, 5-10 cm long and 4-7 cm broad, light green when young, but becoming leathery and dark green on the upper surface and dull green on the lower. The flowers are inconspicuous, usually white or cream and pedunculate, ascending or erect, corymbose cymes, collected into a terminal leafless panicle, or the lower

peduncles arising from the axis of reduced leaves. The calyx is in five divisions, the pointed lobes are bright green; the corolla is composed of 5 narrow, white or creamy-white petals, covered with silky hairs on their outside surface. The fruit is a bright-red ovoid berry, approximately 2.5-3 cm in length and 2-2.5 cm in width. It is covered with very short hairs and contains a thin layer of white pulp, approximately 0.2 cm thick, surrounding a single spherical or ovoid seed.

Origin and distribution

Icacina senegalensis is indigenous to west and central Africa and is found growing wild on light sandy soils in the savanna areas of Senegal, The Gambia, northern Ghana, Guinea and parts of the Sudan.

Cultivation conditions

The plant requires light soils and a marked wet and dry season, but with only moderate rainfall in the wet season (80-100 cm).

Planting procedure

The plant usually occurs wild, and is seldom cultivated. However, it is occasionally planted in Africa and it is reported from Senegal to be propagated by pieces of tuber, planted before the wet season, at about 440 plants/ha.

Pests and diseases

No pests and diseases have been reported.

Harvesting

The tubers are harvested by hand as required; owing to

their size and the fact that they can penetrate to about 25-30 cm below the surface they are difficult to dig out and at one time the plant was nicknamed 'abub ntope' or 'break hoe' in northern Ashanti.

Primary product

Tubers - these resemble large turnips or beetroots and show considerable variation in size, ranging from 30 to 45 cm in length up to 100 cm, with a diameter of about 30 cm, and weighing from 3 to 25 kg. The tubers are greyish in colour with a thin skin enclosing white flesh, which is usually speckled with yellow spots that correspond to bundles of xylem. They contain a bitter toxic principle.

Yield

In Senegal yields have been reported to average 2-3 t/ha, although in some parts of west Africa yields are reported to reach 20 t/ha.

Main use

The tubers are used mainly as a famine food and sometimes as a source of starch or flour.

Subsidiary uses

In western Ashanti the tubers are reported to be used medicinally.

Secondary and waste products

The fruits are often eaten by children and the seeds are sometimes dried and pounded to yield a flour, especially at times of food scarcity.

Special features

The tubers contain about 10-15 per cent of starch, the grains of which are irregular in shape, some spherical and some elliptical, with lengths varying from 12 to 50 microns. Flour manufactured from the tubers has the following approximate composition: water 11.7 per cent; protein 10.3 per cent; fat 0.7 per cent; carbohydrate 74.5 per cent; ash 2.8 per cent; calcium 150 mg/100 g; iron 7 mg/100 g; thiamine 0.04 mg/100 g; riboflavin 0.18 mg/100 g; niacin 1.4 mg/100 g. In addition, a bitter toxic principle, reported to be a gum resin, is present in quantities ranging from 0.9 to 2.8 per cent.

Flour obtained from the seeds has the following approximate composition: water 12-13 per cent; protein 8 per cent; fat 0.1 per cent; carbohydrate 72-73 per

cent; ash 0.5 per cent.

Processing

When used as a foodstuff the tubers are cut up and placed in clean running water for several days, to remove the bitter principle and to facilitate maceration. They are then dried, pulverised and sieved to give a greyish-white or creamy-yellow flour. The yield of flour from the raw tuber is approximately 8-10 per cent.

Major influences

The false yam is a common weed in many savanna areas of West Africa, particularly where the true yam has been cultivated. It could be utilised to provide a source of commercial starch in certain areas and would be of value in those areas where crop failures causing a

shortage of subsistence foods are likely to occur.

