

HORTICULTURE

VEGETABLE SCIENCE

(Vegetables, Tubers & Spice Crops)

Potato and Tuber Crops

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Keywords

Nursery management, Weed management, Water management, Potato, Cassava, Sweet Potato, Yam, Colocasia, Tannia, Elephant foot yam, Arrowroot, Yam bean , coleus, Tuber crop, Cultivation practice

Potato

Importance and Scope

Potato (*Solanum tuberosum* L.) is one of the four major food crops of the world. The other three crops being rice, wheat and maize. It is an important crop and it can supplement the food needs of the country in a substantial way as it produces more dry-matter food, has well balanced protein and produces more calories from unit area of land and time than other major food crops. The problem of malnutrition and under nutrition can be largely solved if potato is accepted as a major food and not merely as a vegetable in our country. It is a nutritious food containing practically all the essential dietary constituents. Like cereals, carbohydrates are the major constituents of potato. Besides, it contains essential nutrients such as proteins and minerals like calcium, phosphorus and iron, and vitamins (B1, B2, B6 and C). There is great potential of exporting potatoes from India both for seed and table purposes to our neighbouring countries of South-East Asia and to Middle East countries. Potatoes can even be exported to some of the European countries during March-May when fresh potatoes are not available in these countries.

Area and production: Among the major potato growing countries of the world, China ranks first in area, followed by the Russian Federation, Ukraine and Poland. India ranks fourth in area in the world. The present area under potato in India is about 1.4 million hectares. India produces a total of about 25-28 million tonnes of potatoes every year and ranks fifth in production also after China, Russian Federation, Poland and Ukraine. From each hectare of land, it produces about 16-19 tonnes of potatoes. In European and American countries the potato productivity is about 30-40 tonnes per hectare. The states of Uttar Pradesh, West Bengal and Bihar account for nearly 3/4 of the area and 4/5 of the potato production in the country. The highest area and the production is in Uttar Pradesh followed by West Bengal and Bihar. The highest productivity of the crop is in West Bengal followed by Gujarat. Potato is one of the principal cash crops and it also contributes to Indian economy in several ways.

Climate and soil requirements

Potato is basically a crop of temperate region but there is a large variation in the gene pool with respect to crop's response to thermoperiods. Generally potato crop is raised in India when maximum temperatures are below 35°C and minimum temperatures below 20 °C (with ideal tuberization temp. between 16-22 °C).

Soil: Potatoes can be grown in alluvial, hill, black, red and laterite soils having pH in the range of 5.5-8.0. Deep Alluvial soils of Indo-Gangetic plains with almost neutral soil reaction are the most suitable. Maximum area under potato is in alluvial soils, followed by hill, black and red soils. Saline, alkaline and sodic soils are however, not congenial for potato production. Soil should be fine, loose and without compacted layers that hinders root penetration and deforms tubers. Compacted layers also restrict drainage of water. Clods and stones present reduce root contact with soil and also cause deformation of tubers. Well-drained coarse or sandy loam to loamy soils, rich in organic matter are ideal for potato cultivation. Such soils ensure availability of sufficient oxygen for the growth of

roots, stolons and tubers, retain moisture and are helpful in drainage of excess water that allows production of beautiful tubers.

Varieties and Hybrids

The early introductions and subsequent systematic attempts to introduce potato varieties mainly from European countries were not very successful. These varieties were primarily bred for long-day and long-duration conditions of Europe where moderate temperatures prevail both at the time of planting and harvesting. Therefore, they did not do well under short-day, short growing conditions of sub tropical plains of our country where high temperatures prevail both at the time of planting and harvesting. Therefore, the major goal of potato breeding is to breed high yielding varieties suitable for the above conditions. Among the other goals/problems, late blight is the most devastating disease occurring regularly in epiphytotic form every year in the hills and very frequently in plains. The widely present large number of viruses infecting potatoes through contact or aphid vectors is responsible for bringing down yields of potato stocks and are most important constraints in potato productivity. Bacterial wilt in mid-hills and pockets of Assam, Meghalaya, Maharashtra and Orissa, wart in hilly regions of West Bengal, cyst forming nematodes in southern hills and potato tuber moth in warmer plateau areas of Maharashtra, Karnataka and Madhya Pradesh are the other major diseases and pests of potato in the country. In recent years potato processing industries have come up in a big way needing varieties containing low sugars and high dry-matter for preparation of specific value-added products like chips, French fries, cubes and other dehydrated products.

In the year 1949, the Central Potato Research Institute was established. This Institute began work on breeding of new potato varieties suitable for Indian conditions. The varieties bred by it always have the prefix name 'Kufri' denoting the name of the place in the Himachal Pradesh where actual hybridization work is done. The Institute starting from 1958 till date has released 41 improved potato varieties for different agroclimatic regions of the country. Many of these varieties possess resistance to diseases like late blight and wart and pests like cyst nematode. The earlier potato varieties were either the clonal selections from the then prevailing popular varieties that survived following introduction from foreign countries, e.g. Kufri Red from Darjeeling Red Round and Kufri Safed from Phulwa or had mainly foreign varieties in their parentage. Progressively there was a gradual shift in the choice of parents in favour of Indian cultivars and parental lines and currently the new varieties often involve an indigenous variety in their parentage. Many of the initially released varieties are no longer in cultivation simply because better varieties have been developed.

The important potato varieties grown widely in India are Kufri Chandramukhi, Kufri Jyoti, Kufri Bahar, Kufri Badshah, Kufri Sutlej, Kufri Sindhuri, Kufri Lalima and Kufri Pukhraj. Kufri Chipsona I and Kufri Chipsona II are the two released varieties for producing potatoes for processing. However Central Potato Research Institute has recently released two more potato processing varieties viz. Kufri Chipsona III and Kufri Himsona.

Cultivation Practices

Potato is planted directly in the field; however, true potato seeds (TPS) are raised in nursery. The seedlings of TPS raised in nursery beds may either be transplanted in the field or left in the nursery for producing seedling tubers. The planting density depends upon the location, method of planting, purpose for which the crop is raised, etc. Normally when mechanical cultivation is practiced a spacing of 60 cm between rows and 20 cm between plants is adopted which results in a planting density of 83,333 plants per ha. When manual planting and interculture is adopted then the row-to-row spacing is reduced to as low as 45 cm. In the hills where animal drawn implements are used, row-to-row distance of 50 cm and plant-to-plant distance of 20 cm is adopted.

After pre-planting tillage operations, different methods are used for potato planting in various parts of the country. Ridge and furrow method is the most popular method carried out manually or mechanically. In manual method, the furrows are made with the help of curved/narrow-blade spade followed by fertilizer mixture application, covering it with soil and finally making of ridges. The seed tubers are dibbled on each ridge whereas in mechanical method, furrows are made with the help of tractor drawn 2-4 row marker cum fertilizer drills so as to apply fertilizer in one sequence. This is followed by planting of tubers with the help of 2-4 row planter cum ridger. In absence of fertilizer drill and automatic planter, ridges are made with tractor drawn ridger after application of fertilizers and tubers are dibbled manually 5-7cm deep on the ridges. In another method, the field is marked with the help of rope or marker and fertilizer is placed on the marked lines. Tubers are placed to the side of these lines and then ridges are made either with bullock-drawn implements or with narrow-blade spade manually. In the hills, after placement of fertilizer in shallow furrows drawn with hand tools (*Khilna* or *Kudal*) tubers are placed and covered with soil to make ridges. In all these methods care is taken that seed tubers do not come in direct contact of fertilizers.

Breeding methods

Potato is a self-pollinated crop but is vegetatively propagated. The cultivated tetraploid varieties are highly heterozygous. Most of them are also pollen sterile. Selfing or inbreeding in potato leads to loss of vigour of the progeny and non- flowering. Hence the conventional method or pure line method of breeding is generally not practiced. The vegetative mode of propagation in potato offers the advantage after breeding since breeder can take advantage of outstanding individuals (clones) occurring at any stage of breeding, and subsequently obtain genetically identical plants irrespective of the degree of heterozygosity of the genotype. The breeding methods that are successfully used are:

Hybridization and selection: In hybridization, crosses are made between selected parents. Hybridization can be between varieties (inter-varietal) or between species (inter-specific). Since yield and most of the desirable characters are polygenic in nature, the parents for hybridization are generally selected on the basis of their combining ability. Genetically distant crosses with wild species are avoided, as they result in progenies with wild characters, which are difficult to eliminate. Segregation of characters takes place in the F1 generation following hybridization and thereafter clonal selection is practiced in F1 and subsequent generations. Being vegetatively propagated, breeders take advantage

of selecting and multiplying genetically identical individuals in the succeeding generations.

Potato naturally flowers under cool climate and long day conditions of more than 14 hours light. Such conditions are available during long summer days when potatoes are grown in the hills. Hills are therefore, ideal for hybridization work. Potato flowers are hermaphrodite (bisexual) and therefore, emasculation is done in selected female parents mostly in the evening. The five stamens forming a cone surrounding the protruding stigma are removed carefully from the flower buds that will open next day. The emasculated buds are then bagged with butter paper bags ensuring no pollination from foreign pollens. Flowers from the selected fertile male parents are collected a day in advance. Shade-dried and pollens are extracted next day in the morning in small petri-dish or container. Pollination in the emasculated flowers is done usually in the morning when the stigma is most receptive either by dipping it in the pollens or by applying pollens with the help of soft brush. Each flower bunch is then labelled showing details of cross and bagged again to protect pollination from foreign pollens. The butter paper bags are removed 2-3 days after pollination and berry setting in successful crosses is observed in about 5-7 days. When berries attain sufficient size, they are bagged in small muslin cloth bags to save them from dropping and allowed to mature. The seeds are extracted from ripened berries by macerating in water and separating the seeds from pulp after repeated washings.

Back cross method: Cultivated potato does not possess resistance to most of the diseases and pests. Resistance genes are mostly found scattered in wild and semi-cultivated species available in the centre of origin and diversity in South America. In this method the hybridization is done between cultivated and wild or semi cultivated species with the aim of transferring specific characters like resistance to diseases and pests. It is followed by repeated back crossing keeping cultivated type as the recurrent parent. Selection is practiced in successive back cross generations for the character to be retained from the wild species. However, transfer of the resistant genes from wild species into cultivated potato is a difficult task. The differences in ploidy level, incompatibility and sterility factors and flow of resistant genes along with undesirable genes causes problem of their elimination even after several generations of back crossing.

Mode of pollination

The flowering of potato depends on variety and region of cultivation. Under short day conditions in the plains, most of the potato varieties do not flower but they flower in cooler climate in the hills when planted in summer. The flowers are born on a stalk known as floral axis. The inflorescence may be simple or compound, erect or drooping and flowering may be profuse, moderate or scanty. Potato flower is a complete flower, as it possesses all the four essential parts of flower such as calyx, corolla, androecium and gynoecium. The flower color may be white, blue, red-purple, blue-purple and their shades according to variety. The flowers of potato are perfect and self-pollinated. However, cross-pollination up to 2-4% may occur with the help of insect pollinators. Most of the varieties of potato bear sterile pollen; therefore formation of fruit or berries does not take place. The seeds are formed in small green berries, which turn yellow on maturity.

Management of water, nutrients and weeds

Potato responds well to manures and fertilizers as compared to cereals and legumes. The fertilizer requirement varies with the soil and previous crop. Recommended doses (kg/ha) of N, P₂O₅, K₂O are 180:80:110 for alluvial soils and 115:45: 50 respectively for black soils. Nitrogen is the primary limiting nutrient in potato production directly affecting the tuber yield in all soil groups. It increases roots, foliage and tuber growth. Nitrogen is applied to the crop in two split doses, i.e. half at the time of planting and remaining half at the time of earthing up for effective utilization by the crop. Both calcium ammonium nitrate (CAN) and ammonium sulphate are good sources of nitrogen for potato crop. Urea though less efficient is the cheaper source and can also be applied either alone or in combination with CAN in 1 : 1 ratio of N basis.

Phosphorus and potassium are the other two essential elements in potato production. Phosphorus increases tuber yield by increasing the yield and number of medium size tubers whereas potassium increases the number of large size tubers. The application of P and K in furrows in full dose at the time of planting gives the best results. Water-soluble phosphate fertilizers like superphosphate and DAP are most suitable for potato. Similarly potassium sulphate is a better source of K than muriate of potash. The residual phosphorus and potash are generally adequate and nitrogen requirement is reduced by half in succeeding cereal crop. Farmyard manure has been found to be useful in potato production and its application @ 30 tonnes/ha has been found to meet entire P and K needs of potato and succeeding cereal crop besides meeting micro-nutrient needs.

Mulching: Use of mulch helps in conserving soil-moisture, reducing soil-temperature and inducing quick germination in winter. It also suppresses weed growth. Plant material such as paddy straw, maize or *jowar* stalks or farm refuses acts as good mulch and is applied on ridges. In hilly regions, local available material such as pine needles or leaf litter are quite effective in controlling run off loss and conserving moisture.

Irrigation: Water is one of the essential components required for growth and development of crop. The total water requirement of crop varies between 350-550mm depending upon soil type, climate and crop duration. Pre-planting irrigation is advantageous for uniform germination. Second irrigation is given after about a week and subsequent irrigations as and when required. Light and frequent irrigations are better than heavy and less frequent irrigations. When irrigation water is in short supply, water is applied efficiently and economically at critical stages in crop development, i.e. at stolon formation, tuber initiation and tuber development stages of crop. Irrigation is stopped about 10 days before harvesting of crop to allow firming of tuber skin.

Weed management: Weeds compete for nutrients, moisture, light and space and cause considerable loss in potato yields. They also harbour a few pathogens and act as host to a number of insects and pests. Important weeds of potato fields in plains are *Anagallis arvensis*, *Chenopodium album*, *Trianthema monogyna*, *Vicia sativa*, *Cyperus rotundus*, *Spergula arvensis*, *Melilotus* spp., and *Oxalis* spp. In the hills *Amaranthus* spp, *Chenopodium album*, *Cynodon dactylon*, *Oxalis latifolia*, *Polygonum* spp., *Spergula arvensis*, *Digitaria* sp and *Setaria glauca* are the most common weeds in potato fields.

Weeds are effectively managed by cultural or chemical methods or combination of both the methods. They are effectively controlled by hoeing and weeding when the crop is about a month old followed by earthing up. Among the herbicides pre-planting application of Fluchloralin and Pendimethalin and pre-emergence application of Alachlor, Linuron, Metribuzin, Nitrofen, Oxyfluorfen, Ametryn, Simazine, etc., are the most effective herbicides for weed control. Among post-emergence herbicides, Paraquat at about 5% emergence is quite effective.

Harvesting and yield

Harvesting of potatoes is done before the maximum soil temperatures rise above 26-30° C. It is completed by end of January in central and eastern plains and by 15 February in the western plains to avoid rotting of tubers due to high temperatures in March/ April. The crop is harvested 10-15 days following stoppage of last irrigation. This allows tuber skin to become firm and tubers do not get bruised on harvesting. Harvesting is done manually with the help of spade or *khurpi* or by bullock drawn single row digger/plough. It is also done mechanically with the help of 1-4 row potato digger.

Post harvest Handling

Nearly one fifth of the total potato production in the country is used as planting material in the following season. Therefore, post-harvest handling particularly of seed stocks becomes very important. After harvesting, potatoes are kept in heaps in cool places for another 10-15 days for drying and further curing of skin. Heaps 3-4 metre long, wide at the base and about 1 metre wide at the top are the best. In hills the harvested potatoes are spread in well-ventilated rooms for drying. Before grading, all the cut, damaged and rotted tubers are removed. The tubers are then graded and packed in gunny bags according to sizes preferably in 4 sizes, e.g. small (less than 25g), medium (25-50g), large (50-75g) and extra large (above 75g). After grading potatoes meant for use as seed during the next year are treated with 3% boric acid solution for 30 minutes for protecting against soil-borne pathogens, e.g. black scurf, common scab, etc. before storing in bags. In the plains the seed potatoes after drying, curing and grading are stored in cold stores where temperature is maintained between 2°-4°C with high relative humidity. The low temperature checks sprouting and rotting, and high relative humidity reduces weight loss in tubers.

Diseases and Pests

The potato plant and its underground tubers are afflicted by several diseases and pests. The important ones are late blight of potato, which affects the stems, leaves, and the tubers and causes heavy losses in tuber yield. The disease appears in the crop in the hills every year and frequently in the plains also. Other leaf spot diseases affecting leaves and stems are early blight, phoma and leaf blotch. Among the diseases affecting tubers, the blackscurf, common scab and wart are important. The blackscurf and common scab diseases are present in all potato growing areas of the country in different intensities. These diseases do not affect the yield much, however, they disfigure the tubers and reduce their market value. The wart disease affects both the plants and the tubers. It causes heavy losses in tuber yield. The disease has been confined to the Darjeeling hills of West Bengal by legalization (internal quarantine measures). The brown rot of tuber is

another important disease of potato. This disease causes wilting of plants in the field and hence is also known as bacterial wilt disease. This disease is present mainly in the mid-hills in the country and in pockets of Assam, Meghalaya, Maharashtra, Karnataka and Orissa. Aphids and leaf-hoppers are the important vectors as they are responsible for transmitting and spreading a number of viral and mycoplasmal diseases. Among pests, the cutworms, white grubs, potato tuber moth and cyst nematodes are important. The cutworm damages the plants in field by cutting the stem at ground level and the white grub damages the underground tubers in the field. The potato tuber moth is present in the plateau region and in some pockets in the hills of Himachal Pradesh. It damages the plants in the field and the tubers in both fields and stores. The cyst nematodes are confined to the southern hills only. They affect the roots, hinder the movement of nutrients to the plant and thereby reduce crop yields.

Effective control measures have been developed against most of the diseases. The integrated disease management (IDM) components that are employed in crop protection are (i) deployment of short-duration varieties which may escape the disease and do not allow build-up of pathogen, e.g. for late blight, soil and tuber borne diseases and bacterial wilt (ii) use of agronomic practices like healthy seed, hot and cold weather cultivation, green manuring, irrigation, fertilizer application, storage and adoption of seed plot technique e.g. for viruses, aphids, late blight, potato tuber moth, etc., (iii) use of bio-control measures like host resistance, bio- agents, plant products and sex pheromones for diseases like late blight, early blight and other foliar diseases, wart and pests like cyst nematodes and iv), use of chemicals e.g. fungicides, insecticides and other chemicals alone or in combination with other components for control of diseases like early and late blights and other foliar spots, soil and tuber borne diseases like black scurf and common scab, pests like potato tuber moth and cyst nematode. Many varieties released by CPRI have multiple resistant to disease and pests are given in table below.

Varieties with multiple resistances

Variety	Resistance to				
	LB	EB	Wart	Viruses	Cyst N.
Kufri Jyoti	MR	MR	I	T	-
K. Megha	HR	MR	-	T	-
K. Kanchan	MR	MR	I	T	-
K. Swarna	HR	-	-	-	R
K. Thanmalai	HR	-	-	-	R
K. Badshah	R	R	RG2	T	-
K. Sutlej	R	R	RG2	-	-
Total resistant varieties	22	9	4	5	2

CPRI has also developed IDM technology for various disease and pests and the salient component as below.

IDM Components for Major Diseases

Disease	Variety	Agr. Pract.	Biocontrol	Chemical
Late blight	R*, SD**	Irrigation, High ridging	<i>Penicillium, Trichoderma</i>	Mancozeb, Metalaxyl
Soil/Tuber diseases	SD	***	Fusarium	Boric acid
Bact. wilt	SD	***	<i>Bacillus, Pseudomonas</i>	Bleaching powder
Viruses	Tolerant	Seed plot technique	Meristem culture. Thermo-/Chemotherapy	
Wart	Immune	-	-	-
EB & LS	R	Sanitation	-	Mancozeb + Urea

*= Resistant **= Short duration varieties ***= Healthy seed, Crop rotations, Hot/Cold weather cultivation etc.

Cassava

Importance and Scope

Cassava (*Manihot esculenta* Crantz) a native of Brazil in Latin America was introduced to India (Kerala) by the Portuguese in the 17th Century. Popularly known as tapioca it was popularized as a food crop by Shri Visakhram Tirunal, the then Maharaja of the erstwhile Travancore. The crop has gained importance as a cheap source of carbohydrate, mainly for human consumption. Its importance in tropical agriculture is due to its drought tolerance, wide flexibility to adverse soil, nutrient and management conditions including time of harvest. Cassava can be grown in areas of rather uncertain rains that prevent the successful cultivation of other crops. As cassava has no definite harvest time farmers can have a staggered harvest, which provides security against famine. Thus indeterminate harvest of cassava adds to the advantage in cassava based cropping system. Being a photo-insensitive crop, cassava can be profitably cultivated throughout the year. Apart from the high energy content of roots, its foliage can produce upto 5 tons of crude protein per hectare per year.

Presently, the world production of cassava is about 165 million tonnes (FAO, 1997) and approximately 60% of the production is used as human food serving as an important staple for more than 500 million people in the world. Apart from its role as a staple/subsidiary food, during the past few decades there has been growing recognition of the value of cassava roots as a low cost energy source for livestock and as a raw material for industrial starch and fuel alcohol.

Area, distribution and production: The four southern states, viz., Kerala, Tamil Nadu, Andhra Pradesh and Karnataka are the main growers of cassava in India. The trend of its acreage and production shows that while its area has reduced marginally from 0.246

million ha from 1989-91 to 0.244 million ha in 1997, its productivity has increased from 20.6 t ha⁻¹ to 24.5 t ha⁻¹ during the same period.

Climate and soil requirements

Cassava is extensively cultivated in different agro-climatic zones. It tolerates very hot climate but temperatures below 18-20°C reduces growth and yield. Cassava does not tolerate shading since it leads to stem and internode elongation leaving no carbohydrate for root growth. Shading also decreases the leaf life in cassava. Cassava efficiently avoids drought by dropping its leaves and remains essentially dormant during drought. Hence cassava can be grown in areas of uncertain rains; Cassava however, does not withstand exposure to frost. A well drained loamy soil is the best suited for the crop. Poorly drained heavy and rocky soils are unfavourable for growth and yield. It can also not thrive on water-logged soils. Cassava, however, can be grown successfully in acid soils of low pH the optimum soil pH being 5 to 6.

Varieties and hybrids

There are a number of varieties of cassava which are grown in different regions of the country. Most of these have been developed by the Central Tuber Crop Research Institute (CTCRI), Thiruvananthapuram. Important varieties are Co 1 Co2 Co3 H97 H 165 H 226 M4 Nidhi Sree Prakash, Sree Harsha, Sree Sahya and Sree Visakham.

Cultivation Practices

To increase the multiplication rate, the Central Tuber Crops Research Institute has developed miniset technique. In this technique cuttings are taken from mature disease free stems consisting of 5-6 cm of the stem tip with two node cuttings from below. The two node cuttings are planted end to end horizontally in well prepared nursery about 5 cm deep, with buds facing either sides. A spacing of 5 cm is provided between two rows. Growing tips and four node top setts are planted erect at 5 x 5 cm spacing to prevent decay due to excess moisture content in these tender parts. The nursery bed is irrigated frequently as needed. The mini setts are sprayed with systemic insecticide to control white flies as per need. The mini setts are ready for transplanting in about three to four weeks time.

The optimum plant population varies according to ecological conditions. In general, it has been observed that as plant population increases, the total root yield also increases. However, the number of roots per plant, root size and harvest index decreases. A spacing of 90x90 cm for branched and a closer spacing of 75x75 cm for non-branched cultivars has been found to be optimum for maximum production.

Shoot number per hill: Under favourable conditions, the upper dormant buds produce sprouts. The sprouts emerging from the top buds are vigorous than those emerging from the lower ones of the same stakes. Retaining two shoots per plant on opposite sides is advocated as it helps in the production of more number of uniform sized roots all round the base of the plant. Nipping of excess sprouts after retaining two, 2-3 weeks after planting is advocated.

Gap filling: Long stakes of 40 cm are advocated for gap filling as against normal stakes (20 cm.long) Apart from long stake of double length, gap filling can be done by

transplanting seedlings raised in the nursery. At the time of planting itself 5 to 10% of seedlings may be planted at a close spacing of 4.5 x 4.5 cm in nursery under irrigation at reasonable interval so that these seedlings from the nursery can be used for gap filling.

Mode of Pollination

Members of family Euphorbiaceae are cross pollinated and entomophilous. The reason for cross pollination being monoecious along with protogynous nature of plant. In cassava, flowering occurs only in branched plants and profuse flowering only in spreading and branching plants. Early flowering within 3 months is observed in a few clones. Since economic produce is the tuber, which is a vegetative part, earliness could not be correlated with flowering. Cassava is generally female fertile, however, the male sterility is widely prevalent. Though stigma receptivity is only up to 3 PM on the day of anthesis, receptivity lasting for a few hours more had been identified in a few profusely flowering clones. The flowering and seed set are generally common among the exotic species because of the wide prevalence of branching types among them. Successful inter-specific hybridization has been reported from many countries between cassava and other *Manihot* species like *M. glaziovii*, *M. dichotoma* and *M. saxicola*. Transfer of genes responsible for high tuber yield, resistance to viruses and drought are to be attained through such inter specific hybridization. Many of inter specific hybrids are male sterile but with partial female fertility.

Management of water, nutrients and weeds

Irrigation : Cassava is grown mostly as a rainfed crop in Kerala, but in low rainfall areas like Tamil Nadu, it is grown as an irrigated crop. Irrigation at approximately 25% available moisture depletion level throughout the growing season could double the tuber yield as compared to control (no irrigation). Supplementary irrigation at IW/CPE ratio = 1.0 increases the cassava yield by 90% over the rainfed crop.

Nutrients: Cassava is considered as a rustic crop that grows relatively well on poor soils without application of much fertilizer but responds well to the application of manures and fertilizers. It extracts relatively large amounts of nitrogen from the soil especially when leaves and stems are removed with roots. For the production of one tone of dry matter, cassava removes 6.45 kg N, 1.23 kg P and 8.5 kg K. Nitrogen deficiency is commonly encountered in sandy or very acid soils. In most of the high yielding varieties, the response to nitrogen is in the range of 75-100 kg N per hectare. Among different sources of N, calcium ammonium nitrate (CAN) and urea were found to be the best for cassava in laterite soils. Application of N in two split doses, viz., half as basal and the remaining half at two months after planting has been found to be superior to other split applications. High nitrogen application results in luxuriant growth of top but low root to top ratio.

Phosphorus deficiency and response to P application are common in the acid laterite and red soils. In acid laterite soils of low available P status, cassava responds to P application up to 100 kg P_2O_5 ha⁻¹. When applied along with FYM, both SSP and Mussoorie rock phosphate were at par. In low P soil, even though cassava initially responded to 100 kg P_2O_5 ha⁻¹, the response declined gradually due to build up of soil P status. In acid laterite soils, placement of SSP to a depth of 5 cm is beneficial. Full dose of P applied as basal

produced significantly higher tuber yield over half P as basal and half as top dressing after two months or full dose applied after two months.

In acid laterite soils, cassava responded favourably to the application of 100 kg K₂O ha⁻¹ beyond which there was a gradual decline in yield. Application of 50% dose as basal and 50% two months after planting increases the starch and dry matter content of tubers.

Organic manuring: Traditionally cassava is fertilized only with organic manures such as farm yard manure and wood ash and even today this is followed by subsistence farmers. Application of cow dung alone to cassava resulted in an increase in bitterness and cyanogen content of tubers. Significant increase in cassava tuber yield is obtained by application of farm yard manure 12.5t/ha and 100kg each of N, P₂O₅ and K₂O per ha.

Green manuring: Vigna (cowpea) has been found to be a superior green manure on the acid infertile soils. Cassava is benefited by the rotation and association of cowpea and sunhemp, respectively. Green manuring *in situ* can eliminate the practice of using FYM in the cultivation of cassava and can bring down the cost of inputs substantially. Burying of green manure crops, particularly cowpea improves the nitrogen content of the soil.

Harvesting

Cassava being perennial in nature, there is no definite harvest time. The tuberous roots continue to bulk from 2nd month onwards and when it attains a considerable weight (400-600 g per tuber) the crop can be harvested. Varieties, which are early bulking, can be harvested within 6-7 months time. When tubers are over mature they become fibrous and the quality is reduced by lower starch content. Harvesting tends to be easier when planted on ridges or beds than on flat ground. In loose or sandy soils harvesting is easier than in clay or heavy soils. Due care must be taken not to inflict injury to the roots to avoid post harvest losses.

Post harvest Handling

The crop is ready 10-11 months after planting. Short-duration varieties can be harvested 6-7 months after planting. Delay in harvesting may result in deterioration in cooking quality of the tubers.

Diseases and Pests

Cassava mosaic disease, brown leaf spot anthracnose/die back and tuber rot are the major diseases. The symptoms of mosaic disease are chlorotic areas intermixing with normal green tissue giving mosaic pattern. In severe cases leaves are reduced in size, twisted and distorted, reduced chlorophylls and photosynthetic area. It causes about 25-80 % yield reduction. Use of disease-free planting material, growing field-tolerant varieties -H97, H165, Sree Visakham and Sree Sahya, rouging out infected plants and strict field sanitation are recommended for managing the disease.

Brown leaf-spot caused by *Cercospora henningsii* appear as brown spots on both sides of leaf surrounded by yellow halo. It damages leaves and reduces chlorophyll contents

causing premature defoliation. Growing field-tolerant varieties H97 and Sree Visakhham and spray of fungicides are recommended for its control.

Anthracnose/die back caused by *Colletotrichum manihotis* appears as leaf spot on both sides of the leaves. Spotted tissues become necrotic and dies. The disease reduces photosynthetic area and also premature withering of the leaves, which affects the yield. Chemical control through spray of fungicides is recommended for its control.

Tuber rot (*Phytophthora drechsleri*) causes brown discolouration of internal tissues and rotten tissues emit foul smell. Improved drainage, removal of infected tubers from field and incorporation of *Trichoderma viridae* into soil are recommended for its control.

Scale insect (*Aspidiella hartii*) causes white scale colonies on stems. Drying of stems takes place under storage. Stem becomes weak and dry, causing side branching to give bushy appearance. Viability of planting material is reduced, resulting in poor establishment. For control of this pest, scale-free stems should be collected for storing and planting. Staking stems in horizontal position encourages multiplication of scales due to the development of higher temperature and humidity. Therefore healthy stems are to be kept in vertical position under shade and diffused light to facilitate easy aeration. As a prophylactic measure the stems may be sprayed with insecticides at the time of storing. If further infestation is observed, one more spraying may be done. The infested stems should be rejected and burnt at the time of planting.

Termite (*Odontotermes obesus*) causes poor establishment of setts/seedlings, resulting in drying of the plants. In case of severe incidence soil application of Carbaryl (10%) dust or spray of Chlorpyrifos (0.05%) is recommended.

White grub (*Leucopholis coneophora*) attacks plants which become pale- yellowish and slowly wither and dry. The grubs feed on developing roots and commonly in young plants. Collection of adult beetles, deep ploughing to expose the grubs and soil application of Carbaryl (10%) dust are useful for controlling this pest.

Spidermites (*Tetranychus cinnabarinus*, *T. neocaledonicus*) colonizes on lower surface, causing depletion of chlorophyll content of leaves due to which elongated yellowish streaks, chlorosis, withering and drying of leaves occur. Spraying water at run-off level/insecticides, foliar application of urea followed by spraying of Dimethoate (0.05%) in severe cases to contain the pest outbreak is recommended as an IPM approach.

Thrips (*Retithrips byriacus*) causes leaves to become pale, with dirty brown excreta. In severe infestation the leaves roll and dry up. Reddish nymphs are seen crawling. Depletion of chlorophyll content of leaves affect photosynthetic efficiency and tuber yield. Spray of insecticides like Dimethoate (0.05%) is recommended.

Spiral whitefly (*Aleurodicus dispersus*) causes yellowish speckles with crinkling and curling of leaves. In severe infestation black sooty mould develops. Adults and nymphs

are covered with white waxy and powdery scale. Spray of neem-based products like Azadirachtin is recommended.

Common whitefly (*Bemisia tabaci*) is important as a vector of Indian cassava mosaic disease (ICMD). Spray of Dimethoate (0.05%) is recommended for its control.

Chips borers (*Araecerus fasciculatus*, *Lasioderma serricorne*, *Rhyzopertha dominica*, *Dinoderus minutus*, *Sitophilus oryzae*) reduce Cassava chips to a powdery mass. Drying cassava chips to a very low moisture content (below 10%) and storing using suitable packing material, which can prevent reabsorption of moisture, is a good management practise to prevent infestation. Polythene coated jute bag, woven plastic bags, metal bins, etc., can be used for long-time storage.

Flour beetle (*Sitotroga cerealella*, *Tribolium castaneum*) causes flour to be webbed together and grubs feed within, causing weight and quality loss. Storing clean and dry chips, disinfestation before storing using safe fumigants and impregnating the storage bags using Malathion (0.5%), Fenvalerate (0.1%) or Azadirachtin (Nimbecidin 2%) before storing the chips reduces insect infestation.

Sweet Potato

Importance and Scope

Sweet potato (*Ipomoea batatas* L. Lam.) is also believed to have originated in or around northern South America. It is a herbaceous, perennial plant, but is grown as an annual by vegetative propagation using either storage roots or stems cuttings. The tuber is an important source of carbohydrate. Certain varieties having yellow flesh are rich in carotene, a precursor of vitamin A. The edible sweet potato is variously referred to as a root, a root-tuber or a tuber. Sweet potato is a short duration crop, adaptable to a wide range of growing conditions. It exhibits no strict seasonality making it suitable as a combination crop with other crops

Area and production: Sweet potatoes are widely grown throughout the world from 40⁰N to 32⁰S under contrasting systems of agriculture. It is grown in almost 111 countries, all over the world. Asia accounts for 78.7 per cent of the area under cultivation of which majority (67.7 percent) is accounted by China. As regards production, 93.1 per cent is accounted by Asia in which the contribution of China is 87.7 per cent. In India, sweet potato is grown in 0.14 million hectares with an annual production of 1.17 million tonnes at productivity of 8.3 t ha⁻¹. The major sweet potato growing states in India are Orissa, Uttar Pradesh and Bihar. The crop is usually raised as a rainfed crop in *kharif* season and with supplemental irrigation during the *rabi* season.

Climate and Soil requirements

Sweet potato is a warm weather crop and its growth is best at temperature around 24°C. Hence, it can be grown throughout the tropics, but in temperate regions, the aerial portion die out during winter. Warm sunny days and cool nights are very much favourable for storage root formation in sweet potato. Root formation requires cooler temperature (about

24 °C mean temp.) while the weather should be warm for root bulking. Shading of the crop results in reduced tuber yield.

Sweet potatoes require at least 500 mm rainfall during the growing season and an annual rainfall of 750-1000 mm is considered the best. They can tolerate considerable periods of drought but yields are very much reduced if water shortage occurs at the time of tuber initiation. Sweet potatoes grown under high rainfall frequently produce vigorous vine growth but poor tuber yield. The ideal conditions for high yield are good rains during the period of early growth and dry sunny weather during the period of tuber bulking and maturity. Sweet potato can be grown on a wide variety of soils, but sandy loams, reasonably high in organic matter with permeable subsoil are ideal. On heavy clays, shoots and leaves grow well, but the yield is poor with tubers of irregular shape. Dry and compact soil favours lignification leading to the formation of pencil like roots and more vine growth. pH 5.6 to 6.6 of the soil for sweet potato cultivation is optimum. Sweet potato is an acid tolerant crop it cannot withstand salinity and alkalinity. Salinity significantly reduces growth of stems and roots and results in lateral rolling of leaf lobules, reduction in leaf size and necrosis of older leaves.

Varieties

Bhuban Shankar, Co1, Co2, Co3, Gouri, H41, H42, Kiran, Rajendra Sakarkand 5, Samrat, Sree Nandini, Sree Vardhini and Varsha are some of the improved cultivars recommended for growing in different parts of the country, having better yield, wider adaptability and early maturity.

Cultivation Practices

In order to produce vines for planting one hectare of land, about 100 m² of land and about 100 kg medium sized (125-150g), weevil free tubers are required. The tubers are planted at a spacing of 20 cm on ridges formed 60 cm apart. To ensure quick growth of vines, top dressing with 1.5 kg urea/100 m² at 15 days after planting is advisable. The nursery is irrigated on alternate days for the first 10 days and once in three days thereafter. After 45 days of growth, the vines are cut to a length of 20-30 cm for further multiplication in the secondary nursery.

Vines collected from the primary nursery are further multiplied in the secondary nursery in an area of 500 m² to produce enough vines for planting one hectare of land. Farm yard manure or compost is applied @ 1 kg m² and ridges are formed at a spacing of 60 cm. Vines obtained from the primary nursery or from freshly harvested crop are planted in the secondary nursery at a spacing of 20 cm on the ridges. To ensure enough vegetative growth, five kg of urea is applied in two splits on 15th day and 30th day after planting. For better establishment of vines in the nursery, daily irrigations are provided for the first three days and on alternate days for one week. Thereafter, irrigation may be restricted to once in three days. The vines get ready for transplanting at about 40-45 days after planting.

Selection of planting material: The apical cuttings are the best to secure high yields from sweet potato. Starch content and reducing, non-reducing and total sugars were

highest in tubers from plants grown from apical cuttings. A vine length of 20 - 40 cm with at least 3-5 nodes is optimum for tuber production in different parts of India.

Preparation of vines: Cut vines with intact leaves are stored under shade for two days prior to planting in the main field to promote better root initiation, early establishment and higher tuber yield. Optimum root length of cuttings for transplanting was <1 cm as longer roots were easily broken. The leaves can be removed when the vines are to be transported for off to reduce the bulk.

Planting system: The land is ploughed or dug to a depth of 20 cm and harrowed to pulverize the soil. Mounds, ridges and furrows and flat bed methods of planting are being practised in different locations. It is preferable to plant sweet potato on mounds in areas experiencing problems of drainage. Ridges formed across the slope are recommended in slopy lands to prevent soil erosion. Among the different methods of land preparation, the highest tuber yield was obtained when planted on mounds. The higher yield obtained in mound system of planting is attributed to better soil aeration and less tendency for soil compaction. The cuttings are planted in the soil with both the ends exposed and the middle portion buried in the soil. Vines are also planted in an inclined position with half of its length buried in the soil. The number and weight of total and marketable tubers are higher when slips are planted horizontal to the soil with 5 or 6 nodes covered than when planted perpendicular to the soil. Horizontal planting also results in higher plant survival and better development of the root system.

Spacing

A close spacing is generally recommended for sweet potato to achieve maximum tuber yield. However, when sweet potato is planted on mounds, no specific spacing is followed and vines are planted on mounds by accommodating 3-6 vines per mound. A general spacing of 60x20 cm has been recommended by Central Tuber Crop Research Institute (CTCRI) to accommodate 83,000 plants per hectare.

Mode of Pollination

Many of varieties do not flower. The crop is highly cross-pollinated due to self-incompatibility and male sterility. Cross incompatibility has also been reported. By grafting sweet potato on related species of *Ipomea*, flowering has been induced in the crop. It is reported that related species provide 'flower inducing substance' once they are used as rootstock. Though sweet potato is considered to be shy in flowering, there is a drastic variation in the flowering behaviour of its clones. The habit varies from profuse flowering to almost nil flowering in normal habitat.

Management of water, Nutrients and Weeds

Irrigation: To ensure proper sprouting and establishment of vines, a moist seedbed is required for 4-5 days. When sufficient soil moisture is not available at planting, irrigation has to be provided daily for the first three days followed by irrigation on alternate days for one week. The tuber initiation phase, which falls around 20 DAP, is very critical and maintaining optimum soil moisture during this period is essential to obtain economic

yield. Irrigation would generally increase the yield and improve the grade and quality of marketable tubers.

Nutrients

Organic manuring: As sweet potato removes appreciable quantities of plant nutrients, incorporation of considerable amount of organic manure at planting has been recommended to maintain soil productivity. Application of 5-10 t ha⁻¹ FYM is advocated.

Nitrogen: Sweet potato generally responds to small doses of nitrogen application. Excessive nitrogen application results in profuse leaf production at the expense of root yield. Nitrogen deficiency is usually noticed in sandy soils and soils low in organic matter content. Phosphorus deficiency and response to P application are most common in acid soils, especially in laterite and red soils, which contain high levels of Fe and Al such as Oxisols, Ultisols, Inceptisols, etc. Rock phosphate maintains or slightly improves the availability of P in soil. Since sweet potatoes do not require very large quantities of phosphate for root development, a dose of 25-50 kg ha⁻¹ P₂O₅ is optimum. Differential response to applied potassium has been reported from various parts of India. Soils high in available potassium status do not respond to added potash in some locations while potassium fertilizer increased the yield of sweet potato by increasing the number of tubers and the ratio of large to small tubers at other locations. A general recommendation of 40-60 kg/ha of N and K₂O and 50 Kg/ha of P₂O₅ is recommended for the lowland conditions. Full dose of P and half of N and K as basal dose at the time of planting and remaining half 30 days after planting along with weeding and earthing up is recommended.

Intercultural operations

Weeding: Sweet potato vines are so aggressive that they cover the soil surface quickly and suppress most of the weeds. However, weeds are a problem in the early stages of the crop and keeping the field weed free at this stage is recommended.

Interculturing: Interculturing and earthing up of the soil controls weeds, besides improving the physical condition of the soil. About 20 per cent reduction in tuber yield has been recorded in sweet potato due to weed infestation in the early stages of growth. To protect the crop from weeds, at least one weeding and earthing up have to be given between before 35 days after planting along with topdressing of nitrogen.

Harvesting

Environmental conditions and varieties play an important role in deciding the optimum time of harvest in sweet potato. Single harvesting or double harvesting (progressive harvesting) is practised in sweet potato. Percentage weevil infestation increased with age of the crop. The tuber yield per plant also increases if the crop remains in the field longer, but the tubers become less palatable and infestation by sweet potato weevil and/or rotting of tubers may occur. The maturity of the tubers can be determined by cutting fresh tubers. The cut surface of the immature tuber gives a dark greenish colour while, the cut ends dry clearly in the case of mature tubers. The field is irrigated 2-3 days prior to harvesting to facilitate easy lifting of the tubers. In India, manual harvesting of sweet potato is usually carried out.

Post harvest Handling

Sweet potato matures three-and-a-half to four-and-a-half months after planting. Harvesting sweet potato 120 days after planting is normally recommended. Delay in harvesting invites attack of sweet potato weevil. Maturity is indicated when the leaves turn yellow and begin to fall. Maturity is also indicated by the tubers in which the latex dries up without turning greenish black on cutting. Care should be taken to avoid injuries and bruises on tubers. For marketing of fresh tubers, cleaning and grading should be done to get better prices. After harvest, tubers are spread in partial shade for 5-6 days, for healing and curing. In some parts of the country, tubers are stored in a layer of dry sand/soil after curing under ambient conditions. For storing, graded tubers free from sweet potato weevil and bruises should be selected. Farmers store the graded tubers by keeping in a shaded pit and covering it with paddy straw. Finally, the heap is plastered with mud or cowdung slurry. Tribal farmers of Koraput district of Orissa store their sweet potatoes by heaping the tubers in a corner of their huts and covering the heap with a thin layer of paddy straw. This heap is plastered with soil+cowdung paste

Diseases and pests

Chlorotic leaf distortion (*Fusarium lateritium*) causes bright chlorosis on young leaves, twisting or deforming leaves in advanced stage. White powdery growth of fungal structures is seen on leaf surface and margin of leaf blade. It affects leaf opening and reduces the chlorophyll content. Spray of Carbendazim-75wp (Bavistin-0.001%) at monthly interval, or spray of dipotassium hydrogen phosphate or disodium hydrogen phosphate (0.001%) 3-4 times at fortnightly interval have been found to control the disease.

Feathery mottle disease (Sweet potato feathery mottle potyvirus) causes ringspot, pink vein-banding, mosaic and puckering. Spots enlarge and intermix with pink vein-banding and entire leaf becomes pinkish. It reduces the chlorophyll content which affects photosynthetic process resulting loss in the yield. Use of virus-free planting material and rogueing of infected plants is recommended.

Sweet potato weevil (*Cylas formicarius*). The Adult weevil makes punctures on vines and tubers. The grubs bore and feed by making tunnels. Feeding and adult emergence holes can be seen on vines and tubers. In severe infestation the collar region of the plants shows unusual thickening due to proliferation and hypertrophy of tissues causing a characteristic terpenoid odour. Even the slightly damaged tubers are unsuitable for consumption due to bitterness. Removal and destroying alternate hosts, use of pest-free planting material, use of weevil-free tender planting material, earthing-up or re-ridging the crop 30 and 60 days after planting, suitable crop rotation are advocated for its control. Need based spray of insecticides and use of synthetic sex pheromone (Z-3- dodecen-1-ol-E2-butate) (1 mg dose) to trap the insects are also recommended.

Vine-borer (*Omphisa anastamosalis*) The pest results in symptoms like terminal drying and wilting of vines. Inner contents of the vines and tubers are eaten by boring. Crop hygiene and crop rotation reduces borer's incidence. Spray of insecticides is advocated in case of severe infestation.

Yam

Importance and Scope

Yams (*Dioscorea* spp.) have been grown in India since very ancient times and *D. alata* (Water/greater yam) is said to be of Indian origin. *D. rotundata* (White yam) is a native of West Africa while *D. esculenta* (Chinese/lesser yam) could be of Burma or Indo-China in origin. It is a staple food crop as well as a cash crop in Western Africa, especially in Nigeria. It is a rich source of carbohydrates, certain vitamins and has high calorific value. Starch constitutes the predominant carbohydrate component in most of the species of yams. Yams are cultivated in every tropical country, but their large-scale cultivation is restricted mainly to West Africa, South-East Asia including China, Japan and Oceania and the Caribbean. Yams are eaten mostly as boiled, baked or fried.

Area and production

Africa is the largest producer of yams in the world where it is a staple food. Major share in yam production in Africa comes from Nigeria. Total world production of yam is 300 mn tons from an area of 33 mn hectares, of which Nigeria alone produces about 196mn tons from an area of about 22mn hectares. The world average production is about 9.1 t ha⁻¹ while that of Nigeria is about 9 t ha⁻¹. In Asia yams are grown in an area of about 17,000 ha producing about 242,000 tons with an average yield of about 14.5 t ha⁻¹.

Climate and Soil Requirements

Yams thrive well under warm sunny weather (temperature of 25 to 30 °C) with plenty of rains. Adequate moisture is required for the growth, development and yield of yams. Evenly distributed annual rainfall of 100 -150 cm spread over six to seven months period is ideal for *D. rotundata*. However, *D. esculenta* comes up well in places receiving a rainfall of 90 to 100 cm. *D. cayenensis* requires fairly long rainy season of about 10 months each year. On the other hand, most *D. rotundata* cultivars can be grown with far less rainfall and seven months of wet weather is often sufficient. The most critical period of rainfall/moisture is the first five months after planting. Yam production is also significantly influenced by day length. It has been found that shorter days favour tuber formation and development while longer days (> 12 hours) apparently influences vine growth.

Deep and loose friable soil with adequate nutrient is well suited for the growth and development of yams. It is also essential to have proper drainage facility in soil, as stagnant water is likely to damage the tuber.

Varieties and Hybrids

A number of varieties have been released in yams. The improved varieties show a yield potential of 18-25 tonnes/ha in greater yam and 18-30 tonnes/ha in lesser yam, while in white yam it is 33-40 tonnes/ha. Important varieties are Sree Keerthi Sree Roopa for Greater yam Sree Latha, Sree Kala, Konkan Kanchan for Lesser yam and Sree and Priya Sree Subhra for White yam

Cultivation Practices

Yams are commonly propagated vegetatively. Either tuber pieces or small whole tubers are used. Propagation by vine-cuttings is not advisable because of slow tuber production. A seed tuber weighing 125-150 g is optimum size for planting in *D. esculenta* (Chinese yam), while in *D. alata* (Water yam) and *D. rotundata* (White yam), 200-250 g tuber pieces or whole tubers are used. Usually larger whole tuber is cut into pieces (setts) consisting of top, middle and bottom. Seed tubers and top portions are ideal for planting. Before planting tuber pieces are dipped in cow dung slurry and dried in shade to protect from damage. Drying of cut pieces gives healing effect, encouraging callus formation. Yam tubers have a long dormancy period (2-3 months depending on species). The degree of dormancy decreases during storage resulting in sprouting and weight loss, a major problem in yam cultivation. To maintain dormancy and controlling storage sprouting, soaking freshly harvested tubers of lesser yam and greater yam in 0.1 % solution of maleic hydrazide for 10 hr is effective. Dormancy can be broken by dipping of tubers quickly in 4-8% solution of ethylene chlorohydrin followed by dry storage. Adequate precaution needs to be taken during this treatment.

In India, traditionally yams are grown in homesteads. The package of practices consists of ploughing or digging of the land up to a depth of 15 -20 cm followed by opening of pits of the size 45 x 45 x 45 cm. About 3/4 th size of these pits are to be filled with dry farm yard manure and top soil. Seed yams or yam setts are then planted in it and mulched with green or dry leaves and soil heaped over them.

Maximum tuber size is obtained when plants are 2 meters apart. Closer spacing results in decreased tuber size but produces more yield per unit area. It is suggested that wider spacing should be used in heavy soils and if staking is not intended. Under ridge and furrow system, 70 cm spacing between ridges and 45 to 60 cm spacing between plants so as to accommodate 25,000 plants ha⁻¹ is generally adopted. A spacing of 1 x 1 m with a plant population of 10,000 plants ha⁻¹ for *D. alata* and *D. rotundata* has been recommended. In general for dwarf bushy plants, a close spacing of 60 x 60 cm is optimum and economically viable.

Mode of Pollination

Yams are vegetatively propagated dioecious species. In *D. alata*, clonal selection had been the only mode of improvement as flowering is erratic and many of the clones are sterile. In the available germplasm flowering of clones in any year is not assured. Moreover, synchronous flowering of male and female clones necessary for sexual reproduction is very rare. It was also found that a large number of female clones are sterile.

In *D. esculenta*, flowering has been found to be very rare. Only few accessions in the germplasm had been found to flower. The flowering types are sterile males and females are not observed among cultivated types. Hence, with the available stocks, genetic improvement of the species does not seem possible in the immediate future. As in the case of *D. alata* in which sexual reproduction was found possible only recently, it is hoped that in *D. esculenta* also fertile types could be located sooner or later.

D. rotundata is found to flower freely and profusely under Kerala condition. Unlike the other edible yams, the clones are highly fertile and seed setting under open pollinated condition is profuse. The crossability of this fertile species as a result of synchronous and profuse flowering of male and female clones is providing the tool for further improvement of this exotic species.

Management of water, nutrients and weeds

Irrigation: Yams are basically tropical crop and hence prefers adequate moisture and plenty of sunshine. Irrigation is seldom given to yam crop in India, especially under the Kerala climate as the state receives plenty of rains. In most yam growing countries of the world, it is grown as a rainfed crop and therefore, irrigation is not a well defined cultural practice in yams.

Nutrient: Yams are reported to be highly efficient in utilization of native and applied nutrients in soils. For each metric ton of dry matter produced, yam tubers removed almost the same quantity of nutrient from the soil as that of potato crop, but about four times as much N and twice as much P and K compared to the cassava crop.

Yams are highly responsive to manures and fertilizers. Soils containing less than 0.1 per cent N, 10 ppm P and 0.15 me/100 g exchangeable K evoked high yield response in yams. Manuring at the time of ridging or mounding has been found to be beneficial. Apart from farmyard manure (FYM), compost, green manure, etc., are commonly used as organic manure. In the early stages of growth, the newly developing shoot is sustained by the food reserves of the tuber and hence no additional nutrients are required during the first few weeks of growth. Later as the plants divert from foliage production to tuber production, potassium becomes the limiting element. Yams are highly efficient in extracting phosphorous from the soil and seldom need additional requirements partly due to the association of mycorrhizal fungi, which help yam roots to absorb P effectively from the soil. Fertilizer application to yam crop in India is still not widely practised because the crop is usually raised in the homesteads where plenty of organic wastes along with cattle manure and ash are available. In general yams respond well to nitrogen and potassium. The general recommendation however, is 80:60:80 kg ha⁻¹ of N,P₂O₅ and K₂O in two split doses in addition to basal application of FYM @ 10 -15 t ha⁻¹. Optimum time of application of the first dose of fertilizers is one month after planting when the plant changes from dependence on the sett to true autotrophy. This helps in development of large leaf area, thus providing high photosynthetic ability for tuber development. Second split application of fertilizers should essentially coincide with the tuber bulking stage, when the demand for plant nutrients would be at its peak, which has been reported as between 3 and 5 months after planting. Application of half dose of N and K and full dose of P at the first application and the remaining half of N and K at the second application is generally advocated. Amending acid soils with lime to a minimum of pH 5.5 produces higher tuber yield.

Weeds: The weed control measures should begin at an early phase of the plant growth as the plant is particularly sensitive to competition of weeds during this stage. The critical stages for weed interference in yam synchronises with leaf development and tuber

bulking. Traditionally yam crop is weeded manually by using hoe, as it is the most effective and cheaper method as compared to mechanical and chemical devices. Application of a pre-emergence herbicide like Diuron @ 3 -3.5 kg ha⁻¹ has been found to be quite effective. Another crucial intercultural operation in yam cultivation is earthing up which usually accompanies weeding and fertilizer application. Earthing up is an essential feature because it makes up for the loss of soil from the mounds due to run off. As result of earthing up, exposure of the bulking tuber is prevented.

Harvesting and Yield

Yam crop reaches senescence between 7 and 9 months after planting. Time of harvest is not a critical criterion in yams and hence it could be done a couple of weeks before senescence sets in or to the extent of one or two months after senescence. In single harvest, 7-8 months of crop growth after planting are needed for *D.esculenta* while 8 -9 months are required for *D.alata* and *D. rotundata*.

Yams are harvested 7-9 months after planting. The leaves turn yellow and vines start drying up at maturity. Delay in harvesting up to 2 months does not affect yield. Lesser yam yields 25-30 tonnes/ha, while Greater yam yields 33-40 tonnes/ha, whereas white yam yields 18-25 tonnes/ha.

In India, yams are harvested during December-January. Yams need proper storage for 2-3 months. The main problems in storage are rotting and sprouting of tubers resulting in storage loss. The common practice for controlling rotting and sprouting are to remove the rotten tubers and breaking off the sprouts periodically. Sprouting can also be controlled by soaking tubers in 0.1 % maleic hydrazide solution for 10 hr. As the tubers are stored in open barn, the weight loss and rotting in tubers are more. But covered barn structure is more effective in reducing weight loss. Weight loss also can be minimized by heaping tubers inside sand and dry soil treatment.

Post harvest Handling

Yam tubers in storage are subject to considerable loss of weight due to respiration, dehydration and sprouting. There are several methods of storing fresh yams: by tying them on vertical stakes in a shaded or un-shaded area, by heaping them pyramid-wise in houses or under shade or by placing them in pits. A yam barn is a shed with woven stick-walls and a thatched roof or open shaded area with proper fencing. In the barn, the individual tubers are tied to walls. Yams could be safely stored up to four months by spreading them on racks under a thatched room with ample facilities for free flow of air and diffused light.

Dormancy period in yams lasts for 2 -3 months after harvest, but some yam species like *D.rotundata* have longer period of tuber dormancy as compared to *D. cayenensis*. A low level of glutathione is probably associated with prolonged tuber dormancy. Dipping of yam tubers in 2 -chloroethanol of 2 -8 per cent solution has been reported to be effective in breaking dormancy and enhancing sprouting. Soaking the freshly harvested tubers of *D.esculenta* and *D. rotundata* in 1000 ppm solution of maleic hydrazide for 10 hours was very effective in controlling storage sprouting.

Diseases and pests

Leafblight/ anthracnose (*Colletotrichum gloeosporioides*, *Glomerella cingulata*)

Brown spots encircled with yellow halo develop at the apex and edge of leaf. Light and dark brown concentric circles are formed. Leaves are damaged, reducing yield potential. Fungicides like spray of Mancozeb (0.2%) is recommended for its control.

Leaf spots (*Cercospora carbonaceae* *C. dioscoreae*) : Small brown to black spots, enlarge and coalesce together. In severe cases entire field is seen as burnt and blighted. Leaves are damaged. Spray of Mancozeb or Captan (50wp) (0.25%) as per need is advocated for its control.

Mosaic (Yam mosaic virus) : Leaf mottling, chlorosis, cupping, puckering, veinbanding and necrosis are symptoms. Leaves are affected, reducing yield potential. Use of disease-free planting material is recommended for managing or reducing the disease incidence.

