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NUTRIENT MANAGEMENT FOR TUBER CROPS - A REVIEW

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ABSTRACT

Tubers are important food crops in tropical world. Tropical tuber crops have hitherto received inadequate attention. As area increased significantly and new production techniques devised in the last decade, nutrient management shall remain an essential aspect for improving the quality and quantity of tubers. This review gives an account of the nutrient management research carried out on tuber crops.

Tuber crops are the second most important food crop of man next only to cereals. They constitute either staple or important subsidiary food for about a fifth of the world's population. Tropical tuber crops have hitherto received inadequate attention. However the situation is changing and acreages under tuber crops have been increasing and new production techniques were devised in the past decade. The formation of the International Society of Tropical Root Crops during the last decade is a manifestation of this increased importance. Tuber crops are important in several aspects. They have a higher biological efficiency as food producers and show the highest rate of dry matter production per day per unit area among all the crops. Further, they constitute important and cheap source of food and energy. FAO data show that about 400-450 million people in 26 tropical countries derive 300 Kcal of energy per day from cassava, a crop that can produce 250 x 10^3 cal/ha/day as against 176 x 10^3 for rice and 110 x 10^3 for wheat. Most of the tuber crops are able to produce economic yields in a variety of marginal soils and environmental conditions. Their capacity to grow under near drought conditions is remarkable. Sweet potato can be grown under temperate to tropical conditions and is also drought tolerant like cassava. The tubers being rich in starch are being increasingly used as raw material for many industries such as animal, fish and poultry feed. Obviously, nutrient management shall be an essential aspect in the management of tuber crops. This paper reviews the research carried out in this direction.

A. Potato

Potato originated in the Peru-Bolivian region in the Andes (South America), largely raised in cool regions where the mean temperature of the growing season does not exceed 18°C. About 80% of the area under the crop in the world is concentrated in the temperate zone of Europe and western USSR.. In India, Potato is grown during the cool season. About 81% of the potato is grown in plains during winter under short-day conditions; about 13% in the hills during summer under long-day conditions and around 6% in the plateau during the rainy season under almost equinox conditions. In the Nilgiris hills in Tamil Nadu, it is grown round the year because of equable climate.

The crop in the hills is grown mainly on well-drained acidic soils of varying depths but that in the plains is grown on alluvial soils with neutral to alkaline reaction and in the plateau areas on red, black-cotton and mixed-red sandy soils. On drying, the fine-textured black soils are prone to develop cracks which may expose the tubers to light resulting in greening and attack by tuber moth.

Nutrient Management

Tuber yield was increased significantly by application of K alone and in combination with P. The response was of linear nature. The

K application at the rate of 80 kg ha^{-1} had pronounced residual effect on cheena and significant residual effect on maize. Application of P alone and in combination with K had little direct effect on potato and residual effect of cheena and maize. Farmyard manure application at both the levels (15 and 30 tonnes ha^{-1}) had significant effect on tuber yield and the response was linear. Its residual effect was significant on maize. Farmyard manure @ 30 tonnes ha^{-1} was able to meet P and K needs of potato and other crops in rotation and maintain available P status of the soil. Application of 40 kg P ha^{-1} from fertilizers could not maintain the available P and K status of the soil at the initial level but it was significantly better than the control.

Investigations were carried out by Sharma *et al.* (1981) on the acid soil of Shillong and Simla to study the effects of Mg and P on the yield of potato. In acid soil of Shillong (pH 5.2), there was positive response to $MgSO_4$ upto 20 kg ha^{-1} whereas in Simla soil (pH 6.6), the response to Mg was not significant. However, there were significant responses of potato to P on both the soil types. Mg and P had synergistic effect on the concentration of each other whereas the applications of both Mg and P had a depressing effect on the concentration of Ca in the plant. Mg and P increased the dry matter in tubers.

Application of urea 5 to 10 days before planting in furrows and pre-treatment of urea with soil for 48 h before application increased its efficiency by 10 and 11% as compared to its application at the time of planting (Singh and Grewal, 1984). Improvement in efficiency of urea was associated with greater uptake of N and K. Broadcasting of urea before first and second irrigation after the planting was inferior to its application at the time of planting.