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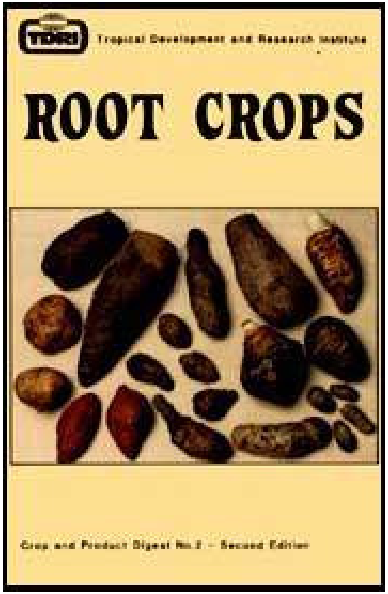
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- **Yacn (Polymnia sonchifolia)**
- **Yam (Dioscorea spp.)**
- **Yam bean (Pachyrrhizus erosus)**

Appendixes

Giant taro (Alocasia macrorrhiza)

Common name

GIANT TARO.

Botanical name

Alocasia macrorrhiza (L.) G. Don.

Family

Araceae.

Other names

Alavu, Alooku, Alu (Ind.); Ape (Polyn.); Babai' (Kiri.);

Big (Philipp.); Birah (Mal.); Boro (Assam); Brak (Mal.); Dokuimo (Japan); Hog tannia (Guy.); Inhame gigante (Braz.); Kape (Pacif. Is.); Manaka, Mankachu, Mankanda (Ind.); Oht (Pon.); Pindu (N. Cal.); Puluka (Tuv.); Snt (Indon.); Talanu (Sam.); Toyoeu (Braz.); Uvea (Polyn); Vaaga, Via (gaga), Viamiloa (Fiji).

Botany

Giant taro is a tall succulent herbaceous plant, reaching 4.5 m in height, with a thick cylindrical stem arising from a basal corm. The leaves are borne on long petioles which arise from the stem and are sheathing on the lower half, but the blades are more or less heart-shaped with rather rounded basal lobes: the blades point upwards forming a straight line with the petiole (unlike Colocasia or Xanthosoma spp. in which the blades point downwards to form an acute or right angle with the leaf

stalk). The leaf blades have a conspicuous midrib, raised on the upper surface, and grow up to about I m in length. They are usually green, but there are variegated forms which are blotched or mottled with white. The spathe has a glaucous, yellowish-green blade. Cormels are formed around the basal corm. The plant contains latex.

Origin and distribution

The giant taro is thought to have originated in Sri Lanka, but has become widely distributed in the South-East Asia subcontinent, Malaysia, Indonesia and Polynesia, and has spread to parts of tropical America.

Cultivation conditions

Temperature - the species is essentially tropical and

temperatures below 10°C are detrimental to growth.

Rainfall - taro requires a reasonably high (in excess of 170 cm per year) evenly-distributed rainfall and cannot survive a long period of drought. It is frequently found naturally along river banks, but cannot stand waterlogging.

Soil - the plant grows well in medium to heavy soils provided drainage is adequate. Response to nitrogen fertilising has been demonstrated.

Planting procedure

Material - suckers are commonly used, but shoot tips with a few inches of stem and rolled up young leaves, or sections of stem having two or three buds are also frequently employed.

Method - planting is in holes 15-25 cm deep for suckers or 8-15 cm deep for cormels.

Field spacing - Alocasia is commonly an intercrop with yams, and the spacing is usually 3.5 x 3.5 m. In pure stand 60 x 60 cm to 1.5 x 1.5 m is used.

Pests and diseases

The giant taro is resistant to most pests and diseases, although in India considerable losses have been reported due to an unidentified bacterial leaf spot disease.

Growth period

The crop life is usually 12-18 months, but harvesting can be delayed for up to four years.

Harvesting and handling

The giant taro is normally dug by hand; the plant can remain in the ground for about 3 months after reaching maturity without any deterioration and is in fact often 'field-stored'.

Primary product

Stems - unlike most other edible aroids, in which the edible parts are subterranean, it is the fleshy aerial stems of the giant taro that provide the primary product. These stems may be up to I m long and 20 cm in diameter, normally weighing 8-10 kg, though 20 kg or more is not uncommon.

