RESOURCE MANAGEMENT FOR INTERCROPPING WHITE YAM (*Dioscorea rotundata* Poir) IN COCONUT GARDEN

BY

SUJA, G.

THESIS
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In memory of my mother

DECLARATION

I hereby declare that this thesis entitled **"Resource management for intercropping white yam (*Dioscorea rotundata* Poir) in coconut garden"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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SUJA, G.

CERTIFICATE

Certified that this thesis entitled **"Resource management for intercropping white yam (*Dioscorea rotundata* Poir) in coconut garden"** is a record of research work done independently by **Mrs. Suja,G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

3/12/2001

Vellayani,
3-12-2001

Dr. V. MURALEEDHARAN NAIR
(Chairman, Advisory Committee)
Professor and Head,
Department of Agronomy,
College of Agriculture,
Vellayani, Thiruvananthapuram.

Approved by

Chairman:

Dr. V. MURALEEDHARAN NAIR
Professor and Head
Department of Agronomy
College of Agriculture
Vellayani, Thiruvananthapuram.

Members:

1. **Dr. (Mrs.) P. SARASWATHI**
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College of Agriculture, Vellayani

2. **Dr. (Mrs.) R. PUSHPAKUMARI**
Associate Professor
Department of Agronomy
College of Agriculture, Vellayani

4. **Dr. (Mrs.) V.L. GEETHAKUMARI**
Associate Professor
Department of Agronomy
College of Agriculture, Vellayani

5. **Dr. P. RAJENDRAN**
Associate Professor
Department of Soil Science and Agricultural Chemistry
College of Agriculture, Vellayani

External Examiner:

Dr.N.SANKARAN
Professor and Head
Department of Agronomy
Tamil Nadu Agricultural University
Coimbatore

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LIST OF ABBREVIATIONS

@	at the rate of
AICRP	All India Co-ordinated Research Project on Tuber Crops
BCR	Benefit cost ratio
^{0}C	Degree Celsius
Ca	Calcium
CD	Critical difference
CGR	Crop growth rate
CIAT	Centro Internacional de Agricultura Tropicale
cm	Centimetre
CPC	Coir pith compost
CRD	Completely randomised design
CTCRI	Central Tuber Crops Research Institute
Cu	Copper
cv	Cultivar
DAP	Days after planting
DM	Dry matter
Fe	Iron
Fig.	Figure
FYM	Farm yard manure
g	gram
g day^{-1}	gram per day
g m^{-2}day^{-1}	gram per square metre per day
HI	Harvest index
IAA	Indole Acetic Acid
IBA	Indole Butyric Acid
IITA	International Institute of Tropical Agriculture
K	Potassium
kg ha^{-1}	Kilograms per hectare
LAI	Leaf area index
m	Metre
MAP	Months after planting
meq	milli equivalence
Mg	Magnesium
mm	millimetre
Mn	Manganese
mg g^{-1}day^{-1}	milligram per gram per day

mg 100 mg^{-1}	milligram per 100 milligrams
N	Nitrogen
NAA	Naphthalene Acetic Acid
NAR	Net assimilation rate
P	Phosphorus
PAR	Photosynthetically active radiation
Plants ha^{-1}	plants per hectare
ppm	parts per million
RBD	Randomised block design
RGR	Relative growth rate
RRII	Rubber Research Institute of India
spp.	species
t ha^{-1}	tonnes per hectare
TBR	Tuber bulking rate
viz.,	namely
var.	variety
Zn	Zinc
%	per cent
μ g g^{-1}	micro gram per gram
μ Em^{-2} s^{-1}	micro Einsteins per square metre per second
2,4-D	2,4-dichloro phenoxy acetic acid

INTRODUCTION

INTRODUCTION

Tropical tuber crops form an important staple or subsidiary food especially for the low income groups. Certainly in part, farm households see the value of roots and tubers "in their ability to produce large quantities of dietary energy and their stability of production under conditions when other crops may fail" (Alexandratos, 1995). The adaptation of these crops to marginal environments, their contributions to household food security, and their great flexibility to thrive in mixed farming systems and environmentally sound production of competitive products for food, feed and industry from these crops offer opportunities to link small holder farmers with the emerging markets.

The compatability and flexibility of tuber crops in diverse cropping systems has been well documented. One of the feasible ways of increasing the farm level income and employment opportunities from small and marginal coconut holdings is intercropping with tropical tubers like cassava, yams and edible aroids. In such a system the coconut palms generate cash income and the tuber crops partially meet the food and feed requirements of the farm family.

Yams (*Dioscorea* spp.) form an important food source in tropical countries mainly West Africa, South East Asia and the Caribbean. Although yams are mostly used for their high content of carbohydrate, they have a higher protein content and better balance of amino acids than many other root and tuber crops. Yams are also important as source of pharmaceutical compounds like saponins and sapogenins which are precursors of cortisone and steroidal hormones. This aspect has generated considerable research attention recently.

Among edible yams, Asiatic yams viz., greater yam (*Dioscorea alata*) and lesser yam (*Dioscorea esculenta*) are common intercrops in many coconut growing regions of Asia. African white yam, (*Dioscorea rotundata*) