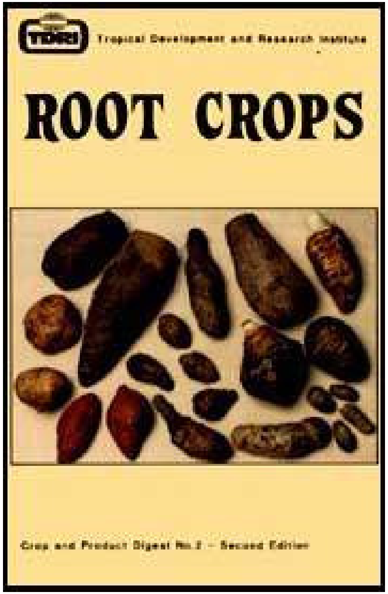

Root Crops (NRI, 1987, 308 p.)

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

Kudzu (Pueraria lobata)

Common name

KUDZU

Botanical name

Pueraria lobata (Willd.) Ohwi syn. P. thunbergiana (Siab. and Zuva) Bouth., P. hirsuta Schneid. non Kurz., P. triloba (Lour.) Makino. P. tuberosa (Roxb.) DC.

Family

Leguminoseae.

Other names

Arrowroot vine; Baite, Bala (N. Cal.); Denai (Yap. Is.); Fen-ko (China); Gmadhi hulu (Ind.); Japanese arrowroot; Ko, Ko hemp, Ko hue, Ko t'eng (China); Kudazinila teigi (Ind.); Magnagna (N. Cal.); Rheru (Mar Is.); Va yaka, Yaka (Fiji).

Botany

Pueraria is a small genus of perennial twining herbs or shrubs with tuberous roots. P. lobata is a vigorous vine, which climbs or trails over the ground with stolons rooting at the nodes. The leaves are trifoliate with entire or slightly 3-lobed leaflets, pubescent, 5-12 cm long and 4-10 cm broad. The flowers are borne in dense, pubescent racemes 20-50 cm long, are mauve to violet and fragrant. The pods are flat, oblong-linear, 5-10 cm long, hairy with 8-20 seeds. P. tuberosa is generally similar but the leaf margins are entire, the racemes slightly longer, and the flowers are blue to purplish-blue; the pods are constricted between the 3-5 seeds, and somewhat shorter. In both species the roots are elongated and often tuberous, and may reach to as much as I m in length and 40 cm in diameter and weigh up to 40 kg, though such sizes are relatively uncommon. They may be tapering, cylindrical or a variety of irregular shapes.

Origin and distribution

P. lobata is believed to have originated in the China/Japan region of eastern Asia, where it is still cultivated for the edible roots, especially in China. It was at one time a staple food in South-East Asia and Oceania. It was introduced into the USA as a food plant, but became popular as a crop for erosion control, and quickly spread out of control and has assumed pest proportions in some areas. It was introduced into India in the

1920s, but was not as successful as P. tuberosa which has long been cultivated there. These two species, along with one or two other species of Pueraria are now widely cultivated in the tropics and subtropics, mainly as as cover crop in regions liable to soil erosion.

Cultivation conditions

P. lobata does best in moderately humid subtropical and warm temperate regions; P. tuberosa thrives in a wider range of conditions from sea level in the tropics to 1 200 m (in India), except in very humid or arid areas. A wide variety of soils may be used, though sandy loam is preferred. Both acid and alkaline soils are tolerated, with pH between 5 and 8. It can be grown on poor acidic soils deficient in calcium and phosphorus, but responds well to fertilisers, either organic or chemical. Soil preparation can be minimal. For establishment the land should be ploughed but ridging or furrowing is not essential; in India planting is often in small hills.

Planting procedure

Material - seeds or cuttings. P. lobata does not set seed

freely but P. tuberosa produces seeds abundantly.

Method - vegetative propagation (more commonly used, especially for P. lobato) employs rooted cuttings (crowns), 1-2 years old, planted in holes large enough to hold the roots comfortably. Watering should be carried out until the crowns are established. Regular cultivation is required in the first one or two years for the plant to produce the numerous intertwining stolons which root and produce tubers at the nodes.

Field spacing - seeds are sown at about 100 x 100 cm. For crowns, 30 x 30 x 30 cm is commonly used.

Seed rate - about 400 crowns/ha (a single plant will normally cover 5-6 m2 of ground per year, and this planting rate should ensure a full cover).

Pests and diseases

Kudzu appears to be relatively free from serious pests and diseases and when well established forms a heavy enough ground cover to suppress weed growth, though a yellow leaf mould (caused by Mycovellosiella puerariae sp. nov.) has been reported.

Harvesting and handling

The roots are dug by hand: the depth to which they penetrate and the irregular pattern in which they grow (from rooting stolons) does not lend itself to mechanisation. A considerable amount of searching among the tangled vines may be necessary to locate suitable roots.

Primary product

Root tubers - which are starchy, and in both P. lobata and P. tuberosa may be 30-60 cm long, 25-30 cm in diameter and weigh 35 kg (or larger on older plants), sometimes connected to the main roots and each other by thin, stringy roots.

Yield

Yields of 5-7 t/ha have been reported.

Main use

The main use of kudzu tubers is as a source of edible starch, especially in Japan. This starch, 'kudzu powder', is highly regarded and is used instead of arrowroot starch, corn starch, potato starch, etc or gelatine in many Oriental recipes. It is stated to have a subtle flavour and unique aroma, and to produce excellent gels

of exceptional clarity. It is used as a basis for soups, sauces, jellied salads and desserts, noodles, etc.

Subsidiary uses

The tubers may be cooked and eaten in a manner similar to other root crops, but are excessively fibrous, especially in P. tuberosa. The starch can be used as a substrate for the lysine-enriched baker's yeast and ethanol-fermentation process. In China and Japan decoctions of the root are used for colds, fever, dysentery and other complaints; in India dried slices of the root, and in Japan a cream made from kudzu powder, are taken internally for the same purposes.

Other uses

Kudzu is regarded primarily as a perennial multipurpose

crop, being especially valuable in soil conservation because of its deep and strong root system and heavy ground cover, but it is also grown as protein-rich forage or as green manure; the tubers are an added bonus. Its exceptional ability to cover ground and vegetation - even trees - quickly, and the difficulty of eradicating it, has led to its being regarded in parts of the southern USA as an extremely troublesome weed. However, its highly prolific quality has enabled it to perform well in a process being developed for producing methane involving systems of treating waste water with higher plants.

Secondary and waste products

Fibre - the stalks yield about 46 per cent of crude fibre which has been used for centuries in Japan, Korea and China to make a cloth ('grass cloth') that is valued both

for its texture and its durability. Fishing nets are still occasionally made from the fibre.

Tobacco substitute - it has been proposed that the leaves could be used as a tobacco substitute or that an essential oil obtained from the plant might be used as a tobacco additive (see Special features).

Biomass - the extremely high rate of growth of kudzu has led to interest in its possible use in a biomass programme.

Special features

A typical analysis of the edible portion of P. lobata tubers is: moisture 68.6 per cent; protein 2.1 per cent; fat 0.1 per cent; carbohydrate 27.1 per cent; fibre 0.7 per cent; ash 1.4 per cent; calcium 15 mg/100 g; iron

0.6 mg/100 g; phosphorus 18 mg/100 g.

A glycoside daidzin, an aglycone daidzein and an isoflavone puerarin are among compounds identified in the roots. An essential oil has been obtained from the leaves, in which have been identified 2-methoxy-4vinylphenol, 2-methoxy-5-vinylphenol, damascenone, phytol, megastigmatrienones, 3-hydroxy-13-ionone, and 3-hydroxy-13-damascone. The last three compounds have previously been reported only from tobacco leaves.

The dried roots contain about 40 per cent starch; the easily digested grains are round, kettle-drum shaped, or polygonal, 16-35 microns in diameter.

The extract of the vine is stated to contain traces of a gibberellic acid-like substance.

No comparable analysis of P. tuberosa is available, but it has been reported to contain as much as 28 per cent crude fibre on a dry weight basis. It is stated that, in addition to starch, sucrose, glucose and fructose occur in the carbohydrates, and 13-sitosterol is present. It is also reported that an extract of the tuber is active against Helminthosporium sativum.

Processing

Starch (kudzu powder) - the preparation of kudzu powder in Japan is a cottage industry or even done in the home. However, there are a few small commercial plants which produce the starch for export.

The process involves pulverisation of suitable roots and an elaborate succession of settling and filtration stages, and is extremely time consuming and labour intensive:

full details are given in Shurtleff and Aoyagi, 1972 (see Bibliography).

Fibre - vines of suitable length are boiled to loosen the soft layers and after thorough washing are fermented and teased out into fibres. As with starch, the process is complex and labour intensive and is also described in detail in Shurtleff and Aoyagi, 1972.

Production and trade

No information is available about the extent of production of kudzu. In the USA it grows wild over considerable areas of the south-east USA and is occasionally cultivated as a forage or cover crop, but the roots are relatively little used. It also grows wild in parts of south and east Asia, and occasionally is cultivated for its roots as well as for forage or cover. It

appears, however, that much of the material used in processing comes from harvesting the roots or vines from the wild material.

There is a small export trade from eastern Asia to the USA of kudzu powder (starch), mainly to 'health food' outlets.

Major influences

The fibrous nature of the root tubers makes them unattractive as human food, and difficulty of harvesting militates against commercial production. However, the high quality of the starch seems to ensure a continuing popularity in gourmet foods in eastern Asia, and efforts are being made to develop the use of this product in the USA. Recent work in the USA has also suggested that the root could provide a vitamin-enriched source of

starch for ethanol and yeast production. The vine, which does not present the harvesting problems of the root, has also been proposed in the USA as a source of high tensile strength fibre for textiles, clothing and wallpaper. The rapid growth of the vine makes it a possibility for the production of biomass in an energy programme.

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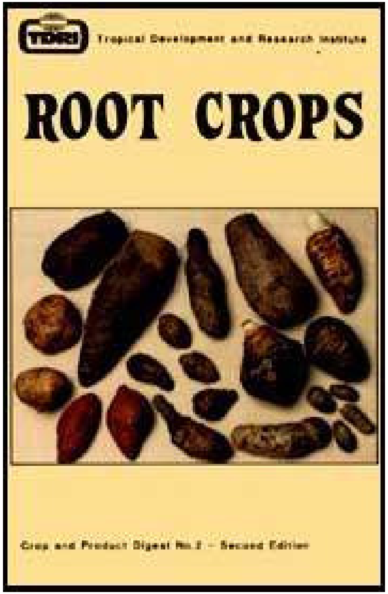
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leontopetaloides)

- **Elephant yam (Amorphophallus spp.)**
- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
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- **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

Lotus root (Nelumbo nucifera)

Common names

LOTUS ROOT, Indian Lotus, Lotus, Sacred Lotus.

Botanical name

Nelumbo nucifera Gaertn. syn. Nelumbium speciosum Willd., Nelumbium nelumbo Druce.

Family

Nymphaeceae.

Other names

Agyptische bohne (Ger.); Ambuj (Ind.); Baino (Philipp.); Bhen (Ind.); Bua luang (Thai.); Chinese water lily; Gliglio de Nilo (It.); Hasu-n-ne (Japan); Jamaica water lily, Kamal, Kanwal, Kumala (Ind.); Lotier (Fr.); Nilli lili (Ger.); Ninfea d'Egetto (It.); Padma, Pankaja (Ind.); Patma (Mal.); Tarate (Indon.).

Botany

A perennial aquatic herb, rooting in mud, with a creeping white globulous rhizome which produces, at intervals, a single leaf and a single flower. Leaves are peltate, 60-90 cm in diameter on very long petioles and are often raised 1-2 m above the surface of the water. They have a wax coating that causes rain water to form large drops that roll off the edges of the blades. The

flowers are solitary at the ends of long stems, each with four sepals and numerous petals and stamens: they are large, 15-25 cm across, very showy, variously coloured in shades of pink, and are followed by a somewhat cone-shaped torus, 5-10 cm in diameter, with 10-30 carpers sunk into the upper surface: these carpers mature into ovoid nut-like, edible achenes. The leaves and stems arise from thick spreading rhizomes which radiate out from the original plant and root frequently; the growth of the rhizomes is rapid and new plants are quickly established from buds on the rhizomes.

Origin and distribution

The plant appears to have originated in South-East Asia and possibly Africa and has spread throughout the lowlands of southern Asia and into Australia. It was early introduced into other tropical and subtropical

regions and was an important plant of ancient Egypt and other eastern Mediterranean countries. It is now grown mainly as an ornamental in lakes and ponds but also as a source of food in many areas including India, Japan, Malaysia, China, Hawaii, and to a small extent, California.

Cultivation conditions

Although mainly grown in tropical and subtropical regions, lotus root can withstand a considerable degree of frost, and in India may be found from sea level up to 1 800 m. It is grown in lakes, ponds and rivers.

Planting procedure

Material - lotus root can be propagated from small pieces of rhizome having at least one eye, or from seed.

Method - a number of methods are described in the literature, among them the following:

(i) Pieces of rhizome are planted with the eyes just above the soil surface and the water level is maintained at about I m of water throughout their growing period.

(ii) Pieces of rhizome are placed horizontally about 15 cm below the soil surface, and water allowed to cover the soil, but with the crown of the developing plant just breaking the surface of the water. The water level is raised as the plant develops.

(iii) A method of planting in a filled pool or pond is to put sprouting pieces in a basket, pot, tub or other suitable container filled with a mixture of soil and compost or FYM, and then place the container in the pool in such a way that the crown of the plant is just

above the water surface. The container should be on bricks or stones, and as new growth appears the container is lowered by removal of bricks to maintain the crowns just on or above the water surface.

(iv) When grown from seed, the seedlings are raised in nursery beds and planted out in the ponds after about 2 months in the manner indicated in (ii).

Seed rate - approximately 45 kg of rhizome pieces are used to plant one hectare, or 10-12 kg of seed. Planting density is low because of the very rapid growth of the rhizomes, reported as up to 15 m2 per year.

Pests and diseases

In Japan, rhizome rots have caused a considerable reduction in lotus root production; two organisms have

been identified, Bacillus nelumblii and Fusarium bulbigenum Wr. nelumbicolum, and are associated with iron deficiency, especially on light sandy soils. Rice root worm, Donacia provostii, also affects the crop in some areas, but effective control is reported to be obtained by a pre-planting application of aldrin at the rate of 1-2 kg/ha. In countries where aldrin is not permitted carbofuran at 5 kg/ha or chlorpyrifos at 2-5 kg/ha should be effective.

Growth period

The rhizomes mature to a suitable stage for eating in approximately 6-9 months, though if not harvested will continue growing until checked by competition with their neighbours.

Harvesting and handling

The roots are normally dug by hand after the ponds are drained just before harvesting, but a mechanical harvesting system is being developed in Japan.

Primary product

Rhizomes - the fleshy starchy rhizomes when harvested at 6-9 months can measure 60-120 cm in length and 5-10 cm in diameter, and resemble the links of large sausage, each individual link being about 7.5-15 cm long and weighing from about 150 g to 1.2 kg. A cross-section reveals one central air passage surrounded by several smaller ones and the flesh can vary in colour from white or grayish-white to pink or orange-buff. They are very fibrous and when freshly cut they exude a mucilaginous juice.

Yield

In India the crop is reported to yield 3.5-4.5 t/ha.

Main use

The fresh rhizomes are eaten after roasting; dried slices are fried as chips or used in curries. The rhizomes may also be pickled and quick frozen, but must be eaten young otherwise they are very tough and fibrous.

Subsidiary uses

The rhizomes can be used as a source of a starch, similar to that of arrowroot.

Secondary and waste products

Carpels - the carpers are regarded as a delicacy and are eaten after the removal of the outer skin and the embryo, which is intensely bitter. They are eaten raw,

roasted, boiled, candied or ground into a flour.

Flowers - the flowers are often used for decorative purposes, especially in religious festivals, and were formerly used as a source of perfume.

Leaves, petioles - these are sometimes eaten as a fresh vegetable. The petiole yields a yellowish-white fibre and the leaves are sometimes used for medicinal purposes.

Special features

Rhizomes - figures for composition of the edible portion of the rhizomes have been quoted as: energy 331 kJ/100 g; water 78.3 per cent; protein 1.4 per cent; fat 0.2 per cent; carbohydrate 19 per cent; fibre 0.8 per cent; ash 4 per cent; calcium 4 mg/100 g; iron 0.6 mg/100 g; phosphorus 65 mg/100 g; potassium 500

mg/100 g; thiamine 0.14 mg/100 g; riboflavin 0.2 mg/100 g; niacin I mg/100 g; ascorbic acid 4 mg/100 g.

The starch grains are large, much elongated, 65-100 microns, one end is usually rounded and contains the excentric hilum, the other is usually truncated. The rhizomes are reported to contain approximately 2 per cent aspargine.

Carpels - the dried carpers have the following approximate composition: moisture 10 per cent; protein 17.2 per cent; fat 2.4 per cent; carbohydrate (mainly starch) 66.6 per cent; fibre 2.6 per cent; ash 3.8 per cent; calcium 136 mg/100 g, iron 2.3 mg/100 g, phosphorus 294 mg/100 g. In addition to starch, the carbohydrate content consists of sucrose 4.1 per cent, and reducing sugars 2.4 per cent (as percentages of

fresh weight).

Alkaloids - the leaves, carpers and rhizomes are reported to contain alkaloids: nelumbine, which acts as a cardiac poison, has been isolated from the petioles, pedicel and seed embryo, while the leaves contain roemerine, dehydroroemerine, nuciferine, dehydronuciferine, pronuciferine, nornuciferine, N-nornuciferine, armepavine, liriodene, N-methylcoclaurine, anonaine and dehydroanonaine.

Processing

In China, a fine white starch, similar in properties to that from arrowroot, is obtained by pulping the clean washed rhizomes and pressing the resultant pulp in a wooden press. The milky extract is collected, mixed with an equal quantity of pure, clean water and the starch left

to settle out. It is filtered and then dried on bamboo mats in the sun.

Major influences

There is a demand for lotus root as an ingredient in Chinese foodstuffs, in Japan and in India, but development outside China has been hampered mainly owing to the high cost of harvesting the crop; however, the development in Japan of a technique for mechanical harvesting may ease this situation.

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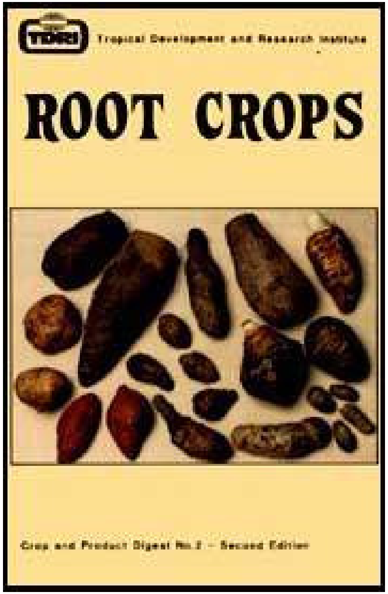
Root Crops (NRI, 1987, 308 p.)


TDRI
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ROOT CROPS
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- **False yam (Icacina senegalensis)**
- **Giant taro (Alocasia macrorrhiza)**
- **Hausa potato (Solenostemon rotundifolius)**
- **Jerusalem artichoke (Helianthus tuberosus)**
- **Kudzu (Pueraria lobata)**

Maca (Lepidium meyenni)

Common name

MACA.

Botanical name

Lepidium meyenni Walp.

Family

Cruciferae.