A field study was conducted on slightly alkaline alluvial soil to ascertain the effect of PK fertilizers and FYM on potato-wheat rotation during 1979-80 and 1980-81 (Upadhyay and Grewal, 1985). Application of 20 and 40 kg P ha^{-1} increased the potato yield and P uptake by tubers but the differences were nonsignificant in both years but were significant in pooled data. Application of 40 and 80 kg K ha^{-1} increased the potato yield and PK uptake by the tubers significantly. The highest tuber yield and PK uptake by the tubers were obtained by the interaction of 20 kg P and 80 kg K ha^{-1}. The application of 30 tonnes FYM ha^{-1} was at par with 20 kg P plus 80 kg K ha^{-1}, with respect to tuber yield and uptake of PK by the tubers. The effect of PK fertilizers and FYM was significant on the yield of large size tubers only. The residual effect of PK fertilizer and FYM was quite pronounced on the succeeding wheat crop. The economic optimum doses of P, K fertilizers and FYM for potato were 15.7 kg P, 112.1 kg K and 26.2 tonnes FYM ha^{-1}. Experiments were conducted by Sharma *et al.* (1988) on soils having varying levels of DTPA extractable Zn to study the response of potato to applied Zn. Significant yield responses to applied Zn were observed on soils having DTPA extractable Zn content up to 0.57 ppm. Applied Zn did not affect the tuber number/m^2. However, it increased the average weight of individual tubers, thereby increasing the tuber number in medium and large grades and as such the tuber yield. Application of Zn increased the concentration of this element in haulms during both the years of study. Uptake of Zn by potato varied significantly at various locations and increased with applied Zn.

Sharma and Grewal (1989) studied the effect of methods of zinc application on potato production. Experiments conducted on zinc deficient alluvial soils revealed that the yield increased significantly by zinc application. However, the degree of response varied with the method of zinc application. Soaking of seed

tubers in 0.05% $ZnSO_4$ solution for 3 h was found to be the best, followed by soaking of seed tubers in 0.025% $ZnSO_4$ solution, two foliar sprays of 0.2% $ZnSO_4$ solution at 40 and 60 days after planting and soil application of 8 kg Zn ha^{-1} at planting. Zinc uptake was highest in soil application of 8 kg Zn ha^{-1}, followed by two foliar sprays of 0.2% $ZnSO_4$ and soaking of seed tubers in 0.05% of $ZnSO_4$ solution.

Mondal *et al.* (1993) conducted a field experiment to evaluate the growth and productivity of potato unde different fertilizer management with particular reference to Sulphur, FYM and crop residues. Maximum dry matter production (855 g/m^2), tuber bulking rate (16 g/m^2/day) and tuber yield (266 q/ha) were recorded at 100 kg ha^{-1} each of N, P_2O_5 and K_2O in conjunction with 10 tons ha^{-1} FYM. Application of S bearing fertilizer (SSP) improved the growth and tuber yield (9%) as compared to the application of DAP. The maximum total uptake of nutrients (115.02 kg N, 25.31 kg P_2O_5, 249.11 kg K_2O and 16.67 kg S ha^{-1}) were recorded where the crop was fertilized with 100% of the recommended doses of N, P (through SSP) and K. Any reduction in their doses without application of FYM/crop residues depleted the soil fertility status. Better net production values (2.16 and 2.12) were recorded at 75% of the recommended doses of N, P (through SSP) and K along with FYM and also in the treatment receiving 100% of the recommended doses of N, P (through SSP) and K.

Singh *et al.* (1994) studied the effect of different levels and methods of nitrogen application on storage behaviour of potato cv. Kufri Badshah. They observed that percentage of rotted and sprouted tubers was increased with an increased application of N. Method of N application also showed significant effect on these parameters. Split application of N, three-fourth as basal dose and one-fourth as top dressing improved the storage life of potato as compared to other methods of N application.

Minhas *et al.* (1994) conducted a field experiment to study the effect of P, lime and animal manure on crop yields in potato-maize, potato-wheat sequence at Palampur. Phosphorus was applied as SSP @ 26, 52 and 78 kg P ha^{-1}, lime as $CaCO_3$ at 5 tons ha^{-1} and well decomposed animal manure at 10 t ha^{-1} besides control. The direct P application, upto 78 kg P ha^{-1} to spring potato and, upto 52 kg P ha^{-1} to autumn potato increased the yield significantly. The P applications also had a significant residual effect on yield of the following crop i.e. maize and wheat after spring and autumn potato, respectively. The direct application of animal manure and lime to spring potato and their residual effect on the following maize crop was not found to be significant, however, the direct effect on the following wheat crop was significant.