Yield

In the Pacific islands harvesting is usually after 18-24

months but the plant may be allowed to grow for up to 4 years, producing corms weighing about 18 kg. Theoretically, yields for pure stands could be almost 200 t/ha at this stage, but no yields for the Pacific region have been reported as all normal planting is intercropped. Much lower yields are reported from Sri Lanka, where harvesting is usually at 11 months, giving about 7-11 t/ha per crop (1.8-2.7 kg per plant) though when grown over coconut husks 6-7 kg per plant is obtained.

Main use

The stem tuber is peeled, cut into pieces and eaten as a vegetable after cooking, usually in curries or stews. Older stems may require prolonged cooking with several changes of water to remove acridity.

Subsidiary uses

Giant taros are sometimes used as a source of a very white easily-digested starch or flour. The underground corms and cormels are also used for food after thorough cooking, particularly in times of scarcity. The leaves may be eaten (eg fried with onions, garlic, chili, etc). Alocasias are widely grown in certain areas, eg Florida, as ornamental foliage plants.

Secondary and waste products

The corms and leaf juices (latex) are reported to be used for medicinal purposes in India and the Pacific islands. The plant was formerly cultivated in Brazil, where it was utilised as a pig feed. It has also been investigated as a possible raw material for the production of alcohol.

Special features

The food value of the edible portion of the raw stem tubers of giant taro has been reported as: energy 293-599 kJ/100 g; water 63-81 per cent; crude protein 0.6-3.3 per cent; fat 0.1-0.2 per cent; carbohydrate 17-27 per cent; ash 1.1-1.3 per cent; calcium 46-153 mg/100 g; iron 0.5-1 mg/100 g; phosphorus 45-72 mg/100 g; niacin 0.4 mg/100 g; riboflavin 0.02-0.03 mg/100 g; thiamine 0.09-0.1 mg/100 g; ascorbic acid trace. Much of the calcium is in calcium oxalate crystals.

Composition changes with age, older material having lower moisture content and higher solids. Few figures have been published showing starch content but there may be substantial quantities of other carbohydrates associated with it. The starch grains are small, irregularly-shaped polygons of four or five sides, 1-5

microns in length, with approximately 21 per cent amylose and 79 per cent amylopectin. Several cultivars of A. macrorrhiza are reported to be cyanogenic; the cyanogenic glycoside is not present in the corms or stems, but the young leaves have been found to contain up to 0.018 per cent of hydrogen cyanide.

Major influences

The giant taro is a minor crop in most Asian countries and production is not likely to expand.

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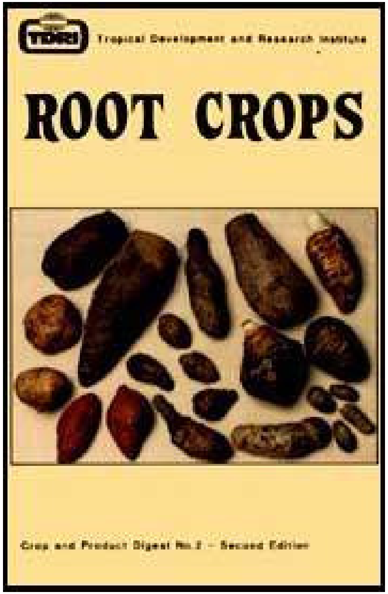
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Yam bean (Pachyrrhizus erosus)
Appendixes

Hausa potato (Solenostemon rotundifolius)

Common names

HAUSA POTATO, Coleus potato, Country potato.

Botanical name

Solenostemon rotundifolius (Poir.) J. K. Morton syn. Coleus rotundifolius Chev. and Perrot.

Family

Labiatae.

Other names

Fra-fra potato (Gh.); Innala (Sri La.); Kembili (Mal.); Ketang (Indon.); Koorka (Ind.); Madagascar potato (Fr.); Ratala (Sri La.); Saluga (Nig.); Sudan potato, Tumuku (Nig.); Vatke (Eth.).