Botany

A turnip-like plant with a rosette of 12-20 basal leaves, roughly elliptical in outline, formed by a flat and fleshy rachis, with minute lobes distally arranged. The basal lobes are elliptical, entire, about 0.5 cm long, the medium and upper lobes are deeply dissected and about I cm in length. Below the ground the central axis is a fleshy structure consisting of the swollen tap root and hypocotyl, similar in general shape to a globe salad radish, but ending in a thick strong root with numerous lateral rootless. The flowers are whitish, about 0.5 cm long, on slender pedicels. The fruit is a 2-celled silicula and the seeds are ovoid, about 0.2 cm long, smooth and

reddish.

Origin and distribution

The mace originated in the high Andes and is rarely found outside this region. It is cultivated to a limited extent in the high Andean plateau region of Peru and Bolivia at an altitude of 3 500-4 000 m.

Cultivation conditions

Maca grows well at high altitudes and is very resistant to frost. The plant is severely exhaustive of the soil so that after cropping the plots are normally left fallow for 10 years.

Planting procedure

Material - mace is propagated from seed which is

obtained from specially selected plants. These are transplanted after harvesting into heavily manured plots and left to produce seed.

Method - the seeds are mixed with fine earth and scattered onto the carefully worked soil and then one or two sheep are allowed to walk over the plot to press the seeds into the soil. The seedlings are not usually thinned and no after-care is given.

Seed rate - approximately 300 kg of seeds per hectare.

Growth period

The crop takes 8-10 months to reach maturity.

Harvesting

Macas are usually harvested after frost has damaged the

leaves; the plants are dug up by hand or hoes, the leaves are removed and the roots cleaned and dried in the sun. All the roots are harvested, even very small ones. Dried maces are stored in bags. They will keep in good condition for years, although after the second year the flavour deteriorates.

Primary product

Roots - the swollen root-hypocotyl is rich in starch and sugars and can be creamy-yellow or light or dark purple in colour; yellow ones are usually the most popular.

Main use

The mace is used as a food both fresh and dry. It is often cooked in milk or water to form a porridge, which has a sweet aromatic taste and is considered a delicacy.

Subsidiary uses

The roots are sometimes used as a flavouring for a local alcoholic beverage called 'aguardiente'; they are also used medicinally to increase fertility.

Special features

In addition to starch and sugars, the presence of alkaloids, fatty acids, tannins and small quantities of saponins has been reported.

Major influences

Although traditionally a useful food crop in the inhospitable high altitude regions of the Andes, cultivation of the mace is declining. However, germplasm has been collected and is being held under the supervision of IICA, Turrialba, Costa Rica.

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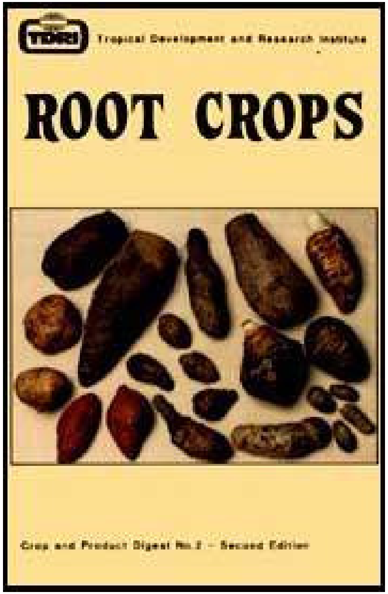

Root Crops (NRI, 1987, 308 p.)

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(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.)

Oca (Oxalis tuberosa)

Common name

OCA.

Botanical name

Oxalis tuberosa Molina.

Family

Oxalidaceae.

Other names

Apio blanco, Cuba, Cuva (Venez.); Huisisai, Ibias (S. Am.); Macachn, Miquichi (Arg.); Papa extranjera (Mex.); Quiba (Venez.)

Botany

A small compact annual tuberous herb, usually 20-30 cm high, with cylindrical succulent stems which can vary in colour from various shades of green to a purplish-red,

and normally arise from the base of the plant in the form of a cone or hemisphere. The leaves are spirally arranged, phyllotaxis 2/5, and may be green or purple, with or without hairs and also showing a great variation in form. The flowers are trimorphic with long, short or mid-length styles. The fruits are 5-celled capsules with 1-3 tiny seeds in each, but are rarely formed. The tubers are rhizomes, developing as terminal thickenings of the stolons, generally ovoid, 5-7.5 cm long, but highly variable in shape and size, and characterised by long transverse shallow depressions in which the eyes are situated. Oca is a very ancient food plant of the Andes and in Peru alone over 140 clones have been recognised.

Origin and distribution

Oca grows in the high Andes and is limited to southern Colombia, Bolivia,

Ecuador, Peru and northern Chile, between 4°N and 17°S and an altitude of 2 800 - 4 500 m.

Cultivation conditions

Moderately cool day conditions and cold (possibly frosty) nights, frequently misty or cloudy weather, favour the growth of the plant. The optimum day-length for tuber formation in oca is 9 hours, while 13 hours is suitable for its vegetative development. Under short days the stolons penetrate into the soil and form tubers, under long days they grow into above-ground stems.

Planting procedure

Material - usually propagated by means of cut pieces of tuber, each piece bearing one to three eyes.

Method - usually planted at the beginning of the rainy

season and generally interplanted or rotated with other tuber crops (eg ulluco or potato), cereals or legumes. The Indians of the high Andean plateau cultivate it by hand in a manner similar to potatoes, and keep it free from weeds and earth it up three or four times during its growth.

Field spacing - planted in rows 50-90 cm apart with 20-40 cm between the plants.

Pests and diseases

In Peru the most serious pests reported are nematodes and the tuber borer Crisomelidas. Many fungi are reported to infect the crop, including Colletotrichum spp., Phyllosticta spp., Puccinia oxalidis, Urocystis oxalidis, Phoma oxalidicola, Septoria sp., and Cercospora oxalidiphila. A strain of arracacha virus B

has been found to infect the plant, though no vector has been identified, and mycoplasma-like bodies have been found in seriously diseased material.

Growth period

Oca tubers mature in approximately 8 months.

Harvesting and handling

The tubers are dug by hand and generally, especially those of the bitter varieties, are left to cure for several days in the sun to eliminate most of the bitterness due to calcium oxalate. Storage life is markedly affected by temperature: at 4°C storage life is stated to be 20 weeks, but at 21°C sprouting occurs and the flavour deteriorates, limiting storage life to about 12 weeks. Converting the fresh tubers to 'chua' (see Processing)

gives a product with long storage properties.

Primary product

Tubers - the starchy tubers are similar to potatoes in size, usually 5-7.5 cm in length and 2.5-3.75 cm in diameter, normally cylindrical or somewhat turbinate in shape. Fleshy overlapping leaf-scales give the tubers a cone-like appearance and conceal the buds in deep set eyes. There is great variation in the colour and flavour of the tubers, some of which are very bitter, others sweet, and the colour can be white, yellow or red.

Yield

Yields are reported to average 4-5 t/ha in Peru, but could be raised to 20 t/ha with improved cultivation methods and disease-free planting material.

Main use

Oca tubers are one of the principal carbohydrate foodstuffs amongst the Indians of the high Andes and are boiled, roasted or candied.

Subsidiary uses

The semi-perishable tubers are often dehydrated to produce 'chua'.

Special features

The bitter forms of oca contain appreciable amounts of calcium oxalate, and it has been reported that most forms are an important source of calcium and iron in the diet of the Andean Indians, though the few available figures do not show exceptionally high proportions of these elements. Composition of the edible portion of oca

tubers is: energy 264 kJ/100 g; water 83.8 per cent; protein I per cent; fat 0.6 per cent; carbohydrate 13.8 per cent; fibre 0.8 per cent; ash 0.8 per cent; calcium 4 mg/100 g; iron 0.8 mg/100 g; phosphorus 34 mg/100 g; vitamin A trace; thiamine 0.05 mg/100 g; riboflavin 0.07 mg/100 g; niacin 0.4 mg/100 g; ascorbic acid 37 mg/100 g.

Processing

Chua, a form of dried tuber, is commonly made, especially from the bitter varieties. For details of its manufacture see the section on Processing under Potato (Solanum tuberosum). For use, the chua is soaked in water and then eaten in soups or stews. An approximate analysis of chua is: water 13.6 per cent; protein 4.2 per cent; carbohydrate 77 per cent; fibre 1.8 per cent; ash 3.6 per cent.

Sweet types of oca are sometimes dried to form a product known as 'cavi', which is cooked with honey or cane sugar syrup.

Production and trade

Oca is consumed mainly by the rural population of the Sierra regions of the Andes and there is little information relating to production. It has been estimated that in Peru production is about 32 600 t/a, of which approxi mately 22 000 t are used for human consumption, 4 800 t are used for seed and losses due to spoilage amount to about 5 800 t.

Major influences

In the high Andes oca is of considerable importance and often rivals the potato. However, unlike the latter crop,

oca has not spread to other parts of the world, mainly because of the perishability of the tubers when exposed to lowland tropical temperatures. However, germplasm is being collected and is held under the supervision of IICA, Turrialba, Costa Rica.

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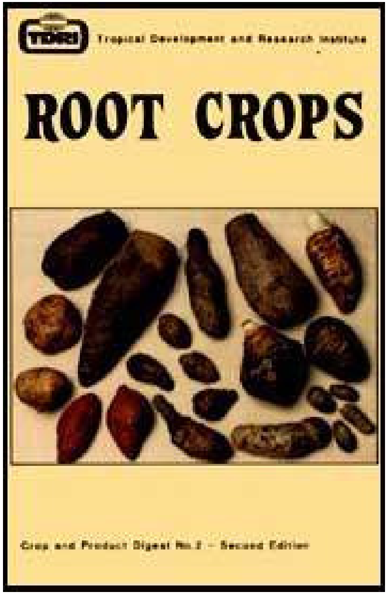

Root Crops (NRI, 1987, 308 p.)

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- **Sweet potato (Ipomaea batatas)**

Potato (Solanum tuberosum)

Common names

POTATO, English potato, Irish potato, White potato.

Botanical name

Solanum tuberosum L.

Family

Solanaceae.

Other names

Aardappel (Nether.); Alu (Ind.); Batata (Port.); Jaga-imo (Japan); Kartoffel (Ger.); Papas (Lat. Am.); Patatas (Sp.); Pomme de terre (Fr.); Viazi (E. Afr.); Watalu (Pak.); Yang shu (China); Yeomilan (Cy.).

Botany

The potato is a herbaceous, freely branching dicotyledonous perennial, usually between 30 and 100

cm tall, with alternate, pinnately compound leaves, made up of three or four pairs of oval leaflets and a terminal leaflet. Cymose inflorescences, arising opposite to leaves (not axillary) near the ends of branches, bear gamopetalous flowers with 5-lobed corollas, which are white, yellow, purple, blue or striped, and about 3 cm across.

The fruit is a spherical berry about 1.5-2 cm in diameter, green or purplish, containing a large number of small seeds. The roots are numerous, fine, fibrous and adventitious. Short stolons with hooked tips are produced from the axils of the lower leaves and become thickened to form stem tubers which have buds (eyes) mainly towards the distal end.
When the aerial part of the plant dies back following the normal maturity cycle in adverse climatic conditions the tubers remain in the ground and sprout to form new

plants when the dormancy of the tuber breaks and climatic conditions are favourable.

Authorities differ as to the number of distinct species of cultivated potato, some recognise as many as 20 species, but the classification of Dodds is widely accepted in which one cultivated species S. tuberosum is recognised, plus five horticultural groups and two hybrid cultivars S. x juzepczukii and S. x curtilobum. There are a great many cultivars, most of which have been bred for temperate climates. Until very recently all potatoes tested in the tropics were selected from such material (India, for example, has tested over 600 temperate cultivars). Only a minute proportion could even be considered for commercial culture under the changed day-length and temperature conditions. However, substantial breeding programmes are underway in several tropical (and temperate) countries

towards the improvement of potatoes for the lowland tropics, often using tropical varieties and species in the breeding lines - varieties that are both physiologically adapted to tropical conditions, and resistant to the major tropical diseases; particular attention is being paid to developing resistance against Pseudomonas solanocearum. True potato seed (see Planting procedure - Material) from appropriate crosses (hybrid seed) may have an important part to play in such improvements.

Origin and distribution

The potato is believed to have originated in the altiplano around Lake Titicaca, at a height of about 3 000 m in the Bolivian Andes, and the main centre of diversity is in the Andes between 10°N and 20°S at altitudes above 2 000 m. This area is still an important source of germplasm for the breeding of new cultivars. Wild species

(varieties) are distributed from Central America to southern Chile. The plant has been cultivated in the Andes since Inca times, but its spread throughout the world has been relatively recent, following its introduction into Spain from Colombia by the Conquistadores in 1570, and its independent introduction into England in 1586. The first potatoes to reach North America came from Europe in about 1621. The potato did not become popular in Europe until about 1663, when it became a staple food in the Irish Republic. During the 16th to 18th centuries it was introduced into the Philippines and other Pacific countries, reaching India in the 17th century. It was little used in England until the 19th century, and about the same time became widely grown in Europe. It is now grown all over the world, especially in temperate climates, though production is increasing rapidly in the tropics and it is now the root crop with by far the

greatest production and the leading position in world trade.

Cultivation conditions

Level land is ideal, especially where operations are mechanised. In tropical highlands, plateaux are often used; in tropical lowlands, valleys are likely to be more suitable than extensive plains as they funnel cool air during the night from neighbouring highlands.

Rainfall - a rainfall of 50-75 cm, evenly distributed throughout the growing period, is considered essential (approximately 2.5-3 cm per week is required). In the tropics up to 15 cm per month can be tolerated. Drought, even for short periods, can have a serious effect upon yields and the quality of the crop, especially when it is accompanied by high temperatures or when it

occurs during the last 9 weeks of growth. Inadequate or irregular water supply not only results in poor yields, but the tubers are usually malformed, often having very thick skins and a knobbly appearance. It is therefore recommended that natural water supplies be supplemented by irrigation when the available soil moisture is only 50-60 per cent of the requirement, particularly during the emergence period. Under arid conditions irrigation, either spray or flood, should be carried out at frequent intervals until the tubers are formed, then the interval is gradually decreased to reduce the possibility of the potatoes developing pre-harvest rots. On light soils, combined with moderately high temperatures irrigation at 3-4 day intervals has been recommended, while on heavier soils 5-7 day intervals should be adequate. When grown under humid conditions, control of late blight (Phytophthora infestans) is often difficult and this is particularly

serious in many tropical areas.

Soil - potatoes can be grown on all soil types, except heavy water-logged clays, but for optimum yields need a well-drained loam or sandy loam, relatively free from stones. Well-drained peat soils are particularly suitable and where the growing season is short, light, well-aerated soils are necessary. The pH may range from 4.8 to 6 (optimum 5.5-6); above pH 6 potatoes are liable to suffer from scab.

The potato is a heavy feeder and responds well to fertilisers, though requirements vary greatly according to cultivar, soil type and climatic conditions. Adequate fertilising is particularly important in the tropics because of the shorter growing period. In the UK 1.25 t/ha of a 13:13:20 complete (NPK) fertiliser is common; for India, nitrogen 120-180 kg/ha, phosphorus 80-100

kg/ha and potassium 80-100 kg/ha or FYM at 12-15 t/ha have been recommended.

Altitude - the importance of altitude is its effect on temperature. Many indigenous South American cultivars can be grown in the tropics at levels of about 2 000 m, but at lower altitudes yields are generally poor. Main crop or late-maturing cultivars from temperate climates can usually be grown with moderate success in the tropics at altitudes between about 400 and 2 000 m, and even down to sea level if there is a marked cool season.

Day-length, light intensity and temperature all interact in their effects on the productivity of potato crops. In general, indigenous South American cultivars will only produce reasonable yields with a day-length of 12-13 hours, but the early-maturing cultivars of temperate regions require a daylength of 15-16 hours; however,

the main or late-crop temperate climate cultivars are successful under long- or short-day conditions.

Certain generalisations can be stated. Yields are dependent upon both tuberisation and the subsequent development of the tubers. In most cultivars the optimum temperature for tuber formation is 15-20°C (up to 22°C in a few cultivars), but short day-length permits tuber formation at higher temperatures. Also, in general, the higher the light intensity during the growing season, the higher the maximum temperature allowing tuberisation. Subsequent development depends upon the deposition of assimilates in the tubers. Net assimilation is at a maximum at about 25°C: above this temperature the rate of respiration increases substantially so that fewer assimilates are retained by the plant. In addition, at high temperatures the partitioning of assimilates between tubers and

vegetative parts favours the latter, particularly for stem and branch growth, this itself reducing the photosynthetic capacity of the plant as leaf area does not increase proportionately.

The best balance of these various factors has been found in temperate regions and is reflected in the high yields obtained in most European countries, the USA and Canada (Table 1). At the other extreme are the lowlands tropics where, until very recently, commercial production was virtually impossible. In tropical uplands the lower (though still high) temperatures, combined with short day-lengths, allow 'reasonable' yields to be obtained. Current trials with heat tolerant clones are showing much improved yields.

Planting procedure

Material - the cultivar to be used is critical. There are many suitable for temperate conditions, both early-maturing and late-maturing. Early-maturing cultivars are not suitable for the tropics, as they require a long day-length, but a few late-maturing temperate cultivars have given moderate success in parts of the tropics.

(i) Tubers, either whole or cut, are normally used for planting. They should be from virus-free stock and these are normally specially grown in areas where the aphid vectors are absent or strictly controlled, often at a considerable distance from the actual production area for the crop. This necessity for virus-free 'seed' tubers has often caused problems in the tropics, requiring the costly importation of planting material from other countries. In some tropical countries it has been possible to grow virus-free seed potatoes in hill areas for planting in the lowlands. Recent work in India has

considerably reduced the cost of seed potatoes, by what is termed the 'Seed Plot Technique'. At certain seasons the aphid (vector) population in the plains is low, and when healthy seed potatoes from the hills are grown during these periods the incidence of virus disease is also low. In the seed plots further precautions are taken by applying systemic insecticides, rogueing infected plants, and removing haulms before the aphid population reaches a certain critical level. Infection is minimal and such seed plots can be maintained in a healthy condition for several generations, supplying seed potatoes to surrounding farms for a number of years before a new injection of hill-grown seed potatoes is required.

Potato tubers enter into a period of dormancy after harvesting; the period of dormancy depends very much upon genetic and environmental factors, but is usually

at least 8 weeks and can be a problem when planting material is required for continuous cropping. However, dormancy can be broken by holding the tubers at 20-30°C for 30-45 days (which are common ambient conditions in the tropics, ie dormancy is broken quickly in such climates), or by treating them with chemicals such as chlorhydrin, potassium or sodium thiocyanate, or gibberellic acid. Naturally-broken dormancy, however, is preferred as it gives a more uniform rate of germination and better growth. Once the period of natural dormancy has ended potatoes will begin to sprout provided that the temperature is above 5°C; the higher the temperature the quicker the rate of sprouting and many growers, particularly those producing early crops in temperate regions, expose the seed potatoes in a 'chitting house' to diffuse light and a temperature of approximately 10°C to accelerate the process. Often the tubers are treated with fungicide before planting to

prevent disease, and when pieces are used these are frequently cut by hand and planted as soon as possible after cutting. Cut tubers can be stored for up to 30 days if they have been cured at 15-21°C and 85 per cent RH for 7-10 days.

(ii) True potato seed (TPS), formerly used only in breeding work, is now becoming a commercial technique. It is easy and cheap to distribute over long distances, which makes it unnecessary to have a source of virus-free tubers relatively close to the main potato growing area. The production of TPS is a specialised but low-cost operation requiring healthy parent plants. Open pollinated seed is collected from commercial varieties. F-l hybrid seed which has greater disease resistance or higher yield potential is being developed. TPS planted directly into the field is often not satisfactory, but planted in trays or a nursery will give

seedlings suitable for later transplanting, or planted in a suitable nursery will give seed tubers for subsequent planting in the usual way. TPS may well prove to be especially useful in the tropics, avoiding the problems associated with obtaining virus-free tubers for planting in these regions.

Method - potatoes may be planted by hand or with mechanical planters, which can be fully mechanical or hand-fed semi-automatic machines. Before planting the field should be ploughed to a depth of 25-30 cm and harrowed so as to produce a fine deep filth. The seed tubers are usually planted in ridges at a depth of 5-15 cm and kept free from weeds; preemergence herbicides can be used for this purpose. In Europe the crop is often repeatedly hoed, up to five times during the season, to control weeds and earthed-up to avoid greening of the tubers.

Tubers grown in a nursery from TPS are planted in a similar manner, or seedlings grown from TPS may be transplanted by hand or mechanically.

In the tropics, planting on ridges would normally be recommended, but whether ridges or level soil be used depends upon local conditions. A flat soil heats up less during the day than ridged soil, as the exposed surface is less: conversely ridged soil is cooler at night, and this may be especially important in areas where nights are warm. Ridging is advantageous in the rainy season or in generally wet locations because it gives better drainage and minimises erosion; flat soil is recommended for relatively dry locations or in the dry season, where daytime temperatures are high and soil moisture is to be conserved. Hilling or ridging after planting helps to control weeds, covers emerging stolons and thus prevents tuber greening, but conversely it loosens the

soil and encourages moisture loss. In general, however, some degree of earthing-up appears to be desirable.

Field spacing - a spacing of 20-30 cm in rows 75-120 cm apart is widely used in temperate conditions, but optimum spacing depends very much upon cultivar and environmental conditions. Wider spacing between the rows normally increases the number of tubers produced; closer spacing increases yield but may decrease the proportion of tubers of marketable size. However, owing to the more rapid maturing of potato plants in the tropics, it is important for maximum light interception to be achieved as early as possible in the life cycle. This may be achieved by closer plant spacing (brought about by smaller distances between rows), but when carried to excess, a high proportion of small tubers is produced, though this also depends very much on the cultivar. It is not possible to give ideal spacings as so many factors

are involved; however, spacings as low as 30 cm between plants in rows 40 cm apart (80 000 plants/ha) have given good results with certain cultivars in Peru, and 60 x 20 cm has been recommended for India. Trials under warm conditions have given maximum tuber yields when clones have reached maximum cover before tuber initiation.

Seed rate - depends upon the spacing and whether whole tubers or pieces are used, but usually ranges from 1.2 to 2.5 t of whole tubers per hectare.

Mulching - is not normally practiced in temperate regions, but for the tropics it is recommended, both for minimising evaporation and for keeping the soil cool. Light-coloured (highly reflective) material should be used, eg rice straw, rice hulls, mature maize leaves, etc are suitable. Mulch should be applied immediately after

planting as the improvement in conditions that it creates is especially important in hastening emergence of the shoots. When the leaves begin to form ground cover the importance of the mulch is reduced.

Shading - in temperate climates this is not normally practiced but recent work in Peru has indicated that artificial shading in the early stages of growth has a ground cooling effect and is beneficial, but reduces yield if long continued. Intercropping can be used to provide shading, but the intercrop should provide only a minimum of competition, eg maize (planted 1-2 months before the potato and widely spaced), palm or citrus groves.

Pests and diseases

Over 100 insect pests, about 100 bacteria and fungi,

about 30 viruses and some 40 or more disorders of unknown cause have been recorded for this crop. Proper control measures are of the utmost importance, together with the breeding of resistant cultivars and the multiplication and distribution of healthy planting material. Some of the common pests and diseases are listed here; many are of world wide distribution though a few are limited to tropical or subtropical areas.

Pests - Aphids are widespread and of considerable economic importance, not only on account of the damage they inflict on the crop but because they are responsible for spreading virus diseases such as leaf roll and mosaic. Several different species attack the crop, including Macrosiphum euphorbiae, Myzus persicae, Aphis gossypii and A. nasturtii. The potato tuber moth Phthorimaea operculella can be very destructive, especially in the tropics, and attacks both the young

plants and the stored tubers. Root eating ants, Dorylus orientalis, have been reported as troublesome in parts of the tropics. Various species of cutworms cause considerable damage to the crop, particularly Agrotis spp., of which the black cutworm, A. ipsilon, is of economic importance in many parts of the world. Diabrotica speciosa (pin worm), leaf miners (Liriomyza spp.) and other leaf-eating insects may cause serious damage in the tropics, especially in the wet season; probably the best method of control is to avoid growing potatoes at this time of the year. The flea beetles, Epitrix cacumeris and E. tuberis, are widespread. The larvae and the adult form of the potato stalk borer, Trichobaris trinotata can cause considerable losses in certain areas, eg the USA. Ladybirds, Epilachna spp., are another widespread pest particularly in dry conditions, and unless controlled can completely defoliate the plants. Wireworms, especially Agriotes spp., are of

considerable economic importance in the USA and the UK. The Colorado beetle, Leptinotarsa decemlineata, is widespread in the USA and many parts of Europe. Both the adults and larvae feed on the potato plants and can quickly defoliate an entire field; in addition, the adult beetles are known to transmit several potato diseases. Root eelworm, Heterodera rostochiensis, is a serious pest, particularly in the UK, where losses as high as 50-60 per cent have been reported for early potatoes grown on infected land during a dry spring and early summer. Other eelworms attacking the crop are Ditylenchus dipsaci and D. destructor; attacks of the latter cause the tuber to dry out, shrink and sometimes crack. The root-knot eelworms, Meloidogyne spp., cause wart-like growths on the tubers, adversely affecting yields, and are serious pests in both temperate and tropical areas. In addition, potatoes may be attacked by slugs and snails; of these the grey field slug Agriolimax agrestis

and the banded grey slug Arion circumscriptus are the most important.

Control of pests is normally by chemicals, eg carbofuran or aldicarb in the furrows before planting for soil pests, and foliar sprays of methomyl or carbaryl for insects attacking foliage; pirimicarb is used against aphids.

Diseases - Late blight caused by the fungus Phytophthora infestans is one of the most widespread and serious of all potato diseases and was responsible for the great potato famine in Ireland during the 1840s. All parts of the potato plant are affected by the disease and infected tubers develop dry or wet rots either before or after harvest, depending upon the degree of infection, environmental conditions and the presence or absence of secondary organisms. There is no cultivar completely resistant to late blight, although some have

a high degree of resistance for several years.

Early blight, caused by Alternaria solani, is another widespread fungal disease of considerable economic importance, but is easier to control than late blight. Scab, due to Streptomyces scabies, often affects potatoes grown in the tropics and in more temperate regions in soils of pH above 6, causing raised greyish white to brown corky areas on the tubers. Black scurf, due to Rhizoctonia solani, is a serious fungal disease, also known as stem canker and 'rhizoc'. It attacks the stems and the tubers, both at and below the soil level resulting in a decrease in the size and the set of the tubers. The fungus has a wide host range and can survive as a saprophyte in the soil, which makes it difficult to control. Verticillium wilt, Verticillium albo-atrum, has become of increasing importance in recent years in both temperate and tropical regions. Several

types of tuber rots, including black rot, powdery dry rot and seed piece decay, are caused by certain species of Fusarium, while other species cause wilting of the plants and stem-end discoloration very similar to Verticillium wilt. In cool temperate regions, skin spot, Oospora pustulans, can sometimes result in the tubers being rejected for human consumption, while in the more northerly areas of the USA powdery scab, Spongospora subterranea, is sometimes a problem.

Of the bacterial diseases, the foul smelling wet rot in the tubers, caused by Erwinia carotovora, is of economic importance. Black leg is another form of soft rot which affects the stems in addition to seed pieces and tubers. Both these diseases are widespread and can only be effectively controlled by the planting of disease-free tubers, careful sanitation and the prevention of tuber injuries. Brown rot or southern bacterial wilt,

Pseudomonas solanacearum, is common in subtropical and tropical regions. Mild attacks cause wilting and death of the plants and if it invades the tubers these break down with an offensive odour. A similar disease which is very contagious and easily spread, particularly when cut pieces of tubers are used for seed is ring rot, Corynebacterium sepedonicum.

Several virus diseases cause serious losses to potato crops. Rugose mosaic, known also as severe mosaic, leaf drop mosaic, potato virus Y and potato vein banding virus, is one of the most serious and widespread, sometimes causing premature death of the plants. It is transmitted by the peach aphid, Myzus persicae; no commercial cultivars have yet been developed which are completely immune to it, though some do possess a moderately high degree of resistance. Leaf roll is another of the more serious virus diseases, and is also

transmitted by the peach aphid and other insects. It is widespread and plants grown from infected tubers are often dwarfed and pale green in colour and may show a characteristic rolling of the upper leaves. The number and size of tubers is greatly reduced and these frequently develop phloem necrosis. Mild mosaic is characterised by a chlorotic mottling of the foliage usually accompanied by a slight crinkling, while other virus diseases include mottle or potato virus X, spindle tuber, yellow dwarf and paracrinkle virus.

The use of healthy planting material is extremely important in disease control. Where Rhizoctonia is a problem the seed potatoes may be treated with benomyl before planting, and shallow planting allows rapid emergence of sprouts, reducing the chance of infection. Verticillium is at least partially avoided by rotation of crops and there are resistant cultivars. Alternaria is

minimised by keeping plants healthy with proper nutrition and water; maneb or zineb are used for control. Phytophthora is treated with copper-based sprays or maneb or zineb. In some countries farmers are advised in advance about the development of weather conditions likely to favour Phytophthora, and preventive spraying is carried out. Viruses are particularly difficult to control; methods include (in addition to the use of virus-free planting material) rogueing and destroying infected plants, control of aphids by insecticides, and, when potatoes are being grown for seed tubers, early destruction of the haulm.

Growth period

Potatoes show varying maturity periods; in temperate climates early cultivars will mature in 3-3 1/2 months, medium in about 4-6 months and late cultivars may take

up to 7 months, depending upon the environmental conditions. Short day-lengths (12-13 hours) lead to earlier cropping and main crop potatoes may mature in as short a time as 4 months, but with reduced tuber yield.

Harvesting and handling

Main crop potatoes should not be harvested until they are fully mature, when the skins have set and there is less likelihood of damage during lifting. In temperate climates the crop is usually harvested 2 or 3 weeks after the foliage has died down either naturally or been killed by mechanical or chemical methods, or a combination of these, or sometimes by frost. In most areas where potatoes are grown on a commercial scale, the crop is harvested mechanically and there is a wide range of methods and machinery used, depending upon the area

to be harvested, the type of soil, labour costs, etc. The more common types of equipment used include diggers of various types, spinners, ploughs and complete harvesters, which lift the tubers, clean them of soil and other extraneous matter, and deliver them into trailers or bags. Frequently the tubers are left on top of the soil for 15-60 minutes, depending upon the temperature, in order for the skin to dry and toughen. Early potatoes are frequently harvested by hand, as the immature skins are easily damaged or rubbed off.

During storage the tubers may be affected by a number of pests, diseases and disorders, and storage procedures are designed to minimise such problems. However, virtually all pests and diseases that cause damage to potatoes in storage also attack the growing crop; many have already been mentioned. Tubers that develop these conditions during storage in most cases

are already infected when put into storage or become infected by the spread of the pest or disease from other previously-infected tubers. In general, low storage temperatures and good aeration markedly reduce the spread both of pests and of diseases.

Physiological disorders are common. Physical damage during harvesting may not only permit easy entry of pathogens, but can lead to internal bruising with discoloration of the flesh, even if the skin is not broken. High or low extremes of temperature cause damage: high temperatures give rise to black heart, resulting from asphyxiation of the tissues at the centre of the potato where the accelerated respiration rate produces shortage of oxygen; chilling (below 2°C) causes collapse of the tissues. Warm temperatures accelerate sprouting, and the associated changes of starch to sugar give sweetness and softening of the tissues, but storage

below 6°C also causes rapid changes from starch to sugars which give an uncharacteristic sweetness and can also cause darkening during certain types of cooking and processing, eg frying or dehydration. Exposure to sunlight leads to greening (and production of toxin). It is therefore essential to put only healthy and dry potatoes into storage, and then to seek a compromise involving as low a temperature as practicable to minimise the development of sprouting and spread of disease, but high enough to avoid low temperature sweetening: in most temperate countries potatoes for eating are stored at about 5-7°C, along with the use of chemicals to delay sprouting: 6-8 months storage life is expected. Among the chemicals used are MENA (methyl ester of naphthalene acetic acid), TCNB (tetrachloronitrobenzene), propham, chlorpropham and nonanol (trimethyl-hexanol). The solids may be dusted onto the tubers as they are placed in store or mixed

with the tubers in granular formulations or the chemical may be vaporised and blown through the stacks of tubers.

Losses can be considerably reduced if the tubers are cured at 12-18°C and 85 per cent RH or higher to encourage cell suberisation, and periderm formation to heal wounds. However, the treatments noted above, except for TCNB and the late application of a vapour, prevent wound healing.

Potato stores range from clamp storage to specially designed buildings. In clamp storage, until recently common in temperate climates, the potatoes are stored in heaps in the field and covered with straw and soil, which gives them protection from light and fluctuations in ambient temperatures, but no humidity control. The lack of aeration often results in serious losses. Storage

in slatted boxes or in sacks, or in dark sheds or other buildings in which cold air is circulated, may be used, though again air circulation around the tubers may be inadequate and may permit overheating in the centre of the bag or box. Purpose-built bulk stores have underfloor ducting through which air can be blown through stacks of potatoes up to about 3.7 m high; vaporised chemicals may be introduced through this ducting. (Storage of potatoes is dealt with in detail by Rastovski and van Es (1981) and Cargill (1976): see Bibliography.)

Primary product

Tubers - which are characteristic of the cultivar in size, shape and colour: they can be round, oval or cylindrical, with smooth or somewhat roughened skin which may be white, yellowish or red.

Yield

In temperate regions yields may be up to about 40 t/ha, but in the tropics yields are much lower (Table 1): although experimentally 40 t/ha has been realised, commercial yields under lowland conditions may be as little as 4-6 t/ha (even in Bolivia, in the Andean highlands, the original home of the potato, yields are only 6-7 t/ha though this is probably associated more with unimproved cultivars than with climate).

Main use

Potatoes are the leading starchy root crop of northern temperate countries and are one of the eight leading staple food crops of the world. They are eaten boiled, roasted, baked or fried and are processed into a very wide range of products, such as canned whole potatoes,

frozen french fries or chips, crisps, dehydrated flakes, powder or granules, potato salad, etc.

Subsidiary uses

Stockleed - since the end of the 18th century potatoes, particularly culls, have been used for stockfeed in European countries. The tubers are fed fresh to cattle or sheep or are stored as silage or dried and used in the form of a meal.

Starch - in certain countries, notably the Netherlands, Denmark and the USA, considerable quantities of potatoes are used for the preparation of a large-grained starch, which is used by the food, paper and textile industries, in the manufacture of adhesives, in the preparation of modified starch products such as amylopectin, and for the preparation of glucose and

dextrins, etc.

	1974–76 average	1984		1974–76 average	1984
World	13.3	15.4	**North and Central America**	25.3	27.3
Africa	8	8.8	Canada	21.5	23.3
Egypt	17.2	16	Cuba	11.4	15.6
Ivory Coast	8.1	12	Dominica	5.1	5
Kenya	7.2	6.5	El Salvador	17.6	18.6
Mauritania	12.5	4.2	Haiti	13.5	15
Morocco	11.4	13.1	Jamaica	8.4	9.2
Nigeria	13.7	14.7	Mexico	11.8	11.9
Republic of South Africa	14.5	13.1	Montserrat	2.5	2.5
Rwanda	6.3	7.9	USA	28.5	31.2
Sudan	18.9	19.2	**South America**	9.1	11.2
Swaziland	2.6	2	Argentina	14.6	17.5
Tanzania	4	5.7	Bolivia	6.4	4.6
Tunisia	9.5	12.2	Colombia	11.8	13
Zambia	8.9	9.4	Peru	6.5	8.8
Zimbabwe	15	15.3	**Europe**	18.4	20.3
Asia	9.9	14.1	Belgium / Luxembourg	33.5	36.7
Bangladesh	9.3	10.6	Bulgaria	11.2	9.8
China	9.1	13.7	Irish Republic	25.7	28.9
Indonesia	7.1	7.5	Netherlands	35.1	41.7
Israel	30.6	46	Portugal	8.8	8.6
Japan	23.9	27.9	[illegible]	[illegible]	[illegible]
Lebanon	6.9	15			
[illegible]	[illegible]	[illegible]			

Philippines	6.2	10.5	Switzerland	[illegible]	[illegible]
Thailand	7.2	11	UK	25.7	37.4
Oceania	20.9	23.5	Yugoslavia	8.9	9.2
Australia	19.9	23.6	**All developed countries**	15.1	16.7
Fiji	6	5.9			
New Zealand	26	25			
Papua New Guinea	4.7	9	**All developing countries**	9.3	13

Source: FAO Production Yearbook 1984.

Table 1: Potato - Average yields for selected countries (t/ha)

Flour - potato flour is the oldest commercially-processed potato product and is utilised by the baking industry, particularly in the USA, where it is used in the preparation of certain types of bread, pastries, cakes, biscuits, etc.

Alcohol - potatoes may be pulped and fermented to produce alcohol; potato spirits have been used extensively in some European countries for many years.

Secondary and waste products

Potato pulp - which is obtained as a by-product in the manufacture of starch, can be fed to livestock, either wet or as a dried pulp. The dried pulp has the following average composition: water 12.3 per cent; protein 8.4 per cent; nitrogen-free extract 69.4 per cent; fat 0.4 per cent; fibre 5.3 per cent; ash 4.2 per cent.

For every 10 t of potato starch produced, 54 t of pulp of 96 per cent moisture content are obtained, or 1.9 t of dried pulp of 10 per cent moisture content.

Potato processing water effluent - increasing quantities of potatoes are being processed and the effluent water can be utilised as a source of high grade starch or for the production of butane or acetone.

Protein - potato juices obtained in the production of potato starch are being used in the Netherlands and Japan as a source of high grade protein.

Peels - potato peels are sometimes used for pig feed.

Potato sprouts - are used as a vegetable in certain parts of the world.

Citric acid - has been extracted as a by-product in the manufacture of starch or by the hydrolysis of potato starch and fermentation of the resultant sugars.

Special features

The composition of potatoes varies greatly according to the cultivar, environment, cultural practices, etc, but typical figures for the edible portion are: energy 318 kJ/100 g; water 79.8 per cent; protein 2.1 per cent; fat

0.1 per cent; carbohydrate 17.1 per cent; fibre 0.5 per cent; ash 0.9 per cent; calcium 7 mg/100 g; phosphorus 53 mg/100 mg; iron 0.6 mg/100 g; potassium 407 mg/100 g; thiamine 0.1 mg/100 g; riboflavin 0.04 mg/100 g; niacin 1.5 mg/100 g; ascorbic acid 20 mg/100 g.

In addition to being a valuable source of carbohydrate, potatoes are also an important source of protein, iron, riboflavin and ascorbic acid. The ascorbic acid value is the approximate value at harvest: this falls to about 15, 10 and 6 mg after 3, 6 and 9 months respectively. The principal amino acids present are leucine, glutamic and aspartic acids and serine.

Starch makes up some 65-80 per cent of the dry weight of the tuber, while sugars can vary from trace amounts to as much as 10 per cent. Sugar content is largely

dependent upon cultivar, maturity, and the temperature and length of time the tubers have been stored. Potatoes high in sugar taste sweet and have a poor texture when cooked, and in general if the sugar content is above 2 per cent the tubers are unsuitable for processing into food products.

Potato starch is large-grained, contains 25 per cent amylose and 73 per cent amylopectin, and has a high phosphate content. Unless specially treated it has a characteristic odour. Its approximate composition is: water 18-22 per cent; protein 0.08-0.18 per cent; fat 0.11-0.18 per cent; ash 0.2-0.4 per cent. The grains are up to 100 microns in length, with the appearance of oyster shells, but there is considerable variation in the size according to the cultivar and the temperature at which the tubers are stored.

The tubers also contain a number of phenolic compounds, which are partially responsible for certain types of discoloration in raw or processed products. In addition, potatoes contain about 0.01-0.1 per cent on a dry weight basis of a steroid alkaloid, solanine. This is mainly concentrated in the skin, particularly around the eyes, and exposure to light increases the amount present (green areas on the skin are evidence of exposure to light). Solanine is responsible for the outbreaks of potato poisoning which have occurred from time to time and potatoes containing amounts in excess of 0.1 per cent are generally considered unfit for human consumption.

Processing

Canning - the potatoes are washed, peeled with lye, steam or by abrasion, or a combination of these

methods, sorted for defects and size trimmed and sliced if necessary. They are then put into cans and boiling water or a 1.5-3 per cent salt solution added; calcium salts may be added to improve the texture (not more than 0.015 per cent of the net weight of the finished product). The cans are heated to above 70°C, closed and heat processed, normally for 20-55 minutes at 114-120°C, depending upon the size of the can used, and cooled immediately to 37°C.

Dehydration - potatoes are dehydrated to give various products, such as dice, flakes or granules. In the preparation of dehydrated diced potatoes the peeled tubers are diced and the enzymes inactivated by blanching in steam or boiling water. The diced potatoes are next sulphited and sometimes treated with calcium chloride to improve their texture, and then dried on trays or conveyor driers. The rate of drying is dependent

upon the size of the pieces of potato, but normally the operation takes 6-8 hours for pieces not more than 5 mm thick. Potato flakes and granules are prepared by various techniques in which cooked, mashed potatoes are dried: drum driers of the single drum type are used for flakes; air lift driers, spray driers, fluidised bed, or other suitable driers are used for granules and 'mashed potato powder'. In some processes 'adding back' is practiced, when previously-dried granules are added to the moist mash to bring it to a suitable consistency for drying. In both the preparation of the mash and the drying process, conditions have to be carefully controlled to avoid breakage of the potato cells, as free starch causes unwanted stickiness in the rehydrated product. Small quantities of additives are usually employed in the process, eg sodium sulphite and bisulphite to give 150-200 ppm in the product to retard oxidative changes during processing and non-enzymic

browning during storage; antioxidants and emulsifying agents may be added to minimise oxidative changes during storage and to improve the texture of the reconstituted product respectively. Skim milk powder is also a frequent constituent of dehydrated mashed potato products. A moisture content of 5-6 per cent is usually considered satisfactory in the finished material, which, if properly packaged, will retain good quality for a year or more. Transparent packs should, however, be avoided as rancidity develops if the dehydrated product is exposed to light.

Starch - potato starch is prepared either by a batch process or a continuous process, depending upon the scale of operation. The batch process nor mally takes about 3 days and yields on average about 71 per cent of the starch content of the potatoes, while the continuous process takes only a few hours and yields on average

approximately 80 per cent. In the batch process the potatoes are first cleaned in running water and then passed through a rasping machine, which reduces them to pulp. The paste is sprayed on vibrating or revolving screens and the starch milk washed through the screen. The milk contains not only starch granules, but other constituents such as fibre, protein, gums, etc and these are removed by repeated washing with water and settling in tanks. When the starch is sufficiently pure it is dried in steam-heated ovens, pulverised and packed for sale. The continuous process is similar to the batch process as far as screening, but then the starch milk passes from the shaker screen to a highspeed centrifugal separator, where the water, protein, etc are removed. The starch milk from the centrifuge is then screened again through a fine-mesh screen and passed on to starch tables for settling. Sometimes this operation is eliminated by the use of slurry separators.

Finally the starch is dewatered to about 40 per cent moisture by rotary filters before being dried in hot-air driers.

Chuo - (or chua) is the name given to potato and a number of other Andean root crops which have been preserved in a particular manner. It is of great antiquity and is important in the nutrition of the inhabitants of the Andean highlands. The product has a long storage life - it has been reported that chuo was found in 1925 in perfect condition in pre-lnca tombs. Chuo preparation requires the climatic conditions that exist in parts of the Andean altiplano, with very low night temperatures (-10 to - 20°C), high day temperatures (20-25°C) and low RH (30-40 per cent).

Two types of chuo are made, chuo blanco (white chuo) and chuo negro (black chuo). The critical features,

common to both processes, are the freezing of the tubers to allow release of the cell sap on thawing, and skillful trampling to press out the liquid and, in the case of chuo blanco, removal of the skins without destroying the integrity of the tubers. Freshly-harvested tubers are spread out and allowed to freeze and thaw alternately for 1-3 days. As much liquid as possible is then squeezed out of the tubers by trampling. When chuo negro is required the trampled tubers are then dried in the sun for about 2 weeks, yielding a black or dark brown product with a strong flavour. Chuo blanco is obtained by washing the trampled tubers to remove the loosened skins, then leaving them in a running stream

for 1-3 weeks, and subsequently drying them in the sun: a chalky-white crust forms as they dry. Both types of chuo are consumed whole, broken into small pieces, or pounded into flour and used in soups and stews.

Many of the Andean subspecies of potato are bitter and virtually uneatable when fresh, and the loss of sap by trampling and washing (chuo blanco) removes a substantial proportion of the bitter glycoalkaloids, though chuo negro still requires soaking for 1-2 days before cooking to render it palatable. The loss of cell juices during trampling and subsequent washing substantially reduces the protein, ascorbic acid, thiamine and niacin content of the product. Analyses of raw potato, chuo blanco and chuo negro from the same potato stock (on a dry weight basis) have been reported as:

Raw potato: energy 1 525 kJ/100 g; protein 9.5 per cent; carbohydrate 84.1 per cent; calcium 41 mg/100 g; iron 3.6 mg/100 g; phosphorus 227 mg/100 g; thiamine 0.45 mg/100 g; riboflavin 0.18 mg/100 g; niacin 6.82 mg/100 g; ascorbic acid 90.9 mg/100 g; glycoalkaloids

30.4 mg/100 g.

Chuo blanco: energy 1 651 kJ/100 g; protein 2.3 per cent; carbohydrate 94.8 per cent; calcium 112 mg/100 g; iron 4 mg/100 g; phosphorus 66 mg/100 g; thiamine 0.04 mg/100 g; riboflavin 0.05 mg/100 g; niacin 0.46 mg/100 g; ascorbic acid 1.3 mg/100 g; glycoalkaloids 4.2 mg/100 g.

Chuo negro: energy 1 626 kJ/100 g; protein 4.7 per cent; carbohydrate 92.4 per cent; calcium 51 mg/100 g; iron I mg/100 g; phosphorus 236 mg/100 g; thiamine 0.15 mg/100 g; riboflavin 0.2 mg/100 g; niacin 3.96 mg/100 g; ascorbic acid 2 mg/100 g; glycoalkaloids 18 mg/100 g.

Production and trade

Production - world output increased by 16 per cent over the period 1961-70, but fluctuated considerably during the period 1967-70, and although production increased there was an overall fall in area harvested during the decade 1974-84 (Table 2). The developed countries continue to produce the majority of the world's potatoes but the proportion contributed by developing countries increased from about 14 per cent in 1969-71 to 30 per cent in 1984.

Trade - a considerable tonnage of potatoes enters international trade both as seed potatoes and as 'ware' potatoes for consumption. For example, northern European countries import early potatoes from Mediterranean countries to partially fill the gap before their own crops mature, and many tropical countries that cannot produce potatoes economically import them from Europe and North America (Table 3).

	Area harvested ('000 ha)			Production ('000 t)		
	1974-76 average	1983	1984	1974-76 average	1983	1984
World[1]	21 877	20 455	20 303	290 267	287 [illegible]	312 209
Africa	494	648	660	2 968	5 695	5 830
Egypt	45	72	75	774	1 [illegible]	1 200
Kenya	44	66	64	318	496	416
Republic of South Africa	47	70	72	681	857	944
North and Central America	740	719	746	18 727	18 877	20 353
Canada	110	113	117	2 354	2 556	2 728
Mexico	56	74	70	661	835	830
USA	543	503	526	15 453	15 146	16 404
South America	959	809	926	8 737	8 875	10 355
Brazil	194	168	174	1 742	1 818	2 210
Asia	5 560	5 941	5 814	55 089	74 772	82 135
Bangladesh	90	108	109	838	1 [illegible]	1 150
China	4 170	4 300	4 065	37 937	50 025	55 033
Europe	6 489	5 509	5 239	117 876	99 699	10[illegible] 106
France	294	204	205	6 150	5 925	6 200
Netherlands	151	163	160	5 319	5 4[illegible]2	6 673
Poland	2 577	2 220	2 147	48 200	34 472	37 437
UK	217	196	198	5 278	5 857	7 398
Oceania	44	48	48	920	1 [illegible]	1 130
Australia	35	37	37	656	858	873
Soviet Union	7 661	6 882	6 830	84 942	83 060	85 300
All developed countries	14 965	13 179	13 046	225 785	201 199	217 396
All developing countries	6 911	7 327	7 259	64 559	85 901	94 813

Source: FAO Production Yearbook 1984.
[1] Discrepancies between world totals and totals for developed and developing countries are due to rounding off of figures.

Table 2: Potato - Area and Production in selected countries

	Imports			Exports		
	1982	1983	1984	1982	1983	1984
World	5 115	4 747	4 752	5 205	4 750	4 759
Africa	323	482	408	196	194	202
Algeria	204	348	241		1	
Egypt	47	26	47	151	140	136
Kenya				0.2	0.3	0.3
Morocco	22	27	27	21	41	53
Republic of South Africa	0.2	2.2	0.3	15	5	4
North and Central America	489	395	418	503	395	319
Canada	127	122	156	358	274	228
Cuba	40	26	30	15	10	8
Guatemala				26	20	13
Trinidad and Tobago	24	28	24	0.3	0.2	0.2
USA	217	157	147	103	89	68
South America	53	50	51	2	2	2
Argentina	4	2	3	2	0.8	1
Venezuela	30	26	29		0.5	0.5
Asia	520	475	487	514	458	529
China				39	77	73
Cyprus	14	8	11	168	163	174
Israel				23	9	43
Lebanon	90	60	80	88	85	90
Malaysia	45	47	45			
Turkey				54	37	73

Europe	3 647	3 300	3 355	3 934	3 656	3 666
Belgium/ Luxembourg	217	255	274	400	365	312
Federal Republic of Germany	1 021	1 135	1 038	184	140	237
France	287	311	396	496	533	404
Irish Republic	85	31	39	18	19	23

Table 3: Potato - Imports to and exports from selected countries ('000 t)

Table 3 (cont.)

	Imports			Exports		
	1982	1983	1984	1982	1983	1984
Italy	484	480	402	288	397	330
Malta	6	5	6	3	4	5
Netherlands	194	734	304	194	168	166
Poland	47		0.2	19	63	72
UK	606	403	385	163	119	178
Oceania	20	20	22	23	26	21
Fiji	10	11	12			
New Zealand				14	13	16
Soviet Union	62	24	10	30	20	20
All developed countries	4 053	3 605	3 671	4 487	4 080	4 050
All developing countries	1 062	1 141	1 081	717	670	708

Source: FAO Trade Yearbook 1984.

Table 3: Potato - Imports to and exports from selected countries ('000 t) (cont.)

The six major exporting countries are France, Canada, Italy, the Netherlands, the Federal Republic of Germany and Cyprus. The developed countries in general export

rather more potatoes than they import: the developing countries import more than they export. Of the developing countries, however, there are some that export more than they import: notable among these is Egypt. About 25 per cent of the Netherlands exports are as seed potatoes, and also a high proportion of those from the Irish Republic and France.

Major influences

In many industrialised countries increasing quantities of potatoes are processed before being sold to the consumer and the production of tubers which meet the stringent requirements of processors as regards size, composition, cultivar, etc are becoming of considerable importance. The potato is also growing in popularity in many tropical countries, where the demand is often being satisfied by imports from more temperate areas,

and there is a need to increase the production of potatoes in the tropics by the development of improved cultivars, better adapted to the environment and more resistant to disease. There is also a need to develop improved storage techniques for the tubers, both for human consumption and for use as seed. Recent research and actual production data give real hope for a rapid increase in potato production in the tropics.

With the exception of the Netherlands, most countries have found it increasingly difficult to produce potato starch at a price competitive with maize starch in recent years, owning to the increasing labour costs involved in the cultivation of potatoes and the greater utilisation of small or misshapen tubers for dehydration.

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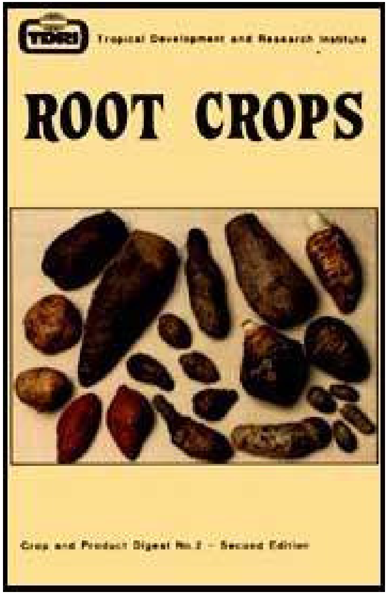
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spp.)

- **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

Queensland arrowroot (Canna indica)

Common names

QUEENSLAND ARROWROOT, Australian arrowroot, Edible canna.

Botanical name

Canna indica L. syn. C. edulis Ker-Gawl.

Family

Cannaceae.

Other names

Achera (Arg.); Achira (Bol., Col., Peru); Araruta bastarda, Bandera de Uribe (Col.); Berg, Bir manso (Braz.); Capacho (Venez.); Chisgua (Col.); Imbirg (Braz.); Purple arrowroot; Sembu (Philipp.); Sug (Col.); Tous les mods (W.I.); Zembu (Philipp.).

Botany

A perennial, herbaceous monocotyledon, rather variable in many characteristics such as colour of foliage, height, size, shape and composition of the rhizomes. The stems are usually purple, normally 0.9-1.8 m in height, but can reach 3 m or even higher and are fleshy and arise in clumps. The large, broad, pointed leaves are entire, normally 30 cm long and about 12.5 cm wide with a marked, thick midrib; they are often purplish beneath. The unisexual flowers have orange-red petals about 5 cm long and 3 petal-like staminodes. The fruit is a 3-

celled capsule with round black seeds. The rhizomes have fleshy segments resembling corms, and are borne in clumps which can reach 60 cm in length. In the Andes two clones are recognised: 'Verdes' with gray-white corms and bright green foliage, and 'Morados' with corms covered with violet-coloured scales.

Origin and distribution

Canna edulis appears to have originated in the Andean region of South America; there is evidence of its cultivation on the Peruvian coast about 2500 BC (earlier than maize and cassava). In South America it now extends from the north, throughout the Amazon basin and as far south as northern Chile; in Central America and the West Indies it has become naturalised as a weed (occasionally cultivated), and it has been spread to parts of Australia, Polynesia and Africa.

Cultivation conditions

The plant is not exacting in its climatic requirements, except that it cannot withstand prolonged exposure to strong winds and in exposed locations must be protected by shelter belts.

Temperature - although best suited to tropical temperatures, Queensland arrowroot can be grown outside the tropics in most areas which have a frost-free period sufficiently long for the tubers to mature. In Hawaii, maximum yields are obtained in areas where both days and nights are relatively warm, and there is little seasonal variation in temperature, yet it is grown extensively in the Aparimac Gorge in Peru, where the days are as warm as 32°C and the nights as cool as 7°C.

Rainfall - it does best with a moderate, evenly-

distributed rainfall, although it can withstand periods of drought satisfactorily. Excessive moisture often promotes abnormal foliage growth, to the detriment of tuber development. In Hawaii, an annual rainfall of approximately 112 cm has been found satisfactory. Irrigation in dry areas may be used.

Soil - the plant can be grown on most types of soil, except heavy clays, provided there is adequate drainage, since it will not tolerate waterlogging. The best yields are obtained on deep sandy loams, rich in humus. It is a gross feeder and experiments in Hawaii have indicated that application of 280 kg/ha of each of ammonium sulphate, superphosphate and potassium sulphate results in higher yields.

Altitude - Queensland arrowroot can be grown at sea level, and in Hawaii produces its maximum yield at

elevations below 450 m. Nevertheless it thrives in Peru at altitudes up to 2 500 m.

Planting procedure

Material - normally propagated from the underground fleshy rhizomes; only those which have attained normal size and development and bear one or two healthy undamaged buds should be used for planting. As a precaution against rotting the rhizomes are sometimes dipped in a 10 per cent solution of copper sulphate before planting.

Method - Queensland arrowroot should be planted on land which has been thoroughly ploughed and cleaned of weeds. In areas where the temperature is fairly uniform it can be planted at any time except during drought. The rhizomes are planted 12.5-15 cm deep in

furrows and kept free from weeds during the initial stages of growth by thorough inter-row cultivation.

Field spacing - on friable loam, spacing of 90 x 90 cm is recommended; on heavier soils, or where weed growth is likely to be a problem, 120x 120 cm is better or even 135 x 180 cm. In Peru the normal spacing used is 60-100 cm between the plants and 100-150 cm between the rows.

Seed rate - approximately 2.5 t rhizomes per hectare

Pests and diseases

Queensland arrowroot is relatively free from pests and diseases; grasshoppers and Japanese beetles are occasionally found feeding on the foliage in Hawaii, where cutworms (Agrotis spp.) are the most

troublesome pest. In Peru, and certain other parts of South America, the crop is sometimes attacked by Calopodes ethlius and Quinta cannae. In addition, the following fungi are reported to affect the crop in Peru: Fusarium spp., Puccinia cannae and Rhizoctonia spp.

Growth period

There is no definite period for maturing; the rhizomes are normally sufficiently mature for lifting 6-8 months after planting, but there is a considerable diversity of opinion as to the best time of harvesting. In Queensland, where growth is checked by cold weather and frosts, harvesting is normally 6-10 months after planting or when the rhizomes indicate they are mature by the triangular slit in the outer scale-leaf of the rhizome assuming a purple colour. In Hawaii, although the rhizomes are often harvested 8 months after

planting, it has been suggested that for starch manufacture harvesting should take place when the plants are 17-19 months old, but there is evidence that it becomes increasingly difficult to prepare good quality starch as the rhizomes age.

Harvesting and handling

The stalks are usually cut by hand and the rhizomes which form a mass near the surface of the soil are either dug by hand or by a tractor with a tool bar fitted with three or four strong tines set at an angle. These break up each of the main clumps of rhizomes into three or four separate portions and also remove a good deal of the soil. The rhizomes are then scraped free from soil by hand and, if required for stock feed or planting, can be stored for several weeks without deterioration, provided they are kept cool and dry; in Japan they are stored over

winter in field pits 30 cm deep. For starch manufacture they must be processed immediately.

Primary product

Rhizomes - the starchy rhizomes vary from cylindrical to tapering and spherical to oval, usually ranging from 5 to 9 cm in diameter and from 10 to 15 cm in length. They are ringed by scale-scars and thick fibrous roots.

Yield

Yields vary considerably according to the length of the growing season, climatic and soil conditions. The following average yields have been reported: Hawaii (8 months) 45-50 t/ha, Queensland 25-37 t/ha, Zimbabwe 15-18 t/ha, Kenya (15-18 months) 50 t/ha.