Field experiments conducted by Savitha *et al.* (2000) at Bangalore during *rabi* 1995 and 1996 revealed that application of 180 kg K_2O ha^{-1} increased the tuber yield by 25.90 per cent over 60 kg K_2O ha^{-1}. Application of K in two splits recorded 5.4 and 15.6 per cent higher tuber yield over 100 per cent basal and thrice split application, respectively. Application of 180 kg K_2O ha^{-1} in two splits produced better quality tubers. Application of recommended dose of K (120 kg K_2O ha^{-1}) in two splits improved the yield and quality of potato tubers due perhaps to higher uptake of K (73.4 kg ha^{-1}).

B. Cassava

Cassava (*Manihot esculenta* Crantz) popularly known as tapioca is a native of Brazil in Latin America and was introduced to India by the Portuguese in the 17th Century. As a food crop it was popularized by Shri Visakham Tirunal, the Maharaja of the erstwhile Travancore during AD 1880 to 1885. Its

importance in tropical agriculture is due to its drought tolerance (shed/drop the leaves under adverse soil moisture conditions), wide flexibility to adverse soil, nutrient and management conditions and time of harvest. Cassava can be grown in areas of uncertain rains that prevent the successful cultivation of other crops.

Cassava with no definite harvest time and being a photoinsensitive crop can be profitably cultivated throughout the year. Its foliage can produce upto 5t crude protein hectare^{-1} year^{-1} (Moore, 1976). Presently, the world production of cassava is about 165 million tonnes (FAO, 1997) of which nearly 60% of the production is used as human food. Apart from its role as a staple/subsidiary food, there has been growing recognition of cassava roots as a low cost energy source for livestock and as a raw material for industrial starch and fuel alcohol.

In India, cassava is mainly cultivated in the Southern States. Though it performs well at lower altitudes, it is being grown up to elevation of 2000 m. It tolerates very hot climate but critical point seems to exist between a daily temperature of 18-20°C below which growth is reduced and yield declines rapidly. At reduced temperature, germination is delayed and leaf formation rate is slow.In general, crop growth increases with solar radiation. Shading decreases radiation interception of cassava which in turn decreases the crop growth rate and root yield (Cock, 1978). Shading increases stem elongation and internode length and hence little carbohydrate is available for root growth. A well-drained loamy soil is the best for the crop. Also, it can be grown successfully in acid soils of low pH. Optimum soil pH is 5.0 to 6.0.

Nutrient Requirement

Vinod and Nair (1992) conducted a field experiment to study the effect of slow release N sources on cassava var. Sree Vishakam at Vellayani. The treatments consisted of urea, neem cake coated urea, urea super granule and rubber cake coated urea each at five levels (50, 75, 100, 125 and 150 kg N ha^{-1}). Urea super granule and neem cake coated urea enhanced the growth characters of cassava such as plant height, number of functional leaves, number of nodes and the leaf area index. N @ 150 kg ha^{-1} gave better results in growth characters. Asokan *et al.*, (1988) studied the yield and quality characteristics of two varieties, viz., Noorumuttan (Local type) and H.1687 at graded levels of N and K_2O (60, 120 and 180 kg ha^{-1} each) for three consecutive years. The residual soil fertility was analysed after three years cropping. The tuber yield for the local type increased by 35 per cent while that of H.1687, by 67 per cent due to N and K application. The yield increase beyond 60 kg ha^{-1} of N and K was not significant. Tuber number, tuber length, height of plant, number of leaves and harvest index were improved by N and K_2O applications. The fertilizer application reduced the dry matter and starch content of tubers. Higher levels of N increased HCN content of tuber, whereas K had no significant influence. There was a general drop in the soil organic carbon after three years cropping.

Nair *et al.* (1988) observed the response of cassava to graded doses of P in acid laterite soil of high and low-P status for five years (1980-85) in a high-P soil (av. P = 100.8 kg ha^{-1}) and for three years (1983-86) in a low-P soil (av. P = 8.9 kg ha^{-1}) to ascertain the effect of P – skipping and application of graded doses of P respectively in these soils. It was observed that in high – P soil, skipping of P for the first four years had no significant influence on the yield of tubers. In low-P soil, even though cassava responded to 100 kg P_2O_5 ha^{-1} initially, the response gradually declined. From the response curves it was

observed that the optimum economic dose of P for cassava in laterite soil was 45 kg P_2O_5 ha^{-1}. Kabeerathumma and Mohanakumar (1990) tested the relative efficiency of Mussoorie rock phosphate and single superphosphate with and without FYM on cassava in acid laterite soil. The direct effect of superphosphate was better than that of rock phosphate for tuber production, whereas in residual effect rock phosphate was found to be superior. Combined application of FYM and both the P sources was found to be beneficial. In case of super phosphate the release of P was faster and its fixation was high.It was at a slow and steady rate for rock phosphate. Rock phosphate along with FYM was a bette: source of P for cassava in laterite soil.