Botany

A small, herbaceous annual, IS-30 cm high, prostrate or ascending, with a succulent stem and somewhat thickish leaves having an aromatic smell resembling that of mint. Flowers are small, pale violet in colour, produced on an elongated terminal raceme. Small dark-brown tubers are produced in clusters at the base of the stem.

Origin and distribution

The hausa potato is believed to have originated in

central or east Africa, but was early spread throughout tropical Africa and into South-East Asia, including India, Sri Lanka, Malaysia and Indonesia, where it is cultivated on a small scale.

Cultivation conditions

Temperature and rainfall - the plant is suited to high rainfall areas; evenly-distributed rainfall and low night temperatures favour the development of tubers. It is grown in India as a monsoon crop and is sometimes grown under irrigation in West Africa.

Soil - optimum yields are obtained on well-drained, sandy loams; heavy clay soils are unsuitable. The plant cannot stand waterlogging and is usually grown on ridges, except in very well-drained soils. Waterlogging causes deformities to the tubers and reduces yields

considerably. The inclusion of 25 t/ha of FYM at planting is recommended, and subsequently application of a 16:8:8 complete (NPK) fertiliser at the rate of 125 kg/ha.

Planting procedure

Material - generally propagated by suckers obtained from germinating tubers.

Method - selected tubers from the previous harvest are usually planted in raised, well-manured, nursery beds, approximately 90-120 cm wide and any convenient length. The tubers are planted in rows 5 x 15 cm about 4 cm deep. If the soil is dry the beds are irrigated to start growth and this is continued if necessary. The tubers germinate in 10-15 days, and give rise to a cluster of sprouts, which are ready for transplanting to the field

after about 3 months. In Sri Lanka three methods of planting out are commonly used: Ordinary planting - cuttings about 15 cm long and having three or four leaves at the top end are planted 7 cm deep in rows down the ridges 22 cm apart. Coiled planting - cuttings about 22 cm long are used and about 12 cm of the more mature portion is coiled and planted in holes about 7 cm wide and 5 cm deep. Horizontal planting - cuttings about 30 cm long are placed horizontally across the ridge, two at a time, in opposite directions and almost touching each other. About 22 cm of the cuttings remain on the ridge and 7 cm outside and there is about 7 cm between each pair of cuttings. Of these three methods, coiled planting is reported to give the best results.

In some areas, eg Madras (India), the seed tubers are planted in a corner of the field and about a month after germination the top suckers, with four or five leaves,

are ripped off and planted 15-20 cm apart in another part of the field. These quickly become established and in about another fortnight a further set of suckers is available for planting out. In this way in about 2 months a hectare of planting material is obtained from an initial 0.2 ha, and relatively few tubers.

Once planted out the crop is normally cultivated twice to control weeds, once about 3 weeks after planting, and then one month later. At the latter, the plants are earthed up to encourage the production of tubers.

Field spacing - in Sri Lanka the hausa potato is usually planted at about 22 cm spacing on ridges 90 cm apart; in India a slightly closer spacing of 15-20 cm along the ridge is sometimes used.

Seed rate - in Sri Lanka about 50 000 plants/ha are

required: these are obtained from cuttings taken from nurseries and raised in three different ways. The following figures indicate the number of tubers planted in the nursery to provide the necessary number of cuttings to plant one hectare: ordinary planting 20 000 tubers; coiled planting 40 000 tubers; horizontal planting 60 000 tubers.

In India, where top suckers are taken at intervals from a nursery bed, 2 500 tubers will produce enough suckers to plant one hectare.

Pests and diseases

The hausa potato is relatively free from pests and diseases though Pycnarmon cribata, Phostria piasusalis and a leaf folder, Hymenia curvalis, have been reported from India as being important. These have been

controlled by spraying with pesticides such as dimethoate.