Main use

Queensland arrowroot is cultivated for the starchy rhizomes which can be utilised as a source of edible starch, as in Queensland, or for animal feeding, as in several African countries. In Queensland approximately 80 per cent of the crop is used for the production of refined starch, I tonne of which is obtained from about 10 tonnes of rhizomes.

Subsidiary uses

Because of the thickness of the fibres the rhizomes are not highly regarded for direct eating. In parts of South America the starch (which contains about 4 per cent sucrose) is often prepared as a dessert.

Secondary and waste products

Tops - the leaves and stalk are also used for animal

feeding and are relished by pigs. The composition of the leaves is approximately: moisture 90.2 per cent; protein 1.1 per cent; fat 0.2 per cent; carbohydrate 7.1 per cent; ash 1.4 per cent; nutritive ratio 1:4.8.

Waste pulp - the pulp and fibrous tissues left after starch manufacture can be used to manure the crop or dried and bagged and used as an animal feedingstuff.

Special features

Analysis of the rhizomes has been given as: water 67-72 per cent; protein 1-1.7 per cent; fat 0.1 per cent; carbohydrate 24-30 per cent; fibre 0.6 per cent; ash 1.4 per cent; calcium 18 mg/100 g; phosphorus 63 mg/100 g; ascorbic acid 7 mg/100 g.

The percentage of starch varies with the age of the

rhizomes and is usually at a maximum between 6 and 15 months, when the sucrose content is also high. The cysteine level in the protein is very low.

Queensland arrowroot starch is characterised by its exceptionally large granules, broadly oval, up to 145 microns in length, with a layered structure resembling a series of stacked plates. The starch gives a clear, transparent, firm gel at a concentration of 3.5 per cent and is easily digested so that it is often used for baby or invalid foods.

Processing

(i) The rhizomes are washed and the fibrous roots removed by hand. This step is difficult to mechanise because of the irregular size and shape of the rhizomes.

(ii) The washed rhizomes then pass to a rasping machine and a slurry is produced.

(iii) The slurry passes to a rotating drum and the fibrous tissue and impurities are deposited on a screen while the starch milk and water pass on to the settling tanks.

(iv) The starch quickly settles out; with starch milk of an initial solids content of approximately 5 per cent, precipitation is complete in about 20 minutes.

(v) The starch is then run off from the bottom of the settling tanks and thoroughly washed with water to eliminate any remaining impurities.

(vi) After repeated washing the pure starch is dried, sieved and packed ready for shipment.

Production and trade

Very little statistical information is available. Production in Queensland during the 1960s fell from a peak of 4 300 t in 1960/61 to 1 910 t in 1968/69. Current production is about 200 t, but it is reported that a small market for high quality Queensland arrowroot flour is again developing in Australia.

Major influences

Queensland arrowroot has potential as a source of edible starch and as an animal feedingstuff. It grows rapidly and can be cultivated over a wide range of climatic and soil conditions in the tropics and subtropics. Under favourable conditions it produces good yields of starchy rhizomes, which can be harvested over a long period, and so the crop is capable of being produced on a continuous basis at minimum cost. Although the plant has been utilised for starch

production in some countries for many years, world consumption is very low, due partly to the irregularity of supply and the low quality of many consignments, and to the rather heavy use of manual labour in the harvesting process.

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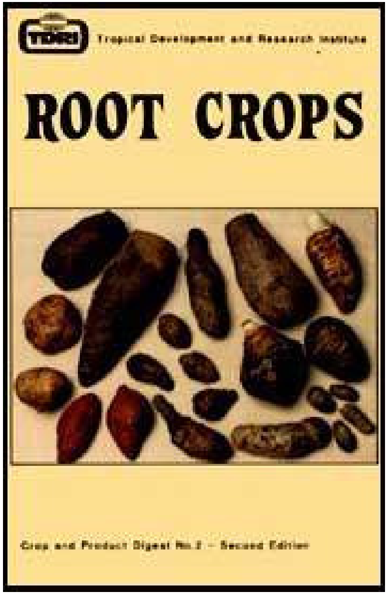
Root Crops (NRI, 1987, 308 p.)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- **Ullucu (Ullucus tuberosus)**

Radish (Raphanus sativus)

Common names

RADISH, Chinese radish, Japanese radish, Oriental radish.

Botanical name

Raphanus sativus L.

Family

Cruciferae.

Other names

Daikon (Asia, Haw., USA); Figal (Ar.); Figeli (Swah.); Hatsuka-daikon (Japan); Labaos (Philipp.); Lobak (Mal.); Lu Fu (China); Monla (Burma); Mourai (Trin.); Muli, Mulla, Mullangi, Mullanki, Mullong (Ind.); Radis (Fr.); Rettick (Ger.); Ripani (Cy.).

Botany

Rophanus sativus is an annual or biennial herb which exists in several different forms: the main distinction is between a small, short-season type of salad radish which is a cool climate plant, and a large type which has a wide range of temperature adaptation. Four botanical

varieties are recognised within the species, R. sativus L., namely radicula, niger, mougri and oleifera, the first two of which are grown for their tuberous roots, while oleifera is grown primarily for the oil in its seeds. Numerous cultivars have been developed within each variety. All varieties intercross freely, and also hybridise with wild Raphanus spp.

The stems may be simple or branched, in the large types reaching as much as I m in height; the basal leaves are long, often pinnately lobed and coarsely toothed, but sometimes are not serrated, while the cauline leaves are simple and linear. The flowers are in long terminal racemes, usually white or lilac with purple veins. The fruit are narrow, indehiscent, 2.5-7.5 cm long and about 1.25 cm in diameter, with a long tapering beak. There are usually 6-12 globose seeds, yellow to chocolate-brown in colour. The tap root (except in var. mougri) is

swollen, and varies from almost globular, about 1-2 cm in diameter in the salad types to as much as I m long and 15 cm in diameter, cylindrical or conical in shape, in the oriental types, and weighing up to 15 kg. The flesh is normally white, though in some may be pink to red. In the salad radish the skin is usually red (occasionally white); in the oriental radish it is normally white.

In this digest it is mainly oriental large-rooted types that are discussed.

Origin and distribution

There are several wild Raphanus, spp. particularly between the eastern Mediterranean and the Caspian Sea, and it is thought that R. sativus must have arisen in this region of Europe and Asia minor. Radish of the niger variety was an important food in Egypt probably as early

as 2700 BC, and is thought to have spread to China by about 500 BC and to Japan by AD 700. The origin of the radicula variety is much more recent and it was first reported in the 16th century (from Europe). The globular forms of salad radish were developed from this variety in the 19th century. The large-rooted radishes are cultivars of the niger and radicula varieties.

Cultivation conditions

Temperature - while the salad types of var. radicula are at their best in cool climates with maximum temperatures about 15°C, all types will tolerate tropical conditions and many do well under high temperatures, with maxima of 30-33°C and minima of 20-22°C. Even the cool climate types require temperatures of 10-13°C for germination and most cultivars are, in some degree, susceptible to frost damage.

Rainfall - a fairly evenly-distributed rainfall of at least 85-100 cm per year is required; with lower rainfall supplementary irrigation is needed.

Soil - radish is tolerant of a wide range of soils, though heavy clays may lead to mis-shapen roots. As the growing season is short, nutrients must be readily available: a general recommendation is for early application of a 6:10:8 complete (NPK) fertiliser at I 100-1 700 kg/ha. In India 40 t/ha of FYM is recommended before planting, followed by top dressing with chemical fertiliser at planting and subsequent application of foliar sprays during growth. Potash has been shown to improve the quality and storage life of the roots, and high potassium fertilisers are used in the Republic of South Africa where the crop is grown for livestock feeding. Deep ploughing is an essential preparation for large-rooted cultivars.

Altitude - in the tropics radish is grown from sea level to at least 1 800 m. In India it is grown as high as 2 700 m in the Himalayas, while var. oleifera has been found suitable for high mountain areas (2 500-3 000 m) in the Yunan Province of China. In Hawaii the Chinese half-long is adapted to year round production in lowland areas and is grown from April to August at elevations over 600 m, while Japanese long types are grown throughout the year at all elevations.

Day-length - the response to day-length varies with the cultivar: many of the red fleshed types require long days in order to produce flowers and seed.

Planting procedure

Material - seed is used for propagation and since, as already noted, radish hybridises easily with wild or

cultivated Raphanus spp. or cultivars only carefully selected seed should be used. Pre-treatment with 200 ppm naphthalene acetic acid or 10 ppm gibberellic acid has been reported to increase yields.

Method - the seed of oriental radish is normally sown in drills at a depth of about 2.5 cm: in the Republic of South Africa it is often mixed with about 100 kg/ha of finely-ground rock superphosphate and sown through the fertiliser hoppers of maize planters. The time of planting depends on local conditions: eg in parts of India radish is sown at the start of the rainy season in regions where rainfall is relatively light, but in regions where the monsoon rains are heavy, sowing is delayed until the end of the wet season. Unless the soil is moist, irrigation should be given immediately after planting and, unless there is rain, further irrigation is required at about weekly intervals. Regular weeding is necessary;

hand-weeding is commonly practiced but nitrofen and diuron have proved to be effective in weed control without damaging the crop. Salad radishes are often sown by hand in nursery beds, often under glass in temperate climates, and then transplanted at the two-leaf stage.

Field spacing - practice differs widely. In the Republic of South Africa the spacing is frequently 30-37.5 cm in rows 90 cm apart (about 32 000/ha); densities as high as 30x 10 cm (300 000 plants/ha) or even more are reported from India and China. Early-maturing salad radishes may be planted at 2.5 x 25 cm (l 600 000/ha).

Seed rate - radish seeds are small, about 70-100/g: about 7-13 kg/ha are required depending upon the size and spacing used.

Pests and diseases

In most areas radishes are relatively free from serious attacks by pests and diseases, but sometimes aphids, particularly Aphis gossypii and the mustard seed aphid Lipaphis erysimi can be troublesome; the latter has been effectively controlled by dusting with DDT or gamma-HCH or by spraying with nicotine sulphate. In addition, flea beetles, Phyllotreta spp., and the cabbage root fly may damage the crop, which is also susceptible to attack by root-knot nematodes (Meloidogyne spp.). In India, severe losses to the crop are sometimes caused by the mustard sawfly, Athalia lugers, and control is either by hand-picking the larvae or by dusting with gamma-HCH.

Black rot, caused by Aphanomyces raphani, which produces blackening and deformity of the roots and is

sometimes associated with boron deficiency, is found wherever white radishes are grown and is reported occasionally to cause serious losses to crops in the Federal Republic of Germany, Canada, Australia and New Zealand. In the Philippines, downy mildew, caused by Peronospora brassicae, sometimes infects the roots, and also a yellowing disease, the causal organism of which is Fusarium oxysporum f. raphani. In addition to some of the above, Indian reports include root periderm brown scorch, Pythium sp., radish mosaic virus, damping off, Rhizoctonia solani, and the seed-borne Alternaria alternata. Other reports include Fusarium spp. and Albugo candida, as well as common diseases of Cruciferae such as crown gall, caused by Agrobacterium tumefaciens, and club root, caused by Plasmodiophora brassicae, the latter in particular from the midwest USA.

Breeding for resistance to pests (eg cabbage root fly),

diseases (eg Fusarium and Albugo), and viruses, is underway.

Growth period

The early-maturing salad types can produce roots of marketable size 20-30 days after planting, and the so-called 'late-maturing' types require only 50-60 days. The large-rooted oriental types, however, require 45-100 days, according to cultivar (eg the Chinese half-long grown in Hawaii, matures in 40-50 days, but under similar conditions the Japanese long type requires 70-80 days).

Harvesting and storage

Early or salad radishes must be harvested as soon as they are mature, otherwise the roots become tough,

pithy and unpalatable and the plants bolt; treatment of some 6 week old cultivars with 0.1 per cent aqueous maleic hydrazide is reported to prevent bolting and help the roots retain their flavour and texture. Winter and oriental radishes remain edible for longer periods and harvesting at the correct stage of maturity is not so critical. The small salad types are often pulled by hand, washed, sometimes topped, and tied in bunches of 6-12 for marketing. Hydrocooling to 4°C is recommended in order to extend their market-life which is very short. Bunched radishes can be kept for 1-2 weeks at 0°C and 90-95 per cent RH; topped radishes can usually be held for 3-4 weeks. Storage at low temperatures in a I per cent oxygen atmosphere has been reported to improve the storage life of salad radishes.

The large roots of late-maturing (winter) radishes and oriental types are either lifted by hand or mechanically.

They store better than salad radishes and will keep for 2-4 months at 0°C and 90-95 per cent RH. At higher temperatures, storage life is often terminated by sprouting but it has been reported that dipping of appropriately trimmed roots in a suspension of campothecin (a naturally-occurring growth regulator) inhibits sprouting and permits storage at 10-20°C.

Primary product

Roots - the enlarged tap roots show wide variation in colour and form according to the cultivar. The early-maturing radishes produce small roots, often globose, of approximately 1.25 cm diameter with a bright red skin, or red with a white tip, and (usually) white crisp flesh. The winter and oriental radish roots are often more conical in shape, usually about 25-40 cm in length and can weigh up to 2.3 kg, although certain oriental radishes can reach a length of 75-100 cm and weigh up to 5-15 kg. Most of these have white skin and flesh.

Yield

Yields of oriental radish are reported to be 15-20 t/ha in India, 12 t/ha in Hawaii and up to 60 t/ha for radishes grown for fodder in the Republic of South Africa. Yields for early-maturing (salad) radishes are lower, about 7.5 t/ha being quoted. Experimental work in Hawaii has yielded up to 50 t/ha of oriental radish suitable for human food. Yield is closely related to spacing; eg in experiments reported from China, at I million plants/ha, yields of 36-46 t/ha were obtained, but the roots were very small: at 500 000 plants/ha, yields were 35.5 t/ha, but the roots were still small. At 250 000 plants/ha, roots of more satisfactory size were obtained and yield was 27.7 t, while at 110 000 plants/ha, the yield was

18.7 t/ha.

Main use

The small early-maturing radishes are usually eaten raw in salads. The large winter radishes and oriental radishes are an important article of diet in many tropical and subtropical (and some temperate) countries, particularly in eastern Asia; the characteristic, somewhat pungent flavour is especially liked in Japan, the Philippines and Hawaii. They may be eaten raw in salads but are more often cooked and eaten as a vegetable (like, for example, turnip), or are made into 'takuwan' or 'sanbaizuke' (see Processing).

Subsidiary uses

Radishes are grown in several countries for livestock

feeding.

Secondary and waste products

The leaves and seed pods of some cultivars are boiled and eaten as a vegetable. It has also been suggested that the leaves could be utilised as a commercial source of leaf protein. In come countries the roots are used medicinally for the treatment of liver and gall-bladder complaints. The seeds contain a non-drying oil which is commercially extracted and is suitable for soapmaking and edible purposes, and is reported to be used in the manufacture of crayons in Japan. The seed cake remaining after oil extraction can be used as a fertiliser or, after the removal of isothiocyanates, as a feedingstuff.

Special features

Roots - average composition of the edible portion has been reported as: energy 86.7 kJ/100 g; water 93.5 per cent; protein 1.05 per cent; fat 0.15 per cent; carbohydrate 3.85 per cent; fibre 0.7 per cent; ash 0.75 per cent; boron 2.08 mg/100 g; calcium 33 mg/100 g; chlorine 19 mg/100g; copper 0.13 mg/100 g; iodine 8 mg/100 g; iron 0.8 mg/100 g; magnesium 15 mg/100 g; manganese 0.05 mg/100 g; phosphorus 29 mg/100 g; potassium 322 mg/100 g; sodium 18 mg/100 g; carotene 0.006 mg/100 g; thiamine 0.03 mg/100 g; riboflavin 0.03 mg/100 g; niacin 0.4 mg/100 g; pantothenic acid 0.8 mg/100 g; ascorbic acid 0.029 mg/100 g; glucose 640 mg/100 g; fructose 390 mg/100 g; campesterol 5 mg/100 g; -sistosterol 6 mg/100 g.

The characteristic pungent flavour of the roots is due to the presence of isothiocyanates, while the coloured cultivars contain anthocyanins which are reported to

occur as naturally acylated, either with ferulic or p-coumaric acids. Catechol has been reported in the red cultivars and flavanols have been detected in minute quantities. A growth inhibitor, raphanusanol, has been isolated from radish seedlings.

Leaves - the leaves of oriental radishes are also nutritious; an analysis gives their approximate percentage composition as: water 87.4 per cent; protein 2.2 per cent; fat 0.4 per cent; carbohydrate 6.1 per cent; fibre 1.5 per cent; ash 2.4 per cent; calcium 400 mg/100 g; phosphorus 300 mg/100 g; ascorbic acid 17 mg/100 g; vitamin A 18 660 IU/100 g.

Seeds - radish seeds contain 30-50 per cent of oil with the following characteristics: SG (30°C) 0.9773; ND (30°C) 1.4704; acid val. 0.9; acet. val. 2.8; sap. val. 178.9; iod. val. 103.1. The fatty acid composition is:

palmitic 1.3 per cent; stearic 1.4 per cent; arachidic 3 per cent; behenic 3.4 per cent; erucic 22 per cent; oleic 60.8 per cent; linoleic 4.5 per cent; linolenic 3.6 per cent.

Processing

After washing, trimming and salting, two types of pickled product are frequently prepared from the roots of oriental radish.

Takuwan - the salted roots are seasoned with sugar, vinegar, some colouring agent, and soaked for some time for flavouring. The soaked material is then bottled for distribution.

Sanbaizuke - is made by treating a mixture of dried radish roots and certain vegetables (eg lotus root, egg

plant, cucumber, etc) with soy sauce, vinegar, pepper and other seasonings. The mixture is salted, compressed and packed for distribution.

Production and trade

	Area (ha)	Production (t)	Yield (t/ha)
1969	na	147.4	na
1970	na	136.1	na
1971	na	159.3	na
1978	65	1 440.9	22.2
1979	85	1 481.8	17.4
1980	81	1 531.8	18.9
1981	81	1 313.2	15
1982	73	1 390.9	19.1

na not available.

Table

Recent statistical information is scant. Published figures from Hawaii are:

A portion of the Hawaiian crop is pickled, averaging

about 425 t for the years 1978-82.

Major influences

There is reason to believe that the production of oriental radish is on the increase. Hawaiian figures show a ten-fold increase since the 1969-71 period, and the very large volume of recent literature from India, Japan, China, the Soviet Union and Central Europe dealing with this crop both as human food and animal feed, suggests that production must be rapidly growing in volume. The main supply to Europe is from Italy, Kenya and the Netherlands. The development of mechanised systems is likely to make the crop more attractive for large-scale operations.

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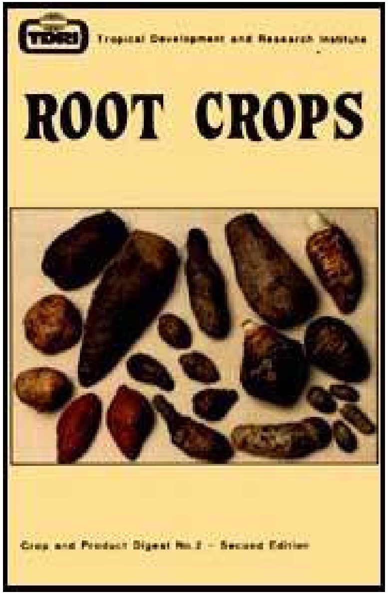
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- **Winged bean (Psophocarpus tetragonolobus)**

Shoti (Curcuma zedoario)

Common names

SHOTI, Zedoary.

Botanical name

Curcuma zedoario (Berg.) Roscoe.

Family

Zingiberaceae.