Field experiments conducted during 1967 to 1973 in acid laterite soils with varieties S-2380, M-4, H-97 and H-165 and using different rates of K and N showed that 100 kg ha^{-1} of K_2O was optimum and further application resulted in 'luxury consumption'. It was also observed that the soil available K level could be maintained at the above rate of K application. With increasing rates of N and K application, increased K uptake was observed. N and K uptake was significantly correlated with tuber yield of cassava as reported by Rajendran *et al.* (1976).

A field experiment was conducted by Asokan and Sreedharan (1977) to study the effect of different levels and time of application of K in conjunction with FYM in variety H-97. The results indicated that maximum tuber yield was obtained at 112.5 kg level of K. Three split application had given a better response at lower levels of K. FYM gave better response at higher levels of K, while utilization index showed decrease after 75 kg K. Dry matter, starch content and cooking quality were increased by K fertilization while, crude protein and HCN content showed a decrease.

Nair *et al.* (1980) conducted a field experiment to study the effect of application of Schoenite and Syngenite, two indigenous sources of K on the yield and quality of cassava, and compared with muriate of potash and wood ash at different levels of K in acid laterite soil. These two sources were at par with Muriate of Potash in increasing the tuber yield. The different sources did not show much influence on starch and HCN contents of tubers, residual available K and K uptake by plants, while increasing levels of K application resulted in an increase in starch content and a decrease in HCN content of tubers. Among the different levels tried, 100 kg K_2O/ha was found to be the optimum for tuber yield. Mohankumar and Nair (1983) reported that sulphur @ 50 kg ha^{-1} gave significantly more yield (18%) than the control. Application of S resulted in an increase in starch (5.3%) and a decrease in HCN content (by 29.2%) of the tubers. The methionine and total protein contents of tubers were also found to increase due to S application. The soluble sulphate content of soil and S uptake by plants also increased by 2.30 ppm and 323.5 mg/plant respectively due to its application.

Korah *et al.* (1988) studied the direct and indirect effects of causative factors viz., available S, S content in plant parts and total uptake by plants on yield and quality of cassava. The treatments consisted of four levels of S (0, 30, 50 and 75 kg ha^{-1}) from a combination of S containing N and P fertilizers. N, P, K were given at recommended levels of 50:50:50. The maximum positive direct effect was observed for S content in leaf (1.6797) and maximum negative direct effect for available S at sixth month. Their correlation with yield was high and positive (0.9769 and 0.9199). The positive correlation of yield with available S at sixth month was mainly due to the positive indirect effect through S content in leaf. The available S at third month and at harvest stage was found to have negative effect

on yield in both direct and indirect ways. Response of cassava and sweet potato, intercropped in the coconut garden, to inoculation with *Glomus fasciculatum* was studied (Sivaprasad *et al.*, 1989). The different cultivars showed varying response to inoculation. Cultivar Ambakadan of cassava and Kajangadu local of sweet potato recorded an increase in yield of 31.79 and 24 per cent due to VAM inoculation respectively. *Glomus* colonisation decreased the yield of H 268 of sweet potato by 20.4 per cent.

Potty (1990) tested the response of cassava to VA mycorrhizal inoculation in acid laterite soil. Root infected cuttings responded favourably in both sterile and natural soils and did not show any disadvantage over the present day practice of direct planting of cuttings. Significant difference was noticed in dry matter production and tuber production in natural soil. Sterilization had very little influence over natural soil. Rhizosphere microflora favours the VA mycorrhizal association and *vice versa* in cassava root region. Total microbial activity was elevated due to mycorrhizal association. Mycorrhizal cassava plants showed higher phosphorus uptake at low phosphorus levels. Micronutrients like copper and zinc accumulated in leaf tops of VA mycorrhizal cassava plants.