Colocasia

Importance and Scope

Aroids comprise several plant species under the family Araceae that are cultivated for food in most of the tropical and subtropical parts of the world. Important cultivated aroids are taro (*Colocasia esculenta*), tannia (*Xanthosoma sagittifolium*), giant taro (*Alocasia spp.*), swamp taro (*Cyrtosperma chamissonis*) and elephant foot yam (*Amorphophallus paeoniifolius*). Popular aroids cultivated in India are taro, tannia and elephant foot yam. Colocasia is rich in starch and its leaves and petioles are also used as green vegetables. The crop also has many medicinal properties and is used in the preparation of ayurvedic preparations. Colocasia tubers are also good source of protein, minerals like phosphorus and iron.

Cultivation of taro is widespread in India, Burma, China, Japan, Hawaii, Egypt, Africa and the Caribbean. Total area under taro in the world is about 10.8 million hectare of which Asia's share is about 1.5 million hectares. World average for cormel yield is about 6 kg ha⁻¹ yield, while the figure for Asia is about 12.4 kg ha⁻¹. Cormel production in the world is about 660 million tons.

Climate and Soil Requirements

Taro requires warm climate with plenty of moisture, which is available in the tropical and sub-tropical countries of the world. It can as well be grown even in the warmer temperate regions. The crop has the ability to withstand waterlogged and reduced conditions, since it can transport O₂ from the leaves to the roots under such conditions. Taro grows well on all types of soils, the ideal type being deep well drained, friable loams, particularly alluvial.

Varieties and hybrids

Colocasia has wide variability and a large number of local cultivars are grown in different parts of India. Satamukhi, Sree Rashmi and Sree Pallavi are improved varieties. White Gauriya, Kakakachu, Panchamukhi, NDC 1, NDC 2, NDC 3, Saharshamukhi, Kadma,

Muktakeshi, Nadia Local, Ahina Local Telia and Jhankhri are promising varieties for eastern zone; Satamukhi and Saharshamukhi for western zone; and Satamukhi, Sree Rashmi, Sree Pallavi and C 16 for southern India.

Cultivation Practices

Colocasia is propagated vegetatively mostly by small cormels weighing 20-25g. Healthy, disease and injury-free uniform sized planting material should be selected and stored in a cool place at least for three months before planting. One ton planting material is enough for planting one hectare. Mini-sett technology has been developed for colocasia multiplication also. In this case, mother corms are detached from healthy plants at harvest. Such selected mother corms are first cut into cylindrical pieces and then cut horizontally into mini-setts of about 10 g weight. The mini-setts are then directly planted in the field on mounds.

Field preparation involves ploughing and turning of soil followed by planting by anyone of the methods, viz., pit, mounds, ridge and furrow depending on the soil type. Among these methods, furrow planting is superior to others due to better soil moisture retention. Depth of planting does not have any marked effect on cormel yield. However, planting seed material at a depth of 5-7 cm is the most accepted practice. Optimum spacing varies for different agroclimatic conditions. In Punjab 45x30 cm or 60x20 cm, in Kerala 60x45 cm and in Uttar Pradesh 60x20 cm have been found to be optimum.

Mode of Pollination

The aroid crops are generally characterized by lack of flowering and seed set. Continuous vegetative propagation had resulted in total lack of sexual phase in many accessions. Flowering is highly erratic. Flowering and fruit set under natural condition has been observed in few diploid accessions of colocasia. In flowering accessions also, natural seed set is prevented by different structural and functional barriers. Flowering behaviour and other cytological abnormalities are also found to affect male and female fertilities and prevent natural seed set.

Natural seed set do not occur in colocasia in diploid accessions when synchronous flowering occurs in two or more clumps. The spadices appear 3 to 4 month after planting (vegetative growth). Flowering period in each clump is 3 to 4 weeks duration. In colocasia, stigma becomes receptive 24 hours before anthesis and lasts up to 36 hours. Pollen is viable for 24 hours and pollen shedding occurs one day after anthesis. Anthesis occurs in the morning and the spadix has fragrance. Fruits flies have been found to act as pollinating agents. The berry has been noticed in the buds in flowering clumps. The berry bunches mature within a month. After flowering plant continues with vegetative growth irrespective of the development of fruit bunch.

Management of water, nutrients and weeds

Irrigation: Taro is primarily adapted to moist environments, but can very well grow under a wide range of moisture regimes. It is essential to maintain the soil moisture near field capacity which when decreases appreciably should be supplemented with irrigation. Moisture may not be a limiting factor when the crop is cultivated in a paddy culture or swampy conditions. However, under rainfed or up-land condition, irrigation should be

assured. Taro when cultivated during summer requires frequent irrigation at about 10 days interval.

Nutrients: Taro is highly responsive to fertilization. A fertilizer dose of 80:60:60 Kg/ha of N, P₂O₅ and K₂O has been found economical for most parts of India. Half dose of N and K and full P should be given at the time of planting, while the remaining N and K is to be applied in two splits the first one 7-10 days after sprouting and applied a month later. Traditionally taro is applied with plenty of organic manure, especially farm yard manure (FYM) to supplement nutritional requirement of the crop. Highest tuber yield is obtained at a manurial basal dose of 12.5 t ha⁻¹ (FYM).

Weeding: Taro field gets heavy weed infestations during the early as well as the later phase of its growth. Therefore, at least two manual weeding, coinciding with the two split applications of fertilizers and earthing up and a third one at later stage of the crop growth are needed to produce high cormel yield.

Suckers/side shoot development is a common feature in taro. This may later on add to the number of tubers obtained, but the corms on these are mostly of unmarketable kind. Tuber size, yield and quality can be increased by desuckering unhealthy suckers and retaining only healthy ones.

Mulching: Mulching after planting helps in conserving the soil moisture and also checks weed growth. Green leaf or paddy husk mulching has a significant effect on increasing yield in taro.

Harvesting and Yield

Taro is ready for harvesting when most of the leaves begin to turn yellow. Duration of the crop varies with cultivars and methods of cultivation. In India, taro is ready for harvest in about 5 -6 months. Harvesting could be done at the convenience of the farmer as no serious deterioration has been reported if the harvest is delayed over a few weeks.

Post harvest Handling

The crop matures 120-150 days after planting. Harvesting is done by digging out the corms and cormels. The mother corms and cormels are separated before marketing. Damage to tubers should be avoided while harvesting. The damaged tubers should be separated from the marketing lot and consumed within 2-3 days. The tubers selected for marketing should be spread on ground under shade for a day and the soil adhering to the tubers should be removed before packing. Tubers should not be packed in airtight containers. Packing in *jute* bags or baskets prevents rotting during storage.

Major diseases and pests

Leaf blight (*Phytophthora colocasiae*) appears as small dark round spots on upper surface which enlarge, by coalescing together, forming characteristic rings of yellow and brown zones. Infection in petioles lead to collapse of plants. It destroys chlorophyll and reduces photosynthetic area, causing 25 -50% yield losses. Growing resistant, tolerant

varieties like Muktakeshi, Jankhri, Topi -I, and Nadia local are advocated. Early planted crop (February-March) escapes the disease.

Mosaic (*Dasheen mosaic virus*) causes interveinal yellowing and mosaic resulting in reshaping and distortion of leaves in severe cases. Use of healthy planting material and rouging infected plants is advocated.

Aphids (*Aphis gossypii*) causes yellowish speckling and curling of leaves. In severe cases sooty mould develops, reducing vitality of leaves. Major pests of taro and elephant-foot yam can be controlled by spraying insecticides such as Dimethoate, Quinalphos or Fenthion (0.05%) at 30 and 60 days after planting.

Thrips (*Caliothrips indivus*) causes characteristic silverish white specks with black dots on the leaves and drying foliage.

Leaf-eating caterpillars (*Spodoptera litura*) causes economic defoliation ranging from 16-80%. Young caterpillars feed on leaves by scraping gregariously. Older caterpillars feed voraciously on the entire leaf.

Scale insect (*Aspidiella hartii*) causes shrivelling due to desapping and feeding. In case of severe infestation, the plant shows withering and drying, reducing vigour and vitality of plants. The infested tubers lose quality and viability. Use of pest-free seed tubers and dipping seed tubers before planting in 0.1% Dimethoate is advocated.

Arecanut beetle (*Araecerus fasciculatus*) bores into tubers and converts it to powder causing loss in weight and quality. Storing uninfested tubers in white sand or saw dust prevents infestation. Seed tubers can be stored in a mixture of sand and Carbaryl dust (10%) in a 100:1 ratio.

Mealybugs (*Pseudococcus citriculus*; *Rhizoecus sp.*) Nymphs and adults and their powdery meal cover the tuber surface. It leads to poor germination and also affects cooking quality. If pest infestation is severe, treatment spray of Dimethoate (0.05%) is effective in checking its further spread.

Tannia

Importance and Scope

Tannia (*Xanthosoma spp.*) produces large corms with coarse starch grains, and is often acrid in nature. However, the cormels are quite popular for edible purpose. Tannia is a popular vegetable crop in many parts of India, grown especially for its cormels and corm; however, its leaves and petioles are also used in some places as vegetable. The crop is ideal as an intercrop in perennials and plantations as it is tolerant to shade.

Tannia originated in tropical America and was the first to be brought under cultivation there. From there, it has spread to South-East Asia, the Pacific islands and Africa. Spread of the crop to the South Pacific and Africa occurred in recent times, probably in the 19th century. In India it is quite a popular vegetable crop in many parts of South India, Andhra Pradesh, Orissa, Bihar, eastern U. P., West Bengal and the North Eastern states.

Climate and Soil Requirements

Tannia prefers warm humid climate prevalent in the tropical regions of the world. For sustained growth and production it requires an evenly distributed rainfall of about 2000 mm. The crop performs well in well-drained loamy soil with slightly acidic reaction (pH

of 5.5 to 6.5). Tannia grows best as an up-land rain-fed crop on well drained soils where rainfall is well distributed throughout most of the year

Varieties and Hybrids

There are no specific released varieties of tannia in India. Only local selections with low acidity, good texture and suitability of leaves for making deep fried rolls are available. Where corms and cormel yields are being preferred, local collections with high yield and less acidity are desired. For making rolls, cultivars with high leaf yield and less acidity are preferred.

Cultivation Practices

Corms and cormels are the usual planting material. Healthy cormels of bigger size and 20-25 cm long are commonly used. The setts from the top portion of the main corm with a thickness of 5-10 cm containing the apical bud are also used for propagation. In home gardens, it is usually grown as a ratoon crop. The cormels are separated annually from the main corm, which is covered with soil after removing the cormels. This practice can be repeated up to 5-6 years. In some parts of Maharashtra and Gujarat where only leaves are harvested, the main corms and cormels are left in the field. They continue to act as new planting material.

Field preparation could be done by ploughing in the summer before the onset of monsoon. This is followed by formation of ridges and furrows 90 cm apart. Planting of setts or cormels is done on the ridges at a spacing of 60 cm to 1m.

Mode of Pollination

Tannia seldom flowers, and some cultivars do not at all. When flowering does occur, the inflorescence arises in leaf axils, and depending on species, one or several species may form flowers, depending on the species are unisexual or bisexual. All are sessile and form on a spike (spadix) enclosed in large bract (spathe). In the unisex inflorescence, pistillate flowers are at the base of the spadix, staminate flowers at the top, and in between are a grouping of abortive sterile flowers. Insects pollinate the flowers, but fruit and seed set are rare. Fruits are berries, each containing 2-5 small (1 mm), oval, hard and difficult to germinate seeds.

Management of water, nutrients and weeds

Irrigation: Tannia prefers upland rainfed conditions more than low land water logged conditions. However, sufficient water needs to be provided for maximum vegetative growth and leaf production during the starch storage period. Under rainfed situation, a short-term drought often may accelerate crop maturation.

Nutrients: Application of manures and fertilizers at the rate of 12.5 t ha⁻¹ of FYM, and 80:60:80 kg ha⁻¹ of N, P₂O₅ and K₂O is recommended. Traditionally full dose of phosphorous and half dose of nitrogen and potash are applied as basal a week after sprouting and the remaining half dose, a month after the first.

Weeding: Two weeding and earthing up operations have been suggested at 30th and 60th days after planting. Application of mulch soon after planting is beneficial to the crop as it conserves soil moisture, reduces temperature around the sett and also suppresses the weeds.

Harvesting and Yield

Tannia is usually hand-harvested by digging out mature corms. The crop is ready for harvest within 9 -10 months after planting with expected yields between 25 and 30 t ha⁻¹. If the crop is grown for leaf purpose, then harvesting of the leaves should be done immediately after they attain maturity. A leaf size of 20-30cm x 20-30cm is ideal for making roll. Thus 40-50 leaves can be harvested from 1 clump during its entire growth period. Leaves are harvested along with the petiole. Petioles are also used as a vegetable. If the crop is intended for taking corms, then it can be harvested when older leaves start turning yellow. Its corms do not deteriorate if left unharvested in the soil and in this way harvesting can be done from 6 months onward up to 9 months. If it is to be grown as a ratoon crop, the soil around the clump should be dug to remove the mature cormels. The main corm is retained along with roots and covered with soil. This can be practised for 4-5 years.

Post harvest Handling

The corms can be stored for a period of 4-5 months under well ventilated and dry conditions. Care should be taken to avoid injury to the corms while harvesting. After harvesting, curing of the corms and cormels is done in sunlight for 4-5 days. The corms and cormels can be stored embedded in dry soil or sand for a period of 4-5 months under ventilated, dry and semi-dark conditions.

Diseases and Pests

No major disease has been reported for this crop. The insect pests of this crop are similar to other aroids and yams as describe in yam.

Elephant foot yam

Importance and Scope

Elephant foot yam (*Amorphophallus paeoniifolius*) is basically an underground stem tuber and is gaining popularity due to its yield potential and culinary properties. It is rich in nutrients and is a delicacy as a food. The tubers are also used for preparing many ayurvedic preparations. *Amorphophallus* has an important position among tuber crops, since it happens to be highly remunerative to farmers.

Amorphophallus is indigenous to tropical Asia and Africa. It is widely distributed at low and medium altitudes in the Philippines, Malaysia, Indonesia, Sri Lanka and the South-East Asian sub-continent. It is a popular tuber crop and is grown as a vegetable in many parts of India.

Climate and Soil Requirements

Amorphophallus is a tropical/sub-tropical crop and hence thrives well under warm humid climate with a mean annual temperature of 30-35°C and a well-distributed rainfall of 1000 -1500 mm spread over a period of 6–8 months. The crop performs well under irrigated condition and hence could be grown even in areas where the rainfall is scanty but has assured irrigation.

Well-distributed rainfall or ample moisture availability during the growth phase of the crop is essential as it promotes proper vegetative development of the crop. It grows well on a variety of soils but a well drained sandy loam or sandy clay loam soil with a near neutral soil reaction (pH 6 -7) is ideally suited for the crop. The soil should be rich in organic matter with adequate amount of available plant nutrients.

Varieties and Hybrids

Gajendra and Santragachi are the two important non-acrid, high yielding Indian varieties of *Amorphophallus*.

Cultivation Practices

For minimising the planting material requirement mini-sett technique has been developed for *amorphophallus*. In this case small corm pieces of 100 g weight are used for planting. Since the buds are located in a ring at the centre of the corm, setts are made out in such a way that each sett has a piece of the central bud. The setts are treated with cow dung slurry and dried under shade for one or two days before planting preferably in a nursery from where it can be transplanted to the field.

When the normal corm pieces are used as planting material then the spacing of 90 x 90 cm is adopted thus giving a plant population of 12,345 plants/ha while a reduced spacing of 60 x 45 cm gives a population of 37,000 plants/ha when the setts are used.

A good soil turning plough during early spring followed by pit formation is the traditional method of land preparation for *Amorphophallus*. The pit size should be of 60x60x45 cm. The top soil dug out is then mixed with farm yard manure or compost (2 -2.5 kg/pit) and the mixture is put back in to the pit prior to placing planting material over it. The planting material is placed vertically in the pits and is then covered with soil and compacted lightly. *Amorphophallus* is planted shallow, as deep planting would interfere with harvest operations, and more over, most of its feeder roots are found on the surface.

Mode of Pollination

It is a cross pollinated crop and dioecious in nature. Flowering is erratic, generally there is little or marginal overlapping of male and female flowering and female accessions flower earlier than male accessions. Flowering is observed as a rare phenomenon in this crop and generally occurs between May and June. Male accessions show consistency in flowering. Male flowers are produced in terminal and axillary panicles. Female flowers are borne on long axillary spikes, 1-2 spikes arising per axil. Pollinations are carried out as and when the corms produce spadixes, which is always a single spadix per corm. The flowers are extremely protogynous, stigma receptivity lasting only 24 to 78 hours before

spathe opening. Anther dehiscence takes place only 24 hours after spathe opening thereby preventing self-pollination. The opened flowers emit nauseating smell attracting carrion flies. They lay eggs upon the bulbous, crimson coloured appendix from which maggots hatch out and fly. Their role in pollination is not known. Fruit or seed set is not observed under natural condition. Pollen is yellowish in colour and sticky with more than 90 per cent fertility. Pollination conducted between 24 to 78 hours before anthesis were found fully successful resulting in fruit and seed set. Reception period of stigma could also be identified by the presence of sticky exudates over this surface.

Management of water, nutrients and weeds

Irrigation: Light irrigation soon after planting is recommended for uniform sprouting. Subsequent irrigations may be scheduled as per need. It is advisable to ensure that water does not stagnate in the field.

Nutrients: Well-decomposed farmyard manure is recommended to be applied @ 25-40 t/ha. Generally a fertilizer dose of 150:60:150 kg/ha of N P₂O₅ and K₂O is sufficient in most areas where it is grown. At the time of planting, the full dose of P and half N and K are to be applied in the pits. The remaining dose of N and K is applied 35 and 75 days after planting at the time of weeding and earthing up.

Weed management: Generally two weeding coinciding with the requirement of top dressing are recommended. The first weeding may be done about 30 days after planting. The second weeding may be done about 75 days after planting.

Harvesting and Yield

The crop is ready for harvesting by about 7-8 months after planting. Maturity is indicated by yellowing and drooping of the leaves.

Post harvest Handling

Care should be taken to avoid injury to the tubers while harvesting. After harvesting the tubers should be spread in shade for 3-4 days for curing. The soil and roots adhering to the tubers should be removed totally before disposal. Baskets or jute bags may be used for packing during transportation.

Diseases and Pests

The pests of this crop are similar to other aroids and yams as described under yam.

Arrowroot

Importance and Scope

Arrowroot (*Maranta arundinaceae*) is an erect herbaceous plant belonging to Marantaceae family. Commonly known as 'West Indian Arrowroot' it grows to about one and a half meter height and produces long, fleshy and cylindrical subterranean rhizomes, which tastes like, corn when boiled. It is primarily grown for its quality starch, which is valued particularly for infants and invalids. It is also used in making various bakery products, special glue and paste, as a base for face powder, as ice cream stabilizer and in

carbonless paper used for computer print outs. Arrowroot starch is also used in the treatment of intestinal disorders and also employed in the preparation of barium meals and in manufacture of tablets. The fibrous material, which remains after the extraction of starch, is used as a cattle feed or manure.

In India, it is grown in North Eastern States (West Bengal, Assam) and in southern India mostly in Kerala as a rainfed crop in limited areas in homesteads. The crop is a native of tropical America and has long been cultivated in the West Indies particularly in St. Vincent, which is the main producer of arrowroot starch.

Climate and Soil

Temperature range of 20-30°C are ideal for the crop with a minimum annual rainfall of 95-150 cm but sufficient soil moisture throughout the growing period is important. Deep, well drained, slightly acid loam soils with partial shade are the most suitable.

Varieties and hybrids

Generally yellow colored local cultivars are grown. However, cultivars having blue rhizomes give higher yield of starch a yellow colored cultivars.

Cultivation Practices

Small pieces of rhizomes (known as bits), 4-7 cm long, having 2-4 nodes each, are planted in well-manured pits. Suckers are also used as planting material. They are separated from clump and planted at a distance of 30-45 cm in nursery during off-season. These suckers grow to new plants, which are uprooted, and foliage are detached to keep 10 cm. long shoot with intact roots. This is used as planting material. Normally 2 clumps are planted at a distance of 45 cm. About 3 tonnes of planting material is enough for a hectare of land.

Raised beds of 50 x50 cm and 15-20 cm high are prepared. The bits/suckers are planted at 30 cm distance at a depth of 5.0 – 7.5 cm and covered with soil. Planting is done just before the onset of monsoon.

Mode of Pollination

The arrowroot inflorescences are terminal bearing with a few white flowers but seed set is rare. Propagation is made through small pieces of rhizome having several buds.

Management of water, nutrients and weeds

Irrigation: Sufficient water supply in the soil throughout the growing period is required for optimum yield. The crop is normally grown as a rainfed crop. However, if dry spell occurs during the initial 3-4 months, supplementary irrigation at weekly intervals may be necessary.

Nutrients: Arrowroot usually thrives well in fertile sandy loam soil. Heavy soils should be made friable by incorporating organic matter or compost. Use of 10 t ha⁻¹ of FYM or compost is advocated for arrowroot cultivation.

Weeds: Field should be kept clean and free of weeds during the first 3-4 months after planting. During weeding, earthing up should also be done. Mulching with green or dried leaves reduces the weeds and also has favourable effect on soil moisture and improves yield.

Harvesting and Yield

Maturity is indicated by yellowing, wilting and drying up of the leaves. The crop attains maturity in 10-11 months after planting. At this stage, the plants are dug-out and the rhizomes separated from the leafy stem. On an average 1 -1.5 kg of rhizomes can be obtained from a single clump (4-7 tonnes/ha). Small rhizomes are used for generating planting material, whereas bigger sized rhizomes are mainly used for starch production through further processing.

Post harvest Handling

The rhizomes normally do not eat decomposition under ordinary storage environment. At some places, rhizomes are stored embedded in dry sand layers in dark. Physical damage to rhizomes during harvest, however, enhances the chances of deterioration under normal storage.

Diseases and Pests

No major diseases have been reported for this crop. The pests of this crop are similar to other aroids and yams as described under yam.

Yam Bean

Importance and Scope

Yam bean (*Pachyrrhizus erosus* (L) Urban) belongs to the family Leguminaceae and sub family Fabaceae (Papilionaceae). It is also called 'potato bean' in English and *Mishrikand* in Hindi. It is popular by known as 'Shankh alu' or 'Sankesh alu' in West Bengal, Assam and Orissa. Yam bean is a starchy root crop with comparatively high sugar content and a moderately good source of ascorbic acid. Tubers contain more than 82% water, 1.5% protein, 10% starch and 5-6% sugar. It is good for salad preparation and in many countries, the seeds are however poisonous. Since Yam bean is a leguminous tuber crop its cultivation, like other legumes, helps improve the soil fertility

The crop is supposed to have originated in hot moist basin of the river Amazon and has been under cultivation in Mexico and South America from pre-Colombian period. The crop is now cultivated in the Philippines, China, Indonesia, Nepal, Bhutan, Burma and India. In India, it is grown in parts of West Bengal, Bihar, Orissa and Assam.