Other names

Indian arrowroot, Kachoor, Kachora, Kunchur, Palagunda, Palua (Ind.); Temu kuning (Mal.); Temu puteh (Indon.); Zadwar (Ar.); Zdoaire (Fr.); Zedoarwurzel, Zittwer ku-kume (Ger.).

Botany

Shoti is a robust perennial with fleshy, branching rhizomes; leafy or flowering shoots arise from the ends of the rhizome branches. The leafy shoots are up to 1 m tall and consist of a pseudostem of closely compacted concentric leaf bases, with the true stem extending for only part of the way within. Each shoot has about 5 leaves, in two rows on opposite sides of the shoot. The

leaf blades are elongated-elliptical, about 35 x 13 cm, with a purple band on each side of the midrib when young, and with close parallel-pinnate veins, usually brownish. The flowers are pale-yellow, borne on spikes about 15 cm tall, in clusters of 4 or 5 in the axils of bracts which are green at the lower end of the spike, tipped with purple in the middle region, and entirely purple at the uppermost end. At the base of each aerial stem is an ovoid tuber which bears several short, thick, horizontal rhizomes and also tuberous roots.

Origin and distribution

The origin of shoti has never been precisely determined, although northeastern India has been considered by some authorities as the most likely area. It has been in cultivation since prehistoric times and has been spread and become naturalised throughout the rest of India,

South-East Asia, southern China, Sri Lanka, Indonesia and the Philippines. Shoti seldom flowers in cultivation, but does so freely when it 'runs wild'.

Cultivation conditions

The plant requires a hot, humid climate with an annual rainfall of 90-125 cm, and grows from sea level to about 1 000 m in the tropics. Forest is the natural habitat, and when cultivated it is usually shaded (eg in areca nut gardens).

Soil - for optimum yields loamy well-cultivated soils are required, but in Bengal shoti is reported to grow successfully on badly-drained sandy soils where many other crops may fail. The application of 25 t/ha of FYM has been recommended, followed by the application of 340 kg/ha of ammonium sulphate, 450 kg/ha of

superphosphate and 450 kg/ha of potassium muriate in two doses, one 40 days after planting and the other after 180 days.

Planting procedure

Material - propagation is vegetative and usually the mother rhizomes are used; if the daughter or finger rhizomes are used or pieces of rhizome with growth buds, then yields are considerably reduced.

Method - in India germination of the rhizomes is often started in well-manured, hand-watered, shaded, nursery beds during February or March. After germination has started, the rhizomes are planted out in the field at the beginning of the rainy season (June/July). Planting on flat beds, which are subsequently earthed up into ridges after the second application of fertiliser, gives better

results than planting in ridges or on flat beds. After planting in the field the crop usually receives a thick mulch and is kept free from weeds.

Field spacing - the recommended spacing is 22-45 cm within and between rows

Seed rate - 1 100 kg of rhizomes are required to plant one hectare.

Growth period

Shoti normally takes about 10 months to produce a crop.

Harvesting and handling

The crop is usually dug by hand when the leaves begin to wither. The finger rhizomes are carefully separated

from the mother rhizomes, which are used for replanting.

Primary product

Rhizomes - the starchy finger rhizomes are greyish in colour externally and have yellowish-white flesh, darkening in the centre with age to a honey-brown colour. They usually grow to about 15 cm in length and about
2.5 cm thick and have a rather musky odour, with a camphoraceous note and a pungent bitter taste.

Yield

In Orissa, India, yields are reported to average 7.5-12 t/ha.

Main use

Shoti is used mainly as a source of an easily-digested starch, which is rather similar to that of arrowroot, and is utilised in India on a cottage industry basis for the preparation of invalid and baby foods.

Subsidiary uses

The tuberous rhizomes of wild plants are eaten, after washing, in times of food scarcity. The tubers have been sliced and dried and exported from India in the form of chips for the preparation of starch.

Secondary and waste products

The rhizomes are also used for medicinal purposes and in the manufacture of perfumes and cosmetics in India. Steam distillation of the rhizomes yields 1-2 per cent of a light-yellow essential oil and during the 9th to 13th

centuries they were shipped to Europe for the extraction of this oil. The leaves are sometimes used for culinary purposes, especially for cooking fish, and the tender young buds may form an ingredient for salads.

Special features

An analysis of the rhizomes has been given as: water 69-70 per cent; starch 12-13 per cent; fibre 18-19 per cent. The starch grains have an average size of 1.6-4.2 microns and are elongated or ovoid in shape, closely resembling those of arrowroot. An analysis of a commercial sample of Indian shoti starch gave: water 13.1 per cent; starch 82.6 per cent; ash 1.01 per cent. The starch had 31.3 per cent amylose content. Shoti starch is readily hydrolysed by acids and possesses a high viscosity similar to potato starch. A sample of the essential oil extracted from the rhizomes was found to

have the following characteristics: SG (30°C) 0.9724 and ND (30°C) 1.5002, and to contain d-alpha-pinene 1.5 per cent; d-camphene 3.5 per cent; cineol 9.6 per cent; a-camphor 4.2 per cent; d-borneol 1.5 per cent; sesquiterpenes 10 per cent; sesquiterpene alcohols 48 per cent. Phytotoxic compounds have also been isolated, and three antibiotic agents have been identified, the most abundant being ethyl p-methoxycinnamate. An unidentified toxin has been found in impure starch. In the usual process for preparing starch very thorough washing is employed, until the product is white: in this treatment most of the protein is removed (residual content about 10 g/kg) and most of the toxin. Less thoroughly prepared starch, containing 155 g protein/kg, and meal (containing 320 g protein/kg) was highly toxic to rats and chicks. It is not known whether the toxin is chemically associated with the protein or whether it is separately removed along with the protein

during the starch purification process.

Processing

Starch - the rhizomes are shredded into a pulp and steeped for 24 hours in ten times their volume of water, with frequent stirring. The starch slurry is filtered off, repeatedly washed with pure water, then centrifuged and dried at 50°C. The recovery of starch is about 83 per cent and by treatment with dilute sulphuric acid or alkali during the washing process, a starch of approximately 94 per cent purity may be obtained.

Major influences

It is generally considered that production of shoti for utilisation as an industrial source of starch is not likely to be economically viable because of the low yield

obtained.

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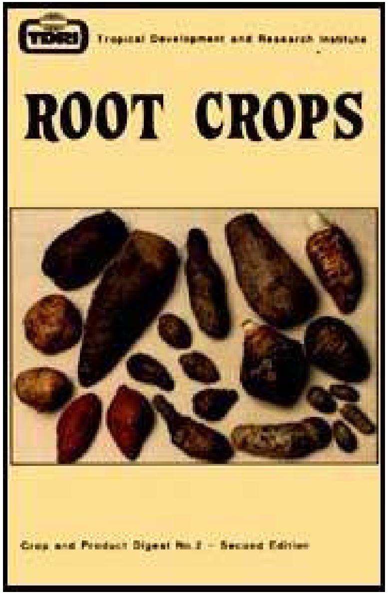
TDRI
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ROOT CROPS
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- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma chamissonis)**
- **Sweet potato (Ipomaea batatas)**
- **Tannia (Xanthosoma spp.)**
- **Taro (Colocasia esculenta)**
- **Topee tambo (Calathea allouia)**

Swamp taro (Cyrtosperma chamissonis)

Common names

SWAMP TARO, Gallan, Giant swamp tarot

Botanical name

Cyrtosperma chamissonis (Schott) Merr.

Family

Araceae.

Other names

Ape de veo (Tah.); Baba, Babai (Kiri.); Bih (Philipp.); Brak (Polyn.); Galiang (Philipp.); lraj (Mar. Is.); Kakake, Karake (Sol. Is.); Lok (Polyn.); Maota (Tah.); Muiang, Mwong (Ponape); Palanau, Palauan (Philipp.); Paluku (Cook Is.); Puna, Pura, Puraka, Pwolok, Simindou (Polyn.); Tao kape (Fiji); Tepuraka (Mortlock Is.); Ula (Polyn.); Via kana (Fiji); Wasrmar (Polyn.).

Botany

The swamp taro is a giant herbaceous perennial with typically 6-8 huge leaves arising from a short subterranean stem. The leaf blades are arrow shaped, 1-

2 m in length, and are borne on stout petioles, 1-2 m long and tapering from about 10 cm in diameter; in some cultivars the lower parts are covered with spines. A mature plant may reach 3-4 m in height. The inflorescence has a long, thick yellowish spathe and a purplish spadix, though the seeds are often not fertile. The stem thickens rapidly at the base becoming a large corm, varying in shape from cylindrical to conical or almost spherical. The size varies with cultivar and age; 15-25 kg is common, but it can weigh up to 90 kg or more in a 10 year old plant. (The giant swamp taro is believed to be the largest plant in the world which produces edible corms.) Cormels which send up leaves and develop into suckers are produced as side shoots on the parent corm after about three years.

Origin and distribution

The swamp taro is thought to have originated in Indonesia and to have been introduced into the Philippines, Papua New Guinea and the Pacific Islands in pre-European times.

Cultivation conditions

A more or less continuous supply of water is essential, though the plant cannot be grown in streams where the water is running swiftly, nor in a fresh marine soil, nor on a slope where the soil is frequently washed away by heavy rains. The plant is tolerant of a wide range of soil types and acidity, and can be grown in areas of moderate rainfall if the soil is deep and swampy, and it is at least partially shaded and sheltered from wind. Ideal growing conditions are natural swamp land rich in humus, covered with 0.2-0.7 m of slow running (or irrigation) water: it is often grown in coastal swamps

just inland of mangrove swamps.

Planting procedure

Cyrtosperma is often the staple starchy food of islanders on coral atolls. The only sure supply of fresh water is the hydrostatic 'lens' which floats at variable depth on the salt water that permeates the lower levels of the coral, sometimes several feet below the surface of the land, and planting procedures have been developed to suit these particular circumstances.

Material - suckers (sprouting cormels) are the commonest planting material although sometimes the top of the corm of the harvested plant is used (setts). In each case one or two of the youngest leaves in the shoot are retained.

Method - in atolls where there are subterranean fresh water lenses, pits are dug deep enough to reach the fresh water layer, which may be 0.5-3 m below the surface. The pits may extend to 10 x 20 m across, and once the fresh water is reached individual holes are dug for each plant and filled with organic material (eg chopped leaves), covered with sand, and the sucker or sett planted in the sand so that its upper roots are at the water level. Additional leaf mulch may be added as the plants grow, or each single plant may be surrounded by a bottomless basket woven in situ from Pandanus or coconut leaves, and the enclosed area filled with a mixture of chopped leaves and soil; as this compost rots and settles more is added. This type of basket cultivation gives the largest corms, but a slow growth rate.

In other areas methods similar to those employed for

wet land cultivation of taro (Colocasia) are used, but great attention is paid to mulching, and shading (if possible natural shade, such as overhanging trees, bushes, etc) is provided until the plants are 1-2 m high. For non-puddled or firmer soils deep planting holes or furrows are prepared (15-100 cm deep) and after the setts or suckers are placed in position, the furrows are partially filled with soil and, if possible, compost, to 10-15 cm above the base of the sucker or sets.

Field spacing - in pit planting 40-100 cm between plants of the larger types: the smaller cultivars may be as close as 30 x 30 cm or 50 x 50 cm. In wet land cultivation swamp taro is often interplanted with Colocasia: the Colocasia is planted at 1-1.5 m, and Cyrtosperma is interplanted between the Colocasia. The latter may be replanted for three annual crops but subsequently the Cyrtosperma is allowed to grow alone for a year longer.

Pests and diseases

The most serious pest is reported to be the taro beetle (Papuana huebneri), which tunnels into the corm. Minor pests include Aphis gossypii, which has been reported to transmit virus diseases, but the importance appears to be small. Rats cause serious losses on some islands.

Growth period

In many areas it is generally considered that the giant taro requires 2-3 years to produce a reasonably-sized tuber, younger than this the tubers of some cultivars are reported to have an unpleasant taste, although on the Pingelap Attoll, Caroline Islands, some early-maturing types are harvested after about one year. Some authorities, however, consider that for optimum results as regards flavour and yield, the crop should be

harvested when the plants are 5-6 years old.

Harvesting and handling

The tubers are dug by hand as required, and normally eaten as soon as harvested. As the crop is for subsistence, rather than for sale, continuous harvesting and replanting is the normal procedure in any one family patch. Storage is not usually practiced, but tubers are sometimes buried in a damp place where they may be kept for up to 6 months.

Primary product

Corms - usually conical to spherical in shape. The size at harvest depends upon cultivar and age. Although corms of 10 years old or more may be very large and weigh 100 kg or more, requiring two or three men to carry

them, they are fibrous and not suitable for eating, though in certain circumstances such corms have a considerable prestige value.

Yield

7 - 10 t/ha for a crop between 18 months and 2 years of age.

Main use

The tubers are the staple carbohydrate foodstuff in many Pacific Islands, where they are eaten boiled, steamed or roasted, sometimes with the addition of coconut milk, or they may be sliced and fried and eaten with sugar.

Subsidiary uses

It has been reported that a number of food products are prepared from the tubers in the Philippines.

Secondary and waste products

The leaves and inflorescence are sometimes eaten as a vegetable.

Special features

Analyses of tubers grown in the South Pacific have been given as: energy 598 kJ/100 g; water 60-70 per cent; protein 0.5-1.4 per cent; fat 0.1-0.5 per cent; carbohydrate 28-36 per cent; fibre 1-1.6 per cent; ash 1-1.9 per cent; calcium 301-598 mg/100 g; iron 0.9-1.4 mg/100 g; phosphorus 28-79 mg/100 g; thiamine 0.03-0.06 mg/100 g; riboflavin 0.08-0.11 mg/100 g; niacin 0.6-1.1 mg/100 g; ascorbic acid trace- 1 mg/100 g.

Workers in the Philippines have reported a starch content ranging from as low as 7.5 up to 22.6 per cent. The starch granules are of medium size, from 4 to 18 microns, and rounded or angular.

Processing

In some islands the tubers may be peeled, sliced and scalded, and then dried in the sun; preserved in this way they can be stored for several months.

Production and trade

No production figures are available. There is some evidence that, following the introduction of polished rice into the Polynesian diet many years ago, swamp taro is not eaten to the extent that it was in the distant past. In the drier islands there is evidence of abandoned

cultivation pits. Until recently the plant was grown solely for home consumption, but in one or two islands is now sold on the local market. There is no international trade in this commodity.

Major influences

Despite the long growing period necessary, swamp taro remains an important staple and source of prestige in many of the Pacific islands, especially as it can yield well on coral atolls which are notoriously difficult agriculturally. It appears to be receiving more attention recently from trained agriculturists, and improvement in practices leading to higher yields may be expected; the crop may therefore become more attractive and play a greater part in reducing the economic burden of imports.

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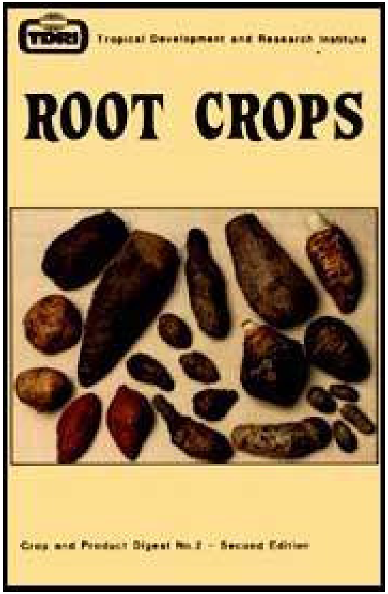

- **Arrowhead (Sagittaria sagittifolia)**
- **Arrowroot (Maranta arundinacea)**
- **Cassava (Manihot esculenta)**
- **Chavar (Hitchenia caulina)**
- **Chinese water chestnut (Eleocharis dulcis)**
- **Chufa (Cyperus esculentus)**
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- **Hausa potato (Solenostemon rotundifolius)**
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- **Queensland arrowroot (Canna indica)**
- **Radish (Raphanus sativus)**
- **Shoti (Curcuma zedoario)**
- **Swamp taro (Cyrtosperma**

Preface

This digest is a complete revision and updating of TPI Crop and Product Digest No. 2, which was published in 1973, and is an attempt to present in a concise form basic data relating to the production and utilisation of most of the root crops of economic importance to countries in the tropics. For quick reference the data are arranged under standard headings and include particulars of growth requirements, planting and harvesting procedures, yield, products and their uses, processing techniques, comments on production and trade, and a bibliography for each crop.

The digest does not claim to be exhaustive or comprehensive. The aim is to provide a ready reference tool, for use particularly by non-specialists, and especially by practical workers in the developing countries concerned with advancing the rural economy. However, it is hoped that in addition it will provide a

starting point for specialists and researchers working on these crops or their products.

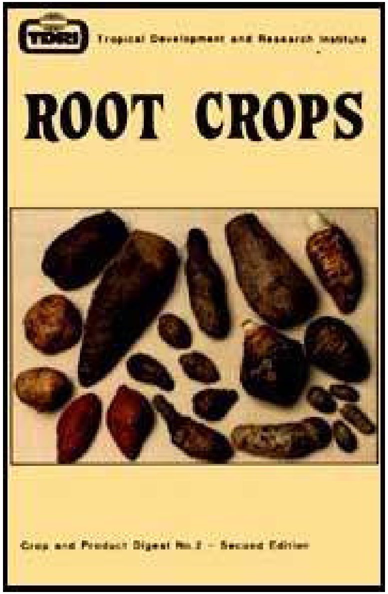
The reviser has received valuable assistance from many persons and organisations during the preparation of this digest. In particular, he wishes to thank the Librarian and Library staff of TDRI who made available a wide range of services, including a computer search of the main agricultural and food processing data bases, and many other members of the TDRI staff, in particular the late Mrs Daisy Kay and the late Mr D. G. Coursey. Special thanks are due to Drs J. C. Caygill, A. K. Thompson and June Rickard who 'vetted' the manuscript, and to many others who provided advice and assistance on specialist matters. Scientific and technical information was obtained from several organizations, including the Royal Botanic Gardens at Kew and at Edinburgh; the Botany Department of the British Museum (Natural History); the

University of Hawaii; the University of Idaho, USA; the University of Puerto Rico; the Soybean Center, California, USA; several branches of the United States Department of Agriculture; the Directorate of Agricultural Research, Wageningen, the Netherlands; the Department of Primary Industries, Queensland, Australia; the Central Potato Research Institute, India; the Bangladesh Agricultural Research Institute; the International Potato Center, Lima, Peru; the Caribbean Agricultural Research and Development Institute, Barbados. In addition to production and trade statistics obtainable within TDRI, information was provided by ULG Consultants Ltd. Warwick, UK; Geest Produce Marketing, Spalding, UK; Montego Imports and Exports Ltd. Toronto, Canada; the Barbados Agricultural Society; the Central Marketing Agency,

Trinidad; and a number of individuals concerned in the

marketing of tropical root crops. Without the help of these, and of many others, the task of updating this digest would not have been possible.

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


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

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

indica)

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

Sweet potato (Ipomaea batatas)

Common names

SWEET POTATO, Louisiana yam, Spanish potato.

Botanical name
Ipomaea batatas (L.) Lam.

Family

Convolvulaceae.

Other names

Apichu (Peru); Artichaut des Indes (Fr.); Batata(s)' (Lat. Am.); Batate(s) douche(s) (Ant.); Batate

ssskartoffel, Bataten-winde (Ger.); Camote (Lat. Am.); Chaco (Venez.); Cumar (Polyn.); Dam long (Camb.); Dankoli, Doukali (W. Afr.); Getica (Braz.); Glycopata (Cy.); Gumbili (Mol.); Imo (Japan); Jetica (Braz.); Kamote (Philipp.); Kara-imo (Japan); Ketala rambet (Indon.); Khoai day, Khoai fang (Viet.); Kumala (Fiji); Kumana, Kumara (N.Z.); Lardak-lahori (Ir.); Mabi(y) (Carib.); Mita-alu (Indon.); Moniato (Cuba); Myonk-ni (Burma); Obi djalar, Obi-djawa (Indon.); Pappas (S. Am.); Patata (douce), Patate (jaune) (Fr.); Patata dolce (It.); Satsuma-imo (Japan); Skirrets (Ir.); Skurar-kanda (Ind.); Trouffe douce (Fr.); Uala (Haw.); Uara (Pacif. Is); Ubi (Indon.); Umala (Sam.); Umara (Haw.); Veeazee (C. Afr.); Vomanga (Madag.); Yam; Ycam; Yeti; Zardakalahori (Ir.).

Botany

A herbaceous, perennial vine cultivated as an annual. There are several hundred cultivars of sweet potatoes and great variation is found in the form and growth habit. Forms that have twining and trailing long stems (0.9-4.5 m) of slender to moderate thickness and moderately to widely spaced leaves are most prevalent, but types with short thick stems, short internodes and semi-erect to erect growth habits also occur. Leaves are spirally arranged along the stems with phyllotaxis 2/5; they may be shouldered, toothed, entire, deeply cleft or variously lobed and the petioles vary in length, thickness and degree of erectness. Pigmentation also is variable, from green to deep-purple. The flowers are solitary or cymose and vary in colour from white to purple. The fruit is a glabrous or hirsute dehiscent capsule 5-8 mm in diameter containing 2-4 angular, brownishblack seeds with a very hard testa. The root tubers are formed by a thickening of parts of the

adventitious roots close to the subterranean part of the stem or at the nodes which rest on the soil.

Origin and distribution

The plant is believed to have originated in South America, and in pre-Columbian times was cultivated in Central America, the Caribbean and parts of South America, Polynesia and New Zealand. It is now grown throughout the tropics, subtropics and warm temperate zones of both hemispheres.

Cultivation conditions

Sweet potatoes are widely grown throughout the world from 40°N to 32°S, under contrasting systems of agriculture, ranging from intensive horticultural practice to subsistence farming, and cultivars differ very

considerably in their adaptability to soil and other conditions.

Temperature - for optimum growth a temperature of 24°C or more, with abundant sunshine and warm nights, with a minimum of cool cloudy weather, is required. Growth is restricted by cool weather and the plant damaged by temperatures below 10°C so that in warm temperate areas there must be a minimum frost-free growing period of 4-5 months.

Rainfall - sweet potatoes require at least 50 cm of rain during their growing season and an annual rainfall of 75-100 cm is considered to be best, with a low humidity as the crop reaches maturity. They can tolerate considerable periods of drought, but yields are very much reduced if a water shortage occurs 50-60 days after planting when storage root initiation has begun.

They are successfully grown under irrigation, four to eight irrigations supplying 112-150 cm of water being generally recommended.

Soil - sweet potatoes can be grown on a variety of soils but sandy loams, reasonably high in organic matter, with a permeable sub-soil, are ideal.

They are sensitive to alkaline and saline conditions and good drainage is essential. Heavy clay soils or soils very rich in humus normally result in low yields and a poor quality product. Yields are usually best on soils with a pH range of 5.6-6.6; on acid soils deficient in calcium or magnesium, liming is often carried out the year before the crop is planted, as infections with certain disease organisms (soil rot or pox and scurf) are more prevalent when the soil approaches neutrality.

The crop responds well to organic manure. Responses reported to artificial fertilisers are conflicting and appear to be influenced by cultivar and climate. Too much nitrogen may encourage vine growth at the expense of tubers. In the absence of local fertiliser experiments, the following application rates are suggested: nitrogen 35-45 kg/ha; phosphorus 50-100 kg/ha; potassium 85-170 kg/ha, or 560-1 120 kg/ha of a 6:9:15 complete (NPK) mixture. With a yield of 15 t/ha the removal of nutrients is nitrogen 70 kg/ha, phosphorus 20 kg/ha and potassium 110 kg/ha. Minor elements such as boron, calcium and magnesium are also required for sound growth, and an inadequate supply of these results in characteristic deficiency symptoms in the vines and tubers.

Altitude - on the equator sweet potatoes can be grown from sea level up to 2 100 m.

Day-length - short days with low light intensity promote root development and sweet potatoes require a day length of 11.5 hours or less to promote flowering; at 13.5 hours flowering ceases, but tuber yields do not appear to be affected.

Planting procedure

Material - except in breeding work, when seeds are used, sweet potatoes are propagated vegetatively, usually by 'vine cuttings' obtained from the previous season's crop or by 'sprouts' or 'transplants' raised from tubers. In addition, occasionally, small pieces of tuber are planted directly into the field, as in the planting of potatoes, but yields are usually low and the quality poor when this method of propagation is used.

(i) Vine cuttings - are favoured, particularly in the

tropics as they are cheaper, the plants are free from soil-borne diseases, and the tubers produced are of a more uniform size and shape. Apical cuttings are generally used as they give better growth and yields than basal or middle cuttings.

Generally the length of cutting used varies from 20 to 45 cm; cuttings with seven or more nodes are favoured since they normally give higher yields than cuttings with only a few nodes. It is generally recommended that 10-20 cm of the cutting is placed below the soil surface at an angle and often the cuttings are left to wilt for 24-48 hours before planting, although there is no experimental evidence to support this practice.

(ii) Transplants - in subtropical and warm temperate areas, notably the USA, sweet potatoes may be propagated by transplanting shoots which have grown

from adventitious buds on tubers that have been planted in nursery beds. In many of the more temperate regions the plants are often raised under glass, or in hot beds heated by manure, hot water pipes, or electrically, since for successful germination a soil temperature of about 21°C is required. High quality tubers, free from cracks, bruises, decayed or diseased tissue, are selected and often subjected to temperatures of 21-24°C for 2 weeks before planting about 1.25 cm apart and 5-7.5 cm deep. Each tuber produces a number of 'slips' or 'draws', which reach 22.5-30 cm in 4-6 weeks, when they are pulled and transplanted into the field, either by hand or with single or multiple row transplanters which often incorporate a device which applies a dilute nutrient 'starter' solution to each transplant. Since the slips do not all develop at the same rate growers normally pull the nursery bed twice. For planting one hectare, a nursery bed of about 35 m2 is required.

In order to reduce the amount of seed stock, the cost of setting up and operating large nursery beds, and to avoid disease problems, many growers plant part of their land with slips obtained from the early vine growth of field plantings of transplants, but the use of these vine cuttings often results in reduced yields owing to the delay in planting because the mother plants must be grown first.

Method - sweet potatoes are normally planted on ridges or mounds, the former being preferred although experiments in Zaire suggest that mounds are better, as they encourage tuber formation. In the tropics, small farmers sometimes interplant sweet potatoes with beans or cassava. Once planted in the field sweet potatoes normally receive little attention apart from weed control at the early stages of growth and the maintenance of ridge height and shape. In the USA,

extensive use is now made of a wide range of effective herbicides for the control of weeds, including naptalam, allidochlor, chloramben, vernolate, diphenamid, prometryn; normally application is pre-planting or pre-emergence.

Field spacing - the spacing used is determined by the following factors: growth habit and root-setting characteristics of the cultivar; type and fertility level of the soil; length of the growing season; and the purpose for which the crop is required. In the last case, if the tubers are required for the fresh market, then high yields of tubers of uniform shape and size are of primary importance, while for canning or freezing small tubers with a diameter of 2.5-5 cm and a length of 7.5-15 cm are required; for industrial uses, such as the manufacture of starch and dehydrated flakes, large roots are preferred because they are easier to handle and

losses during preparation are less.

In the USA, sweet potatoes are commonly planted 30-37.5 cm apart in rows which are 90-105 cm apart in well-drained light soils and 120 cm apart in heavier soils. In the tropics, the vine cuttings are usually spaced 22.5-30 cm apart in ridges 60-75 cm apart.

Seed rate - there is great variation in the number of vine cuttings planted to the hectare, depending upon whether they are planted singly, in pairs, one each side of the ridge, or two or more cuttings per hole. It has been found that there is in fact relatively little difference in the overall yields in plant populations ranging from 25 000 to 125 000 plants/ha but when the population dropped to 12 500 plants/ha there was a significant reduction in yield.

When transplants are used, approximately 25 000-30 000 slips /ha are required and, as a general guide, with a good sprouting cultivar approximately 380-470 kg of tubers will produce enough slips in the first one or two pullings to plant one hectare.

Pests and diseases

Pests - among the insects attacking the leaves of sweet potato are leaf folders (Brachmia spp.), Bihar hairy caterpillar (Diacrisia obliqua), both in South-East Asia and Indonesia, and sweet potato hornworm (Agrius convolvuli) throughout the eastern hemisphere; in the western hemisphere, army worm (Spodoptera sp.), Alabama argillacea and Manduca singulata are often serious. In Brazil and Trinidad the stem borer (Megastes grandalis) may lay its eggs in the leaf axils, from where the larvae bore through the stems into the tubers. In

South-East Asia Omphisa anastomosalis is a stem and vine borer that may also penetrate to the tubers. While crop hygiene is an important factor in minimising attack, chemical control is sometimes necessary: carbaryl, endosulphan or diazinon have frequently been recommended. Tubers are also attacked by insects, notably (in Africa) weevils (Cylas spp.), and in the western hemisphere and Pacific islands by the scarabee beetle (Euscepes postfasciatus); infected tubers develop a strong and unpleasant flavour. Cultural methods are particularly important, including crop rotation and the use of insect-free cuttings. Spraying of the plants or soil treatment with such pesticides as carbaryl, carbofuran, chlorfenvinphos, diazinon, etc has been recommended but resistance to chemicals appears to be developing and the breeding of resistant cultivars is being attempted.

In the USA, several species of nematodes are also of importance, in the southern states five species of root-knot nematodes (Meloidogyne spp.) cause considerable losses, while the reniform nematodes (Rotylenchus reniformis) also cause severe damage in some areas. Many other nematodes are also reported as affecting the crop.

Diseases - sweet potatoes are subject to a number of diseases both in the field and in storage. In the USA, losses due to disease are estimated to average 20-40 per cent, but under small-scale methods of cultivation and harvesting, such as occur in many tropical areas, losses due to disease are usually only of minor importance, apart from virus diseases, which include those producing internal cork and russet crack in roots, feathery mottle, mosaic, chlorotic spotting and banding in foliage, and little leaf and witches broom. Losses of

up to 50 per cent of the crop as a result of viruses have been reported from the Republic of South Africa. Transmission is usually by aphids, including Myzas persicae, Aphis gossypii, whitefly (Bemisia tabaci) and others, or by the use of infected planting material. Control methods include rogueing and chemical control of the vectors, and attempts are being made by several countries to produce virus-resistant cultivars and virus-free planting material.

Of the fungal diseases affecting the crop in the field several are of importance. Stem rot (due to Fusarium oxysporum f. baratas) is widespread and can destroy 10-50 per cent of the crop of susceptible cultivars and has been reported to kill 99 per cent of infected plants in certain circumstances.

Black rot (caused by Ceratocystis fimbriata), reported in

the USA, the West Indies, New Zealand, Hawaii and Australia, can develop in stored tubers as well as affecting the plants in the field. Scurf rot or soil stain (caused by Monilochaetes infuscans) is widespread, and produces a brown or black discoloration on the surface of the tubers, which considerably reduces their market value. Foot rot (due to Plenodomus destruens) frequently affects plants raised from transplants and infected plants often produce no tubers although they make reasonable vine growth. Other field diseases of sweet potatoes (and their causal organisms) are root rot (Phymatotrichopsis omnivora), mottle necrosis (Pythium spp.), phyllosticta leaf blight (Phyllosticta batatas), septoria leaf spot (Septoria bataticola) and white rust (Albugo ipomoeae-panduratae). Control methods rely mainly on the use of disease-free and sterilised planting material, eg dipped in thiabendazole or benomyl.

Storage losses due to disease, particularly soft rots, can be very substantial. Soft rot, ring rot or collar rot, caused by Rhizopus stolonifer, is of considerable economic importance, since under favourable conditions it can destroy the entire tuber in a few days. Other storage rots affecting sweet potatoes (and their causal organisms) are Erwinia chrysanthemi (in the USA), black rot (Ceratocystis fimbriata), surface rot (Fusarium oxysporum), dry rot (Diaporthe phaseolorum var. batatatis), charcoal rot (Macrophomina phaseolina) and Java black rot (Botryodiplodia theobromae), which is often a serious problem in the tropics (optimum growth temperature is about 28°C).

Once infection has occurred, little can be done; control lies in prevention. Sound, disease-free material should be used for propagation: resistant cultivars are available for some diseases. Every effort should be taken to avoid

bruising on lifting, and curing (see Harvesting and handling) should be carried out to assist in wound healing. Washing or dipping in a chemical sterilant such as calcium hypochlorite, or a fungicide, eg benomyl, dicloran or thiabendazole has been recommended.

Growth period

Sweet potatoes, although perennial, are normally cultivated as an annual and the crop is normally harvested 3-8 months after planting, depending upon the cultivar and climatic conditions; in the tropics, if grown in the wet season, the crop normally takes longer to mature than when grown as a dry season crop.

Harvesting and handling

The crop is ready for harvesting when the leaves turn

yellow and begin to drop or when a tuber can be cut without the sap rapidly turning black. In many areas the tubers are dug by hand as required, but where there is large-scale production, such as in the USA or Japan, the vines are usually cut away and the tubers harvested by ploughing out or by being dug out with combine-type harvester units. The methods used to harvest sweet potatoes have a very considerable effect upon their market quality and storage life since they are very easily damaged and very susceptible to fungal rots. Unless great care is taken to avoid mechanical injury heavy losses are likely to be incurred and it is for this reason that efficient mechanical harvesters have proved difficult to design and operate effectively. However, substantial advances have recently been reported, including machines which dig the sweet potatoes, detach them from the vines, and deposit them in a container.

Sweet potatoes are highly perishable and are not normally stored for any length of time in the tropics. In the USA, the tubers are often stored for use during the winter and spring by subjecting them to curing immediately after harvesting, a process which toughens the skin and reduces the incidence of infection by fungal disease-producing organisms. This is accomplished by subjecting the tubers to a temperature of 27-29.5°C at 85-90 per cent RH for a period of 4-7 days, care being taken to ventilate the curing room sufficiently to prevent the accumulation of carbon dioxide. After curing, sweet potatoes may be successfully stored at 13-16°C and 85-90 per cent RH. Interleaving with layers of paper soaked in MENA (methyl ester of naphthalene acetic acid) in the ratio of 40 ml/100 kg tubers has been recommended. Different cultivars have different storage lives: in the USA, cv. Jewel has proved to have the longest, keeping satisfactorily for 9 months when treated in the above

manner. At temperatures between 0 and 10°C sweet potatoes are susceptible to chilling injury, which manifests itself in several ways, such as internal breakdown of tissue, increased susceptibility to decay, impaired culinary quality (including the condition known as hardcore), etc, though recent work has shown that under certain circumstances hardcore may be reversed.

Many attempts to achieve long term storage in the tropics have been reported, eg using heaps (which in some cases are arranged on staging over kerosene hurricane lanterns to achieve some measure of curing), pits dug in the soil and lined with leaves or other material, and shelves of various design, etc. There is some indication that pre-storage curing may have been beneficial, though it should be noted that in many tropical areas ambient conditions are very close to those required for curing (30°C and about 9() per cent RH).

No method was satisfactory; 4 weeks or less appeared to be the best that could be expected by any of these methods, though with increase in elevation and the associated reduction in ambient temperature, storage life was considerably prolonged. In Trinidad, where storage of up to 4 weeks is usually regarded as attainable, pre-harvest spraying with maleic hydrazide or treating the harvested tubers with MENA in acetone inhibited sprouting when the tubers were stored for 4-8 weeks.

Primary product

Tubers - the starchy tubers of the sweet potato are the fleshy enlargements of the adventitious roots and a single plant may produce 40-50 tubers, which vary greatly in size, shape, colour, storage, nutritional and processing characteristics. The tubers may range from a

few centimetres to over 30 cm in length, and they may be spindle-shaped or almost spherical and weigh from approximately 100 g to I kg; tubers weighing as much as 5 kg have been reported on some soils. The tubers may have a smooth or irregular or ribbed surface, and the skin and flesh may range from almost pure white through cream, yellow-orange or pink, to a very deep purple, depending upon the amount of various carotenoid pigments present and the presence or absence of anthocyanins. The tubers are often classified into three groups: those with a dry mealy flesh when cooked; those with a soft watery flesh when cooked (because of their tendency to convert much of their starch to sugars); and those with very coarse flesh which are suitable only for animal feed or industrial uses.

Yields

Yields vary greatly according to cultivar, local climatic conditions and cultural techniques. FAO figures show that in 1981, the average in Africa and the Caribbean was approximately 6.5 t/ha, in Asia 13 t. The yields (t/ha) of some major producers were: Burundi 9.9; Madagascar 5.1; Cuba 4.1; Mexico 14.1; Argentina 10.1; Brazil 8.9; Bangladesh 10.9; China 13.9; India 7.2; Indonesia 7.5; Korea 22.2; the Philippines 4.7; Vietnam 6. Israel, a small producer using intensive farming methods, reported an average production of 40 t/ha. During the period 1969-1981 there was little change on a world wide basis, as shown by Table 1.

Table 1: Sweet potato - Average yields (t/ha)

	1969-71	**1979-81**
World	11.6	12.2
All developed countries	15.8	15.4

All developing countries	11.5	12.1

These yields fall very far behind those obtained experimentally, especially in tropical countries. Table 2 shows some published comparisons.

	Experimental yield	Farmers' yield (1979 figures)	Yield gap	Possible improvement (per cent)
Tropical				
India	37	7	30	428
Philippines	35	5	30	600
Nigeria	32	13	19	146
Temperate				
Japan	35	20	15	75
Korea	43	20	23	115
USA	45	13	32	246

Table 2: Sweet potato - Yields obtained in experimental stations compared with the national average (t/ha)

Main use

Sweet potatoes are utilised primarily as a human foodstuff. In the tropics, the major proportion of the crop is eaten straight from the ground as a vegetable, after boiling, baking or frying. In Malawi, they are sometimes boiled or roasted and pounded with groundnuts to produce 'futali'. In some areas, notably India and parts of East Africa, the peeled tubers are sometimes sliced and dried in the sun to produce chips, which are often ground into flour. In the USA, about 60-70 per cent of the sweet potato crop is utilised for human food and they are eaten fresh, canned, frozen or dehydrated, and used in a variety of products such as pie fillings, purees, candied pieces, souffles, baby foods, etc.

Subsidiary uses

Animal feed - large quantities of sweet potatoes, mainly

culls, are used in the USA and certain other countries, as a high carbohydrate feedingstuff for cattle, pigs and poultry.

Starch - sweet potatoes can be used as a source of starch; in Japan, the tubers have been used to produce low-grade starch for over 100 years. In 1968, about 45 per cent of the total Japanese crop was utilised in preparing 350 000 t of starch for use in the textile, paper, cosmetic and food manufacturing industries, and for the preparation of adhesives and glucose.

Flour - sweet potato flour, made by drum-drying or cabinet-drying the peeled sliced tubers, can be used as a partial substitute for wheat flour in bread and pastry making.

Secondary and waste products

A variety of products such as alcohol, acetone, lactic acid, vinegar and yeast may be prepared from the tubers. In the USA, pre-baked or boiled tubers are sometimes pulped and pureed and mixed with certain additives before being baked to give a product 'alayam', which is used as a cookie or ground into a powder for use in ice-cream and certain other food preparations.

Pectin is sometimes obtained as a by-product from the skins and other residues left after processing the tubers for food products or in the preparation of starch.