The inter-relationship of N, P, K, Ca and Mg in cassava was studied by Pushpadas *et al.* (1976). The major treatments were factorial combinations of three levels each of N and P in one and K and Ca in the other experiment with two varieties M4 and 11-105 as the minor treatments. Samples of petioles from the middle one-third of the total leaves were collected at 62 days, 136 days and 203 days after planting and analysed for N, P, K, Ca and Mg. N, P and K content of the tissue increased with the application of N, P and K respectively but N, P and Mg decreased with the application of K. Lime application increased Ca content only during the first stage of sampling whereas N, P and K had no influence on the Ca content. It was also found that H-105 was superior to M4 in K content on all the three sampling dates.

C. Sweet Potato

Sweet potato (*Ipomoea batatas* L. Lam.), believed to have originated in or around northern South America (Huaman, 1992) can be grown on a wide range of soils, but sandy loams reasonably high in organic matter with a permeable subsoil are ideal. It requires a minimum of 500 mm rainfall.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 maturity crop, tolerant to a wide range of growing conditions. In India, sweet potato is considered as a famine relief crop as it had played a pivotal role in alleviating the Bengal famine of 1942. Asia accounts for 78.7 per cent of the area under cultivation and the major share (67.7 per cent) goes to China (FAO, 1997). As regards production, 93.1 per cent is accounted by Asia where the contribution of China alone is 87.7 per cent with a productivity of 19.9 t ha^{-1}.In India, sweet potato is grown to an extent of 0.14 m ha with an annual production of 1.17 mt and 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, utilizing the south-west monsoon (June-August) as kharif crop and with supplemental irrigation during the north-east monsoon (October-December) as *rabi* season crop.

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. Sajjanpongse and Roan (1982) found that too high or too low compaction did not favour tuber formation and according to them, the optimum bulk density for higher yield was between 1.3 and 1.5 g cc^{-1}. The optimum pH of the soil for sweet potato cultivation is 5.6 to 6.6. Sweet potato is listed among the acid resistant crops and 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 (Villafane, 1997). Foliar analysis of salt-stressed plants revealed the accumulation of Na^+ and Cl^- ions to > 400 per cent in leaves as compared to plants irrigated with tap water, suggesting the lack of extrusion mechanism.

Nutrient Requirement

Muraleedharan Nair *et al.* (1976) studied the effect of levels and time of application of N on its uptake by three sweet potato varieties. The variety J.14 recorded higher total N uptake followed by J.13 and the local one. Among the individual components, N uptake by tuber was mainly responsible for varietal differences in total N uptake. There was increase in total N uptake upto 100 kg N ha^{-1}, the differences in uptake by tubers contributing to the differences between levels of application while, time of application was found to have no conspicuous effect. Between the stages, there was an increase in total Nuptake by tubers till harvest, whereas a decline in N uptake by vines was observed from 60th day till harvest. Such a pattern of N uptake by plant parts indicates that there was translocation of a considerable portion of N stored in the vegetative tissues to the developing tubers.

Alexander *et al.* (1975) studied the comparative performance of three sweet potato varieties under different methods of application of N. The results showed significant varietal difference in tuber yield. The variety H-42 recorded the highest tuber yield followed by H-41 and the local variety. Regarding methods of N application, the treatment differences were not significant. However, there was a trend towards the superiority of N application half basally and the other half through foliage 35 days after planting. The treatment with a reduced dose of 37.50 kg basal N ha^{-1} with 18.75 kg N ha^{-1} through foliage was statistically at par with the other treatments receiving the total dose of 75 kg N ha^{-1}.

Desmond *et al.* (1991) conducted field experiments in Typic Paleudalt with low to moderate N levels to compare storage root and foliage yield and N concentration in six sweet potato cultivars developed under N fertilizer independent (NFI) and N fertilizer dependent conditions (NFD). Nitrogen rates 0, 60 and 120 kg ha^{-1} were used. The NFI cultivars as a group tended to outyield the NFD cultivars at no N in both years, whereas differences were not evident at 60 or 120 kg ha^{-1} N rates . Petiole N concentration was increased generally with increases in N rates from 0 to 120 kg ha^{-1} in 1984 and 1985. In 1985, petiole N increases were more progressive and more definite for the NFD cultivars, whereas there was a drop in petiole N among NFI cultivars when N was increased from 60 to 120 kg ha^{-1}.