Growth period

The crop normally reaches maturity in 5-6 months in Sri Lanka, West Africa and Malaysia, and 6-8 months in India. (It has been reported that tuber initiation may be accelerated by about 2 weeks by treatment of the young plants with chlormequat or ethephon (ethrel).)

Harvesting and handling

The tubers are ready for harvesting when the leaves begin to wither, and are normally dug by hand. Harvesting cannot be delayed as the mature tubers deteriorate rapidly if left in the soil, but they can be stored successfully in dry sand or in a cool, well-

ventilated shed.

Primary product

Tubers - these resemble the potato, but are smaller, with an aromatic sweetish flavour. In Sri Lanka, two main types are recognised, the small-tubered type favoured for its delicate flavour and the larger type that produces heavier crops which are easier to harvest. In West Africa, there are three recognised types: nigra, widespread in Mali, with small tubers and blackish skin; rubra, with small reddish-gray or reddish-yellow tubers; and alba, which is whitish.

Yield

Yields normally range from 7 to 15 t/ha, although under very favourable conditions they may reach 18-20 t/ha.

Main use

The tubers can be used as a potato substitute and are usually cooked in a curry and eaten with rice, but they can also be boiled, baked or fried similarly to potato chips.

Subsidiary uses

In Africa, the hausa potato is sometimes used in the treatment of dysentery and in the treatment of certain eye disorders.

Special features

The composition of the edible portion of the tubers has been quoted as: water 75 per cent; protein 1.4 per cent; fat 0.5 per cent; carbohydrate 21 per cent; fibre 0.7 per cent; ash I per cent; calcium 17 mg/100 g; iron 6

mg/100 g; thiamine 0.05 mg/100 g; riboflavin 0.02 mg/100 g; niacin 1 mg/100 g; ascorbic acid Img/100 g. The principal amino acids in the protein are arginine, aspartic and glutamic acids.

Major influences

Although formerly of considerable importance as a staple foodstuff in tropical Africa, the hausa potato has been largely replaced by other starchy foodstuffs, such as cassava and potatoes, and production has declined to such an extent that it has almost disappeared in many areas.

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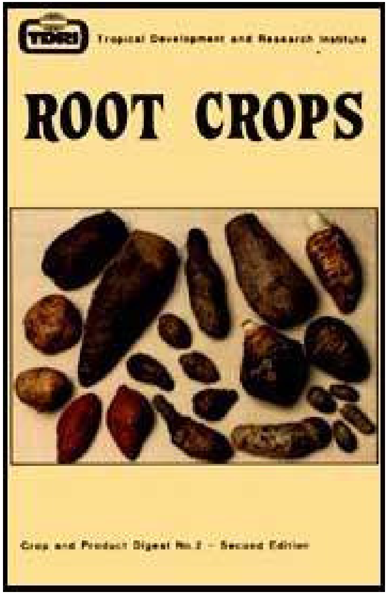
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- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**
- **Lotus root (Nelumbo nucifera)**
- **Maca (Lepidium meyenni)**
- **Oca (Oxalis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

Acknowledgments

Daisy E. Kay revised by E. G. B. Gooding

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This report was produced by the Tropical Development and Research Institute (formed by the amalgamation of the Tropical Products Institute and the Centre for Overseas Pest Research) a British Government organization, funded by the Overseas Development Administration, which provides technical assistance to developing countries. The Institute specialises in post-harvest problems and pest and vector management.

First edition 1973
Price £13.50

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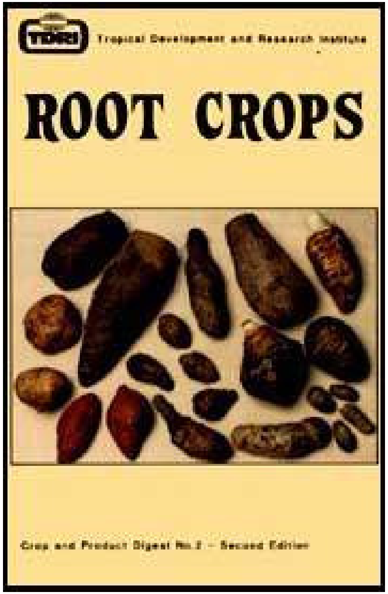
Tropical Development and Research Institute ISBN: 0 85954 200-9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- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma chamissonis)**
- **Sweet potato (Ipomaea batatas)**
- **Tannia (Xanthosoma spp.)**
- **Taro (Colocasia esculenta)**
- **Topee tambo (Calathea allouia)**
- **Ullucu (Ullucus tuberosus)**
- **Winged bean (Psophocarpus tetragonolobus)**
- **Yacn (Polymnia sonchifolia)**
- **Yam (Dioscorea spp.)**