Climate and Soil Requirements

Yam bean requires a hot humid climate and adapts well in sub-tropical and hot temperate zones. The basic requirement is frost-free condition during the growth period. It is grown up to an altitude of 1000 m. It has been observed that thermo-periodism has got a definite effect on tuberization. Though yam bean requires 14-15 hours of photoperiod for good vegetative growth, short days with cool nights are effective for good tuberization. A well-

distributed rainfall during the growth period is required for optimum tuber yield. Excessive rain causing water logging is deleterious to the crop. Cool climate during early growth period adversely affects the initiation of tubers and also results in a prolonged vegetative phase.

Fertile, well-drained, sandy loam soil is best suited for cultivation of yam bean. This crop adapts well to loamy and clay loam soil. Water logging adversely affects yam bean cultivation. Optimum soil pH requirement is 6.0 -7.0.

Varieties and Hybrids

There are 2 types of cultivars available in market. Mexican types have larger tubers (500-700g), whereas local types have smaller tubers (200-300g). The Mexican types are less sweet compared to the local ones. The Mexican types have a tendency to develop cracks on their tubers. They are less preferred in the Indian markets. The flesh is white with less fibre. There is no cracking. Rajendra Mishrikand 1, an improved variety, is very popular in North Bihar. It is recommended for cultivation in Bihar and West Bengal. Its average yield is 40-55 tonnes/ha in 110-140 days. Other promising line, L 19, gives better yield in Bihar, West Bengal and Orissa.

Cultivation Practices

Yam bean is propagated usually through seeds. The seedpods are generally 7 –15 cm long with 8-10 brownish-yellow to red seeds. Seeds are dorsally ventrally flat. Plants can also be raised from sprouted roots of previous crop but this is not normally practised. The seed rate varies according to spacing of the crop. A seed rate of 20-60 kg/ha is generally adopted by the farmers. The mature pods containing seeds are source of a toxic substance 'rotenone' and are sometimes harmful for cattle grazing in the field.

Deep ploughing of land twice using a mouldboard plough is essential. Plank the soil after each ploughing to have a well pulverised soil as well as to conserve moisture. A good tilth is required for yam bean cultivation. Traditionally Yam bean is sown during June-July with the onset of rain in Northeastern India. Yam bean seeds can be sown on hills at the rate of 3-5 seeds per hill. Hills are prepared at a spacing of 0.75 -1.00 m with 15 cm height. It has been observed that planting the seeds on ridges results in better yield.

Normally yam bean starts flowering 75 days after sowing. It is desirable to remove the flowers and not allow the plant to bear pods for getting better tuber yield. It has been observed that spraying 2,4-D (50 ppm) at flower initiation stage causes abscission of flowers and results in better yield of tubers.

Mode of Pollination

Yam bean is a self pollinated crop. The flowers are violet or white and borne on erect pedicels in racemes producing 7-14cm long and 1-2 cm wide pods. Flowering commences in the short days when new vegetative growth diminishes and storage root enlargements accelerates. Normally 10 months are required to produce mature seeds. Cultivars with greenish-brown colored seeds are preferred because they are more productive than those with either green or brown seed.

Management of water, nutrients and weeds

Irrigation: Normally there is no need to irrigate the *kharif* crop. In case there is scarcity of rains, irrigation is required. For September sown crop, it is advisable to give supplementary irrigation so that the crop will not face moisture stress during tuberisation.

Nutrients: Apply well rotten compost or farmyard manure (FYM) at the time of land preparation. Application of 15-20 tonnes of FYM or compost along with about 80:40:80 kg N, P₂O₅ and K₂O ha⁻¹ is recommended. Entire dose of P and K may be applied as basal dose at the time of planting along with half dose of nitrogen. Remaining half dose of N is top-dressed at 40-50 days after sowing along with interculturing and earthing up.

Weeds: Weed infestation is more in *kharif* crop compared to the late (September-sown) crop. It is advisable to do the first interculturing 40 days after sowing and add the remaining half dose of nitrogen and do earthing up. Second weeding is to be done 30 days after the first weeding. The field has to be kept free from weeds by manual weeding or using mechanical implements.

Harvesting and Yield

Yam bean normally takes 150 days after sowing. Usually it is harvested on the occasion of 'Saraswathi Pooja'. If harvesting is delayed, chances of cracking of tubers are more. Shallow irrigation may be given just before digging the tubers manually. The above ground portions are trimmed before digging out the tubers. Harvested tubers can be stored for 2-3 days without any deterioration. If the tubers are stored for a longer period, the creamy colour of the skin changes to purplish brown and loses water resulting in reduction in weight. The harvest can be adjusted to the demand by leaving the crop in the soil without removing top portion. The average yield of local cultivars is 18-20 t ha⁻¹ while that of improved varieties like Rajendra Mishrikand is 36-40 t ha⁻¹.

Post harvest Handling

It can be harvested early or late according to market demand. It is possible to harvest the crop with smaller-sized tubers after 100 days. Otherwise it can be left in the field up to 140 days for better size. Traditionally, the trend is to harvest the crop on the occasion of 'Saraswati Puja' (January) with the start of spring season because of market demand. Delayed harvest leads to fibrous flesh along with cracks in tubers leading to deterioration in tuber quality. Care should be taken to avoid cuts and bruises on tubers.

Tubers are graded according to their size. They can be stored for 3-5 days without any deterioration. When the tubers lose their weight, they become sweeter. Since tubers are firm, no specialized packing is required. They are packed in jute bags and brought to market.

Diseases and Pests

No major disease has been reported for this crop. The pests of this crop are similar to that of aroids and yams as described under yam.

Coleus

Importance and Scope

Coleus is one of the minor tuber crops grown for its edible tubers, which have special, flavour and taste and used as vegetable. It belongs to the family Labiatae and is also called as 'Hausa potato', 'Chinese potato', 'Country potato' or "Coleus potato" in English or as 'Koorka' in Hindi. In India, its tubers are used in curry preparation particularly for its aromatic flavour and sweetness. It can also be baked or made into chips. The tubers are also used as a medicine for curing dysentery and in the treatment of certain eye disorders. Coleus tubers are rich in starch (73% on dry weight basis) but poor in protein content (1-1.5%) on fresh weight basis or 7% on dry weight basis). The tubers are also rich in minerals like calcium and iron and contain certain vitamins including thiamine, riboflavin, niacin and ascorbic acid.

Coleus is supposed to be a native of Central East Africa but has adapted well in South-East Asia including India and Sri Lanka. It is cultivated in India on a small scale in the southern states of Kerala, Tamil Nadu and Karnataka as well as grown in North Eastern states, Madhya Pradesh and in tribal areas all over India.

Climate and Soil Requirements

Coleus comes up well in hot humid subtropical and hot temperate areas where there is no incidence of frost. A comparatively lower temperature in night than daytime favours better tuber development. Coleus requires a reasonably good evenly distributed rainfall and cannot withstand drought conditions. As regards soil, a fertile well-drained, sandy loam to alluvial soil, rich in organic matter is ideal while heavy clay soils are not suitable. The crop cannot withstand water logging or flooded soil conditions as excess soil moisture reduces tuber yield considerably. The soil pH requirement ranges between slightly acidic to neutral (6.6 -7.0).

Varieties and Hybrids

Local selections are popular in different parts of India. These are of two types, viz., those having small-sized tubers with good flavour, and others with large-sized tubers and higher yield. An improved variety Sree Dhara has been released by CTCRI, Thiruvananthapuram, for Kerala state. Its yield potential is 20-25 tonnes/ha over a period of 6 month.

Cultivation Practices

Suckers, stem cuttings or tubers are generally used as planting material. Suckers are raised from healthy mature tubers. Normally 0.4-1.2 tonnes of tubers are planted in 0.2 ha of land to produce planting material (sucker) for a hectare crop. Nursery beds 15 cm high and 1.0 m wide are prepared and tubers are planted at 5 x 15 cm spacing 4 cm below the soil surface. Sprouting starts in 15 days and it grows 15-20 cm long after 3 weeks. Stem-cuttings of 15-20 cm length from these sprouts are used as planting material. However, direct planting of suckers favours better crop establishment. Requirement of planting material is very high and quite expensive for Coleus cultivation. Repeated cuttings of suckers at 15 days interval from same sprouted seed tuber can minimize the quantity of

propagating seed tuber material. Thus a 50 kg seed tuber could generate enough planting material for one-hectare crop within 2 months. But in this method only staggered cultivation is possible.

The soil is ploughed to a depth of 20–25 cm two the three times. This is followed by ploughing using desi plough and plankings. Before final ploughing 10-25 tons per hectare of farmyard manure/compost is broadcast. Ridges of 15 -20 cm height are made 30-50 cm apart and stem cuttings 15 -20 cm long with 5 leaves are planted at 15 -20 cm in between on ridges. In addition to the normal ridge method, coiled planting and horizontal planting is also practised. In coiled planting, a stem cutting of 22 cm length is used and about 12 cm of the more mature portion is coiled and planted in holes of about 7 cm wide and 5 cm deep. In horizontal planting, stem cuttings of 30 cm length are used. Two such stem cuttings are placed side by side touching each other and in opposite directions across the ridges. Two third of the length of these stem cuttings are inserted in soil while the rest project outside the ridge.

Mode of Pollination

Inflorescences in coleus are arranged in racemose cymes. The colour of the two tipped calyx and corolla are uniformly greenish brown and violet, respectively. Anther and stigma are also violet in colour. Pollen grains are sterile hence no seed set occurs. For propagation, seed tubers are first used to produce stem cuttings, which are then transplanted to establish the main crop.

Management of water, nutrients and weeds

Irrigation: Irrigation immediately after planting is recommended to ensure establishment of stem cuttings. Supplementary irrigation during the growing season would be necessary if rainfall is not sufficient.

Nutrients: A crop yielding 25.7 tonnes of tuber removes 106.7 kg N, 13.2 kg P and 107.4 kg K per ha. For good yields an application of 10 tonnes of farm yard manure with a fertilizer dose of 80:60:80 N, P_2O_5 and K_2O per ha with half of N and K and full dose of super phosphate as basal and the remaining half N and K six weeks after planting is recommended. Split application of both N and K is better over basal application. It has also been observed that when Coleus is manured with a basal dose of 10 tonnes of farmyard manure, additional dose of nitrogen by way of chemical fertilizer can be restricted to a maximum of 60 kg per ha.

Weeding and earthing up at six weeks after planting along with top dressing of fertilizers is recommended. It is important at this stage to cover a portion of the stem with soil to promote better tuberisation and tuber development. The second earthing up may be given one month after the first earthing up.

Harvesting and Yield

Coleus is a short duration crop of 4-6 months. The tubers can be harvested when all leaves and stem begin to wither. The tubers are normally dug by hand and harvesting should not be delayed as the mature tubers decay rapidly when left in the soil.

Post harvest Handling

The crop duration is 4-6 months, depending on the cultivar. The maturity of crop is adjudged with onset of leaf fall from the standing crop. After maturity, tubers are to be harvested without delay as in mature tubers decay starts quickly if left in the field. If the mature tubers are left in the field, there are chances of deterioration in their quality.

Diseases and pests

No major disease has been reported for this crop. Leaf and shoot folders and Root Knot nematodes are the major pests of this crop. In the case of leaf and shoot folders the leaves are webbed together and caterpillars feed within the leave causing defoliation. Spray of insecticide is recommended for its control.

Root Knot nematode causes suppression of growth and forms galls on the roots while tubers get malformed. Use of healthy seed tubers, weed free fields and use of non-host or resistant varieties (Sree Bhadra) are recommended.

References

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