The N and K requirement of sweet potato var chindamoni in rainfed uplands of Kerala was studied by Asokan *et al.* (1984). They observed that linear tuber yield increase upto 17.4 t ha^{-1} (maximum) was recorded at 90 kg level of N. A quadratic response model was fitted to the data on yield response to potash. The most economic dose of K_2O was found to be 60.4 kg ha^{-1}. With increasing levels of N and K_2O, the sugar content of the tubers decreased, whereas the starch content increased. The root to shoot ratio was

decreased at higher levels of nitrogen.

Padmaja and Sreenivasa Raju (1999) studied the response of sweet potato to two sources i.e., K_2SO_4 and KCl and four levels of K viz., 0, 10, 20 and 40 kg K_2O ha^{-1}. The results showed that the effect of sources was non-significant while significantly highest tuber yield of 28.2 t ha^{-1} was recorded at 40 kg K_2O ha^{-1}. The dry matter production (42.89 q ha^{-1}), K-content (2.66%) and K-uptake (114.1 kg ha^{-1}) at tuber initiation stage recorded at 40 kg K_2O ha^{-1} level were significantly higher than other levels of K. There was increase in dry matter production (75%), tuber yield (26.2%) and K-uptake (215.5%) over control at harvesting stage of the crop. Contents of forms of K in soil viz., water soluble, exchangeable and 1N HNO_3 extractable K showed a decrease from tuber initiation to maturity stage.

Nair and Mohankumar (1984) conducted the field experiments to study the influence of different levels of NPK and lime on the yield and quality of sweet potato in an acid laterite soil. NPK at 75:50:75 and lime at 2t ha^{-1} were found to be optimum. Lime at the above rate not only increased the yield but also improved the quality by increasing starch and sugar contents in the tuber. Lime application was beneficial in increasing the pH and available P in the soil. The uptake of NPK and Ca by the plant also increased due to liming. Experiment conducted by Kandasamy *et al.* (1988) under pot culture conditions to find out the effect of inoculation of VAM endophytes (*Glomus fasciculatum* and *G. mosseae*) and (*Azospirillum brasilense*) either alone or in combination on sweet potato revealed that joint inoculation of VAM and *Azospirillum* significantly enhanced the shoot length and its dry weight. Combination of these two organisms increased the tuber weight and its starch content besides enhancing the N and P content of plants.

Studies on the effect of planting patterns, fertility levels and growth regulators on sweet potato revealed that mixed culture of two sweet potato varieties Cross-4 and RS-5 in alternate rows with 30 x 15 cm spacing recorded maximum tuber yield. Increasing levels of N-K regimes gave significantly higher weight of tubers per plant, increased tuber dry matter content and ultimately higher tuber yield. Regulating plant growth through the application of CCC @ 200 ppm at 30, 50 and 70 days of planting recorded the highest tuber yield. Two-tier cropping in sweet potato with closer spacing, optimum nutrition and regulated crop growth was found desirable for yield maximisation (Mishra *et al.*, 1992).

D. Yam

Yams are monocotyledonous plants of genus *Dioscorea* and comprising about six hundred species (Coursey, 1967) of which the popular edible species are *D. rotundata* Poir (African yam/white yam), *D. alata* (Water yam), *D. esculenta* (Chinese yam), *D. cavenensis* Lam. (yellow yam), *D. bulbifera* (ariel yam) and *D. trifida* L. (cush-cush yam). About two-third of the world production comes from West Africa. The phenology of yam species shows an annually repeated cycle of growth for six to ten months and dormancy for two to four months, and these two phases approximately correspond to wet and dry seasons respectively. Economically important part of the plant is its underground stem tuber, which is used for its propagation. Yams are grown in India since ancient times and *D. alata* is said to be of Indian origin. 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, the range being 11 – 39 per cent in different species. Protein content ranges from 6 - 13 per cent on dry weight basis (Martin and Thompson, 1973). 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 299.4 mt from an area of 32.82 million ha, of which Nigeria alone produces 195.7 mt from an area of 21.70 million ha (FAO, 1997). The world average production is 9.12 t ha^{-1} while that of Nigeria is 9.02 t ha^{-1}. In Asia yams are grown in an area of 17,000 ha producing 242,000 tons with an average yield of 14.49 t ha^{-1}.