Yam bean (Pachyrrhizus erosus)
Appendixes

Jerusalem artichoke (Helianthus tuberosus)

Common names

JERUSALEM ARTICHOKE, Girasole, Topinambour

Botanical name

Helianthus tuberosus L.

Family

Compositae.

Other names

Aardpeer (Nether.); Aguaturma (Sp.); Brahmokha (Beng.); Canada potato (N. Am.); Carciofo di Gerusalemme or di terra (It.); Cotufa (Philipp.); Elianto tuberoso (It.); Erdartischocke (Ger.); Hathipick, Hatichuk (Ind.); Kiku-imo (Japan); Knollensonnenblume (Ger.); Pera di terra (It.); Pseudokolokasia (Cy.); Root artichoke; Sunroot.

Botany

An erect, hardy tuberous perennial, but normally cultivated as an annual. It attains a height of 0.6-1.2 m in the tropics and 1.8-3 m in more temperate areas. The leaves are approximately 10-20 cm long, the lower leaves opposite and the upper alternate: they are finely pubescent beneath. The number of flowers varies greatly according to climate and cultivar, but the flower heads normally have a diameter of 6-7.5 cm with yellow

florets.
The plant produces a number of small tubers which somewhat resemble potatoes, but have much larger eyes and are often knobbly. There is a limited range of cultivars, one of which was developed in France and has long fusiform tubers of good quality and flavour and is often designated as H. tuberosus var. fusiformis.

Origin and distribution

The Jerusalem artichoke originated in North America and was cultivated by the Indians in the north-eastern part of the continent in pre-Columbian times. It was introduced into Europe in the early 17th century and is now widely grown in both hemispheres, but in general is regarded as of rather minor importance.

Cultivation conditions

Although Helianthus tuberosus is of temperate origin it can be grown in the tropics. The yield is normally higher under long-day conditions, but the lower yield of short-day plants is largely compensated by the rapid growth rate under high temperatures (24-30°C), and moderate yields are therefore attainable in the tropics, though the cultivar is important (see Day-length). However, it is believed that there is sufficient variability in genotype to permit the breeding of high-yielding cultivars for tropical conditions.

Temperature - most cultivars require a growing season of at least 125 frost-free days and optimum yields are obtained where there is an equable temperature in the range of 18-26°C.

Rainfall - a fairly evenly-distributed rainfall of 125 cm or less is required. In dry areas irrigation may be

necessary to start germination.

Soil - the plant is tolerant of soil conditions provided that the drainage is good; yields are poor on heavy clays, particularly if there is a danger of waterlogging. The Jerusalem artichoke is successfully grown in France on soils too poor for potatoes. For optimum yields a light or medium, well-cultivated loam is required and the application of 500 kg/ha of super-phosphate before planting, followed by a side dressing of 250 kg/ha of ammonium sulphate when the top growth reaches 0.3-0.6 m, has been recommended.

It has been reported that when Jerusalem artichokes are grown on nematode-infested soils a reduction of 45 per cent in the nematode population may be brought about.

Altitude - in the tropics the crop does best at elevations

of 300-750 m but it is grown in India at elevations up to 1 200 m.

Day-length - short day-lengths (photoperiods of around 12 hours) are reported to favour tuber formation, but the increased time for photosynthesis under the longer days of more temperate climates gives somewhat greater yields, though, as noted earlier, this is partially compensated for by the more rapid growth under the high temperatures of the tropics.

Planting procedure

Material - propagation is vegetative, by using setts, which are sound, disease-free small tubers, or pieces of tubers: these should weigh approximately 50 g and have at least two or three eye buds. In some areas of the tropics it has been found that the tubers require a

period of dormancy of up to 7 months.

Method - the setts are normally planted in rows, on the level, in small hills, or in ridges, about 7.5-10 cm deep, and are earthed up in the same manner as potatoes when the plants are about 0.3 m tall. Early weeding may be necessary, but the plants grow and spread rapidly, and later weeding should be avoided as the developing tubers are easily damaged. Once established, the crop is difficult to eliminate from the soil as tubers or parts of tubers are frequently left in the ground, and often replanting for subsequent crops is unnecessary.

Field spacing - for maximum yields in the USA a planting distance of 1-1.3 m between the rows and 60 cm between the plants has been recommended. In the tropics, eg India, a closer spacing is often used, 0.3-0.5 m between the plants and 0.6-1 m between the rows,

while various intermediate spacings are noted in the literature.

Seed rate - in India approximately 550 kg of setts are used to plant one hectare; in many other areas the seed rate is approximately 320 kg/ha.

Pests and diseases

The Jerusalem artichoke is relatively free from serious attacks of pests and diseases in the field, but where drainage is poor root rot, due to Corticium rolfsii, can be troublesome. Powdery mildew (due to Erysiphe chicorianum f. sp. helianthi) has been reported from Bulgaria. Common diseases of sunflowers (Helianthus annuus) such as downy mildew, septoria leaf spot, rust and sclerotinia wilt are regarded as potential problems. The tubers are susceptible to the development of rots

during storage. Botrytis cinerea, Rhizopus stolonifer and Sclerotinio sclerotiorum are reported to be fairly common; the last two can cause severe losses even when the tubers are stored at low temperatures. In addition, the tubers are sometimes infected by a fusarium rot, probably caused by Fusarium acuminatum.

Growth period

The crop usually reaches maturity in 4-6 months, although some cultivars mature in 2 1/2 - 3 months.

Harvesting and handling

The tubers are ready for harvesting when the leaves begin to wither and die. They are usually lifted manually with a fork only as required, since they can be 'field-stored' without any deterioration in their quality or

flavour. When grown for pig feed the animals are often turned loose on the plot and root out the tubers. When cultivated on a large-scale the tops are frequently cut off before harvesting and sometimes the tubers are ploughed out, but this is not as efficient as manual harvesting owing to the irregular shape, small size, and distribution of the tubers.
Once harvested the tubers quickly shrink and deteriorate if kept at ambient temperatures, but if sound and disease-free can be successfully stored for 2-5 months at 0°C and 90-95 per cent RH.

Primary product

Tubers - each plant produces a number of small edible tubers, usually 10-20 cm long and 2.5-7.5 cm in diameter, 40-300 g in weight, frequently knobbly and of irregular shape, with large eyes and thin skins. The skin

colour may be white, purple or red, depending upon the cultivar, but the white-skinned ones are generally the most popular.

Yield

On sandy soils in Europe yields normally average about 30 t/ha; in India yields are usually 12-25 t/ha, although under favourable conditions 37 t/ha can be obtained and yields as high as 150-160 t/ha have been reported from the northern Caucasus.

Main use

The tubers are eaten as a vegetable similarly to potatoes, though their irregular form makes then difficult to prepare; they are often used as a constituent of soups and stews.

Subsidiary uses

The tubers are grown for livestock feeding in many areas and are relished by pigs.