The tips of the vines and the leaves are sometimes eaten as a vegetable. A typical analysis of the edible portion shows: water 87.1 per cent; nitrogen 0.57 per cent; ether extract 0.67 per cent; fibre 1.4 per cent; ash 1.59 per cent; calcium 81.2 mg/100 g; iron 10.37 mg/100 g; phosphorus 67.3 mg/100 g; carotene 3.61 mg/100 g;

thiamine 0.06 mg/100 g; riboflavin 0.17 mg/100 g; niacin 0.94 mg/100 g; ascorbic acid 25 mg/100 g. In many parts of the tropics sweet potato vines are used as a green feed for livestock, often as silage. Their feeding value is comparable with that of lucerne hay and yields average 3 600-17 500 kg/ha. In addition, they are also occasionally used as food for Tilapia in fish ponds.

Bacterial and fungicidal substances have been isolated from both the tubers and the vines, and sweet potatoes are used in a number of countries for various traditional medicinal purposes.

Special features

The chemical composition of sweet potato tubers varies widely according to cultivar, climatic conditions, degree of maturity and the duration of storage after harvesting.

The usual range of values for the edible portion is: energy 490 kJ/100 g; water 65-81 per cent; protein 0.95-2.4 per cent; fat 0.4-6.4 per cent; carbohydrate 25-32 per cent; fibre 0.9 per cent; ash 0.9-1.4 per cent; calcium 30-34 mg/100 g; iron 0.8-1 mg/100 g; magnesium 24 mg/100 g; phosphorus 49 mg/100 g; potassium 373 mg/100 g; sodium 13 mg/100 g; carotene trace-12 mg/100 g; thiamine 0.1 mg/100 g; riboflavin 0.05-0.06 mg/100 g; niacin 0.6-0.9 mg/100 g; ascorbic acid 23-25 mg/100 g.

From time to time outbreaks of poisoning of cattle have been reported due to the incorporation of mouldy sweet potatoes in their feed. The metabolites ipomeamarone and ipomeamaranol have been isolated from mouldy tubers and found to be toxic to the liver and other organs, and the latter to cause lung oedema. A disturbing feature is that these metabolites may occur in

tubers which show only slight blemishes, insufficient to arouse suspicion that they are unsound.

Processing

Canning - considerable quantities of sweet potatoes, particularly the yellow types, are canned, notably in the USA, where several different styles of pack, such as canned whole, slices or puree, in syrup or in water are produced. The essential processing steps are: grading, washing, peeling, either by the use of lye or steam, trimming, cutting, pulping when required, filling into cans, syruping when necessary, heating the filled cans in an exhaust box until the product attains a centre temperature of 82-93°C (normally 6-10 minutes for No. 2 and No. 2 1/2 cans and 10-12 minutes for A10 cans), sealing immediately and then heat processing at 115°C for periods ranging from 55 to 95 minutes, depending

upon the initial temperature of the contents, the style of pack and the size of can.

Dehydrated flakes - the washed, peeled, sliced tubers are cooked for about 20 minutes before being reduced to a fine pulp or puree. Approximately 100 ppm of a fungal diastase, Rhozyone S, are then added to the puree, to partially convert the starch into sugar. After holding for 20 minutes the puree, which has a total solids (TS) content of 22-24 per cent, is dried on drum-driers to give a thin sheet of 97 per cent TS content, which is broken into flakes and packed in cans or polyethylene flexible pouches, flushed out with nitrogen or other inert gas in order to avoid oxidation during subsequent storage.

Starch - may be produced from sweet potatoes using conventional wet starch extraction methods, such as

those used in the preparation of cassava starch, provided that the process is kept alkaline throughout (approximately pH 8.6), and processing is carried out as quickly as possible to avoid losses due to fermentation. Quality variation, poor colour of the final product and relatively high production costs have made it difficult for sweet potato starch to compete with maize starch when this is readily available at a relatively low cost.

Production and trade

Production - FAO figures for 112 countries showed total world production in 1981 to be in excess of 145 million tonnes, which is second only to the potato among major root crops. Figures for different regions of the world and the highest producing countries are given in the following table; it should be noted that the estimated production from China accounts for about one-half of

the world's total.

	Area harvested ('000 ha)				Production ('000 t)			
	1969–71 average	1979	1980	1981	1969–71 average	1979	1980	1981
World	**12 268**	**12 202**	**12 026**	**11 770**	**142 141**	**148 294**	**145 045**	**145 765**
Africa	677	775	785	794	4 004	4 992	5 065	5 151
Burundi	101	92	93	93	831	870	920	928
Madagascar	59	73	80	80	348	407	410	410
Rwanda	65	111	116	120	379	874	905	936
Central America and the Caribbean	200	205	204	211	1 367	1 116	1 237	1 347
Cuba	63	80	80	80	246	316	425	425
Haiti	55	64	65	64	280	261	260	270
Mexico	14	4	2	2	142	58	33	33

Table 3: Sweet potato - Area and production in selected countries

	Area harvested ('000 ha) 1969–71 average	1979	1980	1981	Production ('000 t) 1969–71 average	1979	1980	1981
South America	271	175	174	166	3 008	1 483	1 455	1 404
Argentina	44	34	34	24	457	322	302	247
Brazil	183	52	40	90	2 155	819	800	800
Asia	11 0[illegible]	10 919	10 7[illegible]	10 4[illegible]	[illegible]	139 7[illegible]	136 5[illegible]	[illegible] 108
Bangladesh	72	73	72	73	836	795	791	795
China	9 536	9 [illegible]	9 352	9 050	120 511	127 975	125 280	125 680
India	225	220	207	207	2 266	1 623	1 349	1 500
Indonesia	361	287	237	256	2 215	2 194	2 193	2 079
Japan	134	64	65	65	2 550	1 360	1 317	1 317
Korea	12[illegible]	60	55	50	2 0[illegible]	1 447	1 163	1 108
Philippines	134	238	236	235	680	1 120	1 048	1 100
Vietnam	223	392	443	400	1 108	2 152	2 358	2 400
Europe	14	12	12	13	140	135	138	136
Oceania	95	113	114	115	489	595	608	620
Papua New Guinea	82	98	98	99	340	436	440	450
Tonga	5	6	6	7	73	74	80	80
All developed countries	2[illegible]3	137	133	137	3 [illegible]4	2 160	2 016	2 094
All developing countries	12 052	12 065	11 893	11 634	138 [illegible]	146 134	143 027	145 6[illegible]

All 1981 figures are estimates as are all figures for China.

Table 3: Sweet potato - Area and production in selected countries (contiued)

Trade - most sweet potatoes are consumed domestically

and only a small proportion enters international trade whether in the fresh state or in a processed form and very few statistics are available. In the Caribbean, St. Vincent exports a substantial proportion of its annual production (I 000-4 000 t), mainly to Trinidad. Exports - St. Vincent: 1961-65 average, 1990 t/ha; 1972, 1420 t; 1974, 1 750t; 1976, 1 840 t; 1978, 900 t (estimate). United Arab Emirates: 1961-65 average, 25 t/a; later figures are not available. Japan: 1961-65 average, 18 t/a; later figures are not available. Imports - Trinidad and Tobago: 1961-65 average, 2 000 t/a; 1966-70, 1 990 t/a; 1978-80, 1 500 t/a (estimate).

There is a small import trade of sweet potatoes into the UK and some northern and central European countries, but separate statistics are not published. Most comes from the Canaries and the Mediterranean area, a very small quantity from the Caribbean.

Major influences

The highly perishable nature of sweet potato tubers together with the comparatively low yields per hectare usually attained and high production costs have been a severe limitation to the commercial exploitation of the crop. The complete mechanisation of both planting and harvesting techniques would considerably reduce production costs when the crop is cultivated on a large scale but as yet there is no satisfactory fully-mechanised system for harvesting the tubers for the fresh market (though great progress is being made) and, in the USA, prices have increased steadily and consumption has declined by about 60 per cent over the last 30 years.

High production costs have also handicapped the use of sweet potatoes as a source of industrial starch and even

in Japan, where starch has been extracted as a cottage-based industry for many years, production is declining, owing to the increased availability of lower-priced maize starch.

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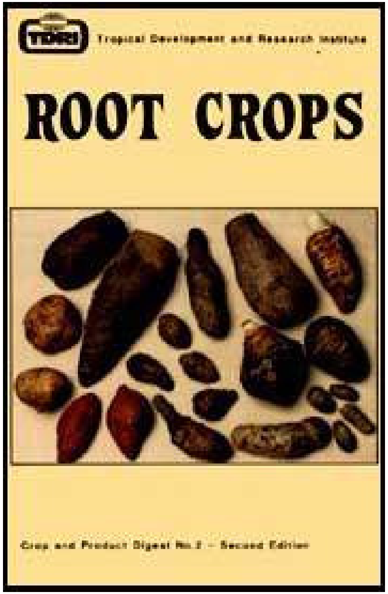
Tropical Development and Research Institute
ROOT CROPS

- **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**

Tannia (Xanthosoma spp.)

Common names

TAN(N)IA, New cocoyam, Tan(n)ier.

Botanical name

Xanthosoma spp.

Family

Araceae.

Other names

Badoo (Jam.); Chou (Gren.); Chou caraibe (Ant.); Cocoyam', Dalo ni tana (Fiji); Kimpool (Indon.); Kong Kong taro (N. Guin); Macabo (Cam.); Maduma (Tanz.); Mafaffa, Malanga(y)' (Ant.); Mangareto (Braz.); Nut eddoe (Barb.); Ocumo, Ocumo cuman (Venez.); Quequeque (Guat.); Rascadera (Braz.); Tajer (Sur.); Taioba (Braz.)'; Talo papalagi (Sam.); Tanyove (Guy.);

Tatale, Tayobe, Tayonne, Tayo tyo (W.I.); Tiquisque (C. Rica); Yautia (Lat. Am.); Yautia bravi (P. Rico); Yautia des anglo saxons (Fr.).

Botany

There is often confusion between the genus Xanthosoma and that of Colocasia since superficially tannias appear to be rather large coarse taros. Tannia plants can reach a height of about 2 m and have a short erect stem and large, long-stalked sagittate or hastate leaves, which differ from those of Colocasia in that the leaf stalk joins the blade at the margin between the lobes (not into the surface of the blade), and the tips of the lobes are pointed, not rounded. The leaves have a prominent marginal vein, and are 50-75 cm long, occasionally more; the petioles are about I m long. The inflorescence is borne below the leaves, with a pale green spathe

about 20 cm long; some cultivars never flower and seed is rarely produced. A corm is produced at the base of the plant and this bears several (usually 10 or more) lateral corms (cormels), each 10-25 cm long.

The taxonomy of Xanthosoma is confused; a number of edible species have been recognised including X. sagittifolium (L.) Schott, by far the most widely grown, X. atrovirens Koch and Bouche, with yellow tubers and favoured in Puerto Rico and Dominica, X. violaceum Schott, a large plant grown occasionally in the Pacific islands but reportedly of little value for food, and X. brasiliense Engl., a small species cultivated solely for its edible leaves.

Origin and distribution

Xanthosoma is native to tropical America and was

cultivated in tropical Central and South America from very ancient times, and only in comparatively recent times (19th century) has been spread widely throughout the tropical world. It is now cultivated in tropical America, the Caribbean, West Africa and the Pacific, and to a very limited extent in some other parts of the humid tropics. The name 'new cocoyam' reflects this late introduction into areas where Colocasia (cocoyam) was previously established.

Cultivation conditions

Temperature - tannias do best in tropical conditions, but can be grown over a fairly wide range; eg in Puerto Rico they are successfully grown in areas where the mean annual temperature is 24°C with maximum variations ranging from 13 to 29°C.

Rainfall - the crop is suited to high rainfall areas, but can be grown with an annual rainfall as low as 100 cm provided that this is evenly distributed, although an average rainfall of 140-200 cm is preferable. Tannias can be grown as an upland crop under irrigation and certain early-maturing cultivars can be grown without irrigation in comparatively dry situations, such as exposed steep slopes.

Soil - tannias can be grown on a wide variety of soils, except hard clays or pure sands, but for optimum yields they require a deep, well-drained, rich soil, preferably with a pH of 5.5-6.5. Unlike taro the crop cannot withstand waterlogging. Good response is given to mulching, and 20-40 t/ha of FYM is recommended when available. There is little precise knowledge about mineral fertilising: both in Puerto Rico and the Pacific Islands nitrogen at 100 kg/ha along with potassium at

100 kg/ha has given good results; split application is recommended.

Altitude - different cultivars have been selected over the years for widely varying conditions and provided that a suitable cultivar is selected, tannias can be successfully grown from sea level up to elevations of about 1 500 m.

Planting procedures

Material - the best material is small corms or cormels. Alternatively, a 5 cm section can be cut from the main corm, and divided into two pieces across its diameter. Setts are also used, ie the top of the main plant including about 5 mm of corm and the leaves cut off about 20 30 cm above the base, but leaving the newly-formed leaf at the centre of the plant.

Method - tannias may be grown in monoculture, but are

more usually grown in crop rotation systems; often they are the first crop in shifting agricultural systems, or are intercropped with plantation crops such as cocoa, rubber, bananas and coconuts. Planting may be throughout the year, although in drier areas (100 cm rainfall) it is usually just before, or at the start of, the rainy season.

Planting in ridges is often recommended: the corms or cormels are planted 7.5-10 cm deep, with the growth bud pointing downwards; if pieces of the main rootstock are used about 2.5 cm is left above the ground. Setts are planted with the base about 10 cm deep. Little attention is given after planting apart from weeding, and sometimes earthing up if planting was on level ground. The application of the pre-emergence herbicide diuron at 1.6 kg/ha has been recommended; other effective herbicides are atrazine, prometryn and ametryn.

Field spacing - is variable but I x I m is most commonly used and requires about I t/ha of planting material (cormels). However, in practice it ranges from about 60x60 cm to 180x 180 cm. The wider spacing gives a higher yield per plant (and 150x 150 cm has been reported to give maximum yield per hectare), but the wider spacings involve increased maintenance as it takes much longer before the leaves shade out the weed growth. These spacing distances refer only to tannia grown in monoculture; there is no general practice for mixed cultivations.

Pests and diseases

In general tannias are relatively free from serious attacks by pests or diseases, although this is probably largely due to the fact that the crop is mainly grown on a small scale and not as an extensive monoculture. In

Trinidad, Venezuela and Guyana, a dynastic beetle, Ligyrus ebenus, has been reported to attack the crops, but can be effectively controlled by spraying with malathion. Other pests which sometimes attack tannias include Aphis gossypii in the Antilles and Surinam, Euetheola bidentata in Surinam, Graphocephala propior, Quinta cannae and Cacographis ortholatis in Venezuela, Aspidiotus destructor in the Antilles and Polynesia, Pentalonia nigronervosa, Tetraleurodes ursorum and Corythucha gossypii in the Antilles. These may all be controlled by the usual insecticides.

Several root rots can affect tannias, with varying degrees of severity. During the 1930s root rot was particularly serious in Ghana and investigations suggested that the causal agent could have been a fungal or bacterial infection, or a combination of both, and that the nutritional status of the crop was also a

factor influencing the severity of attack. Tannias are susceptible to various Pythium rots; in Puerto Rico, a soft rot known as currutaca, due to Pythium ultimum, affects the crops, while in New Caledonia, P. irregulare is reported occasionally to cause serious losses. In Venezuela, the crop is sometimes infected by Cercospora chevalier), C. verruculosa and Punctellina solteroi. Viruses have been reported but do not appear to be serious.

Growth period

The corms are normally considered to be mature 9-12 months after planting, although a crop can sometimes be obtained after 6 months. Higher yields are obtained with later harvesting.

Harvesting and handling

At maturation the older leaves begin to yellow. The mature corms do not deteriorate if left in the ground and they are often harvested as required. The whole plant may be dug up, often by hand, and the cormels separated from the main corm. Sometimes the soil is dug away from the plant and the exposed cormels separated from the parent plant which is covered up with soil and left to produce a new crop. In this way the plant may continue to crop for several years and it is usually at least 6 years before there is a noticeable decline in vigour and quality of the cormels. Great care must be taken to avoid bruising the cormels when they are harvested, otherwise they are liable to develop serious rots if stored. In some countries mechanical harvesters are being developed.

Tannias can be successfully stored under dry well-ventilated conditions for periods of up to 6 months,

although in Trinidad it was found that, when stored at ambient temperatures, there was a loss of eating quality after 8 weeks, but the quality was maintained for 18 weeks or more if the cormels were stored at 7°C and 80 per cent RH. In Cameroon, traditional storage in pits in a confined atmosphere has been found more satisfactory than storing on trays in well-ventilated huts.

Primary product

Cormels - the central corm is usually not eaten (and often is not harvested - see Harvesting and handling), but the lateral corms (cormels) form the crop. These vary in size from 10 to 25 cm in length and 12 to 15 cm in diameter, and about 80 per cent consists of edible, starchy material, the remainder being a scaly peel. The flesh can be white, yellow or pink.

Yield

Experiments in Trinidad have given yields of 30-32.5 t/ha and Puerto Rico has reported yields of 25-37 t/ha of tubers, ie corms plus cormels. Average yields of cormels in the South Pacific are reported as 20 t/ha for tannia grown in monoculture. For mixed cultivation in peasant agriculture yields of 5-7 t are common.

Main use

The starchy corms occupy an important place in the diet of many tropical countries. The main corms are usually acrid and normally only the cormels are eaten. These are boiled, baked, or parboiled and fried in oil. In West Africa, the tubers are sometimes ground to produce 'fufu', for use in stews and soups.

Subsidiary uses

The dried peeled corms may be ground to produce a flour, which is considered to be as palatable as cassava flour, but more nutritious. About 10 kg of tannias will yield 3 kg of flour. The preparation of noodles, using mixes of flours of soya, wheat and high percentages of Xanthosoma flours, has been undertaken experimentally.

Secondary and waste products

The leaves can be boiled and used as a vegetable, similar to spinach (X. brasiliense is particularly favoured for this purpose).

Special features

There is considerable variation in the composition of

tannias and starch contents ranging from 17 to 34.5 per cent have been reported. Average approximate composition of the edible portion has been quoted as: energy 556 kJ/100 g; water 70-77 per cent; protein 1.3-3.7 per cent; fat 0.2-0.4 per cent; carbohydrate 17-26 per cent; fibre 0.6-1.9 per cent; ash 0.6-1.3 per cent; calcium 20 mg/100 g; iron 1 mg/100 g; thiamine 1.1 mg/100 g; riboflavin 0.03 mg/100 g; niacin 0.0005 mg/100 g; ascorbic acid 6- 10 mg/100 g.

The starch grains of tannia are relatively large, with average diameter 17-20 microns, and are less easily digested than those of Colocasia.

Processing

Starch - is occasionally made from the grated tubers.

Production and trade

Production - statistical information on the production of tannia is not readily available, and it is usually grouped with taro or other root crops, though in Puerto Rico production appears to exceed 20 000 t/a and in the Dominican Republic, 30 000 t/a. Tannia is replacing taro to some extent as a nurse crop for young cocoa in West Africa as it is easier to grow.

Trade - recent figures are not available; there is some inter-island trade in the Caribbean with St. Vincent exporting tannia to Trinidad.

Major influences

In recent years production of tannias has tended to increase, particularly in parts of West Africa, because of

their greater resistance to Phytophthora blight compared to taros, and because less exacting conditions are required for their cultivation. Tannias are of particular value for intercropping with plantation crops, but their future probably depends upon whether costs of production can be reduced by improved cultural techniques, such as mechanisation, the use of herbicides and the application of fertilisers. The high degree of genetic variability suggests that there is considerable potential for improvement of this crop through selection and breeding.

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