Yams are tropical crops and thrive well under warm sunny weather with plenty of rains. The crop requires a temperature of 25 to 30°C.Evenly distributed rainfallof 100-150 cm spread over six to seven months period is ideal. However, most *rotunda* cultivars can be grown with far less rainfall (IITA manual, 1982). The most critical period of rainfall/moisture is the first five months after planting (Waitt, 1963). Yam production is also significantly influenced by day length (Onwueme, 1978). 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 of any kind with adequate nutrient and moisture status is well suited for the growth and development of yams. The crop can, however, withstand dry conditions to a good extent. Coursey (1967) reported that maintaining optimum moisture regime from fourteenth to the twentieth week of growth was ideal for better development and yield of tubers.

Nutrient Requirement

Kabeerathumma *et al.* (1991) studied the uptake pattern of N, P and K by three *Dioscorea* species. From the analysis of periodically harvested plants, it was found that the maximum utilization of N and K by *Dioscorea esculenta* and *D. rotundata* occurred within 5-7 months after planting, whereas the demand of P for these species was found to continue with maturity of the crop. In *Dioscorea alata* the maximum utilization of all the three nutrients was found to be within 5 months after planting. However, the concentration of these nutrients in plant parts was maximum in the early stages of growth (3-5 months after planting). The tuber of *D. alata* was observed to be richer in N, P and K as compared to the other two species. The ratio of N and K utilization and the extent of soil depletion were also discussed.

An experiment was undertaken to find out the optimum dose of fertilizers for yams and aroids and the economics of cultivation of those crops when grown under partial shade situations in coconut garden. The results indicated that greater yam recorded maximum yield with full dose of fertilizer, lesser yam with 75 per cent of recommendation and elephant foot yam with 50 per cent of the recommendation of fertilizer for open situation. The maximum benefit cost ratio was obtained with elephant food yam followed by greater and lesser yam (Pushpakumari and Sasidhar 1992).

Experiments were carried out to determine the effect of NPK fertilizers on the yield and storage quality of yellow yam. There were three rates each of N, P and K.The most economic fertilizer combination for total fresh tuber yield was $N_{67.20}$ $K_{67.20}$ kg/ha. Results obtained further show that fertilizers applied to yams in the field had no significant effect on the storage quality of the tubers in the barn (Azih, 1976).

E. Taro

Taro (*Colocasia esculenta*) is believed to have originated in South-Central Asia, perhaps India or Malaysia. Cultivation of taro is widespread in India, Burma, China, Japan, Hawaii, Egypt, Africa and the Caribbean. Total area under taro in the world is 10.78 mha of which Asia's share is 1.44 mha (FAO, 1997). World average for cormel yield is 6.1 kg ha^{-1} yield, while the figure for Asia is 12.39 kg ha^{-1}. Cormel production in the world is 657.3 mt.

Taro requires warm climate with plenty of moisture, available in the tropical and sub-tropical countries of the world. It can as well as grown even in the warmer temperate regions. An important character of the crop is its ability to withstand waterlogged and reduced conditions, since it can transport O_2 from the leaves to the roots under reduced condition (IITA, 1982). Taro grows well on all types of soils, the ideal type being deep well drained, friable loams, particularly alluvial.

Nutrient Requirement

Field experiments were conducted for two seasons by Ashokan and Vikraman Nair (1984) to study the response of taro to applied N and K. Application of N and K increased the tuber yield. Among the higher levels, effect of nitrogen alone was significant. The cormel to corm ratio was improved by N and K applications. The data were found to be in good fit to a quadratic response surface model and the economic optimum doses of N and K worked out from this model were 89 and 79 kg ha^{-1} respectively. The number and size of tubers increased upon N and K applications. The dry matter percentage of corms was not significantly influenced, while the starch content increased significantly with higher levels of N and K.

Field experiments were conducted to study the nutrient uptake pattern of *Colocasia*. From periodical plant analysis, it was found that the nutrient removal by the crop was maximum at harvest stage. For an average production of 17 tonnes of tubers with a biomass production of 6.2 tonnes 124.6 kg N, 19.2 kg P and 134.97 kg K per ha were removed by the crop. Except for P, there was a peak demand for N at third month and K at one to two months of growth (Kabeerathumma *et al.*, 1984).The authors also conducted a field experiment to study the uptake pattern of secondary and micronutrients. From analysis of periodically harvested plants, it was found that the peak periods of removal of the nutrients was between 3^{rd} – 5^{th} month . However, peak demand for all the secondary nutrients as well as Fe and Mn was in the early 2^{nd} or 3^{rd} months of growth, while the demand for Zn and Cu was observed to be around maturity stage. In general, all the micronutrients showed a tendency to accumulate in the root with an advancement in the growth stage of the crop. An average production of 17 tonnes of edible tubers with a total dry biomass of 6.2 t ha^{-1} removes 30.42 kg Ca, 15.87 kg Mg, 11.80 kg S, 10.25 kg Fe, 1.69 kg Mn, 647 g of Zn and 93 g of Cu from the soil.