Secondary and waste products

The tubers can be used as a commercial source of fructose; it is claimed that the plant can produce more fructose per hectare than beet or corn. The main carbohydrate in Jerusalem artichoke is inulin, which is easily hydrolysed to fructose; in corn the carbohydrate is starch that has first to be converted to glucose and then fructose; in beet it is sucrose, that has to be hydrolysed first to glucose and fructose, the glucose then being converted to fructose. Industrial alcohol (ethanol) and 5-hydroxymethyl furfural are additional products. Flour can be prepared from the tubers, and

also a beer-like beverage. A topinambur brandy has been made experimentally in Germany. Protein (1-2 t/ha) may also be obtained, and pulp suitable for animal feeding is a by-product of the fructose and ethanol processes. The green tops also are used as forage, and the stalks, when treated by a soda-chlorine process, yield about 20 per cent of pulp suitable for papermaking.

Special features

Analyses show a wide range of variation: published average figures for the edible portion are: energy 332.3 kJ/100 g; water 78.9 per cent; protein 2.44 per cent; fat 0.41 per cent; carbohydrate 15.8 per cent; fibre 0.7 per cent; ash 1.74 per cent; potassium 478 mg/100 g; calcium 10 mg/100 g; iron 3.7 mg/100 g; phosphorus 78 mg/100 g; thiamine 0.2 mg/100 g; riboflavin 0.16 mg/100 g; niacin 1.3 mg/100 g; ascorbic acid 4 mg/100

g.

The carbohydrate consists almost entirely of inulin and inulides with small amounts of starch, fructose and glucose: occasionally the starch may reach 30 per cent of the carbohydrate, but is usually considerably less. As inulin is not digestible by human beings, utilisable energy intake is much lower than suggested by the table, and allows the tubers to be used as a low energy food, which still satisfies volume intake and hunger. The tubers have also been recommended for diabetics. When used for animal feeding the nutritive value of the tubers has been quoted as: digestible protein 1.2 per cent; total digestible nutrients 15.9 per cent; nutritive ratio 12:3.

The green tops have given analytical figures of: dry matter 27.2 per cent; protein 1.4 per cent; fat 0.3 per cent; nitrogen-free extract 18.5 per cent; minerals 2.1

per cent; calcium 0.44 per cent; phosphorus 0.09 per cent; potassium 0.37 per cent; digestible protein 0.8 per cent; total digestible nutrients 18.1 per cent; nutritive ratio 21:6.

Processing

Fructose - has been prepared commercially by crushing the tubers to extract inulin and starch, which are hydrolysed with acid to fructose or glucose, respectively, in the ratio of about 75:25 (the ratio varies with the cultivar, the maturity of the tubers and the period of storage after harvesting, the fructose portion decreasing with age and length of storage). The hydrolysed juice is then neutralised with lime and the precipitate of calcium fructose derivative filtered off and treated with carbon dioxide to give fructose; average yield from fresh tubers is about 6 per cent by weight.

Recent improvements in technology involve more sophisticated extraction methods and the use of an enzyme preparation from Saccharomyces fragilis which contains a fructosidase (inulase), whilst a microbiological technique has been developed that will give complete hydrolysis of the inulin. As with acid hydrolysis the fructose: glucose ratio is about 75:25. After separation from the glucose the fructose syrup is treated with ion-exchange resins and activated charcoal to remove colouring, foreign flavours and non-carbohydrate impurities.

Industrial alcohol - fermentation of the carbohydrates in Jerusalem artichoke to produce ethanol is a long established process. Recent developments using cells of Kluyveromyces marxianus immobilised in beads of sodium alginate have greatly accelerated both the speed and efficiency of the process. Almost complete

fermentation of the carbohydrate is claimed, with yields of 2 500-6 500 litres of ethanol per hectare, depending upon the size of the crop.

Major influences

The commercial development of the Jerusalem artichoke has been handicapped by the perishable nature of the tubers and the fact that the tubers are usually compared with potatoes, although very distinct as regards composition and flavour. Also, they can sometimes cause digestive disturbances. Other disadvantages are the high cost of harvesting and the fact that it is often difficult to remove all the tubers from the soil; in some areas it has become a noxious weed. Nevertheless, in some countries this root crop is of considerable importance as a livestock feed and as a source of natural sugars and alcohol; there are signs in the literature that

interest could increase as new technologies are developed.

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