In another experiment, total uptake of N increased significantly up to 80 kg N ha^{-1}, but increasing levels of P and K application had significant effect on the uptake of these nutrients at all levels tried. Three split application of N and K was superior to two splits for the uptake of N and K by taro (Mohankumar and Sadanandan, 1990).

Mohankumar and Sadanandan (1989) observed that application of varying levels of N and K had significant effect on increasing the plant height and LAI, but graded doses of P did not show any significant effect on these traits. Tuber and total dry matter production increased significantly upto 80 kg N and 100 kg K_2O ha^{-1}. Levels of P_2O_5 had no significant effect on these characters.

F. Arrowroot

Arrowroot (*Maranta arundinaceae*) commonly known as 'West Indian Arrowroot' is a herbaceous plant primarily grown for its quality starch which is valued as food stuff, particularly for infants and infirms. 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 or computer printouts.Arrowroot starch possesses demulcent properties and is used in the treatment of intestinal disorders. It is 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.

The crop is a native of tropical America and has long been cultivated in the West Indies particularly St. Vincent which is the main producer of Arrowroot starch. 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 grows best at temperatures of 20-30°C. A minimum annual rainfall of 95-150 cm is required but sufficient soil moisture throughout the growing period is of prime importance. The crop thrives best in deep, well drained, slightly acid loam soils with partial shade.

Nutrient Requirement

Field experiments were conducted by Maheswarappa *et al.* during 1995-96 and 1996-97 at CPCRI, Kasaragod to find out the effect of agronomic practices on growth of arrowroot grown as intercrop in coconut garden. Sett sizes (15-20 g and 25-30 g) did not show significant difference with respect to different growth characters, whereas, lower plant population (111 thousand ha^{-1}) showed superiority in plant height, number of leaves, leaf area, LAI and LAD over higher density treatment (166 thousand ha^{-1}). Among organic manures, FYM, Vermicompost applied alone and FYM + NPK treatments showed significantly superior growth attributes compared to Composted Coir Pith applied alone and NPK alone. Control had significantly lower growth characters.

G. Yam bean

Yam bean {*Pachyrrhizus erosus* (L) Urban} also called Potato-bean belongs to the family Leguminaceae. Yam bean is a starchy root crop with comparatively high sugar content and a moderately good source of ascorbic acid.

In India, tender tubers are consumed as a fruit and the taste resembles that of Chinese water chestnut. Because of high water content, low calories and bulky nature, it is good for salad preparation for those who want to adopt dieting. The mature seeds have high content of alkaloids and insecticidal properties. In many developed countries, the tubers are processed, canned and many sweet preparations are made.

The crop has originated from hot moist region of the river Amazon, is now cultivated in Philippines, China, Indonesia, Nepal, Bhutan, Burma and India. In India, it is grown in parts of West Bengal, Bihar, Orissa and Assam. Yam bean requires a hot humid climate and adapts well in sub tropical and hot temperate zones.Fertile, well drained, sandy loam soil is best suited for cultivation of yam bean. This crop adapts well to loamy and clay loam soil. Optimum soil pH requirement is 6.0 - 7.0.

Nutrient Requirement

Experiment involving three levels of N and K (40, 80 and 120 kg ha^{-1}) along with an absolute control (N_0K_0) was conducted to study the influence of N and K on the performance of two yam bean entries (RM -1 and L-109) during two successive years. Uniform basal dose of 60 kg P_2O_5 ha^{-1} was applied except control plots. There was no significant yield variation between the two entries; however, RM-1 produced significantly higher tuber yield in the second year. The tuber yield was found maximum under N_{120} K_{60} which was on par with N_{120} K_{40} and N_{120} K_{120}. But N_{120} K_{80} produced longer tubers. Highest net income (Rs.14,188.10) per ha was obtained by the application of 120 kg N and 80 kg K_2O over no application of fertilizer. TSS content was found maximum in the tubers of control plots (Sen and Mukhopadhyay, 1989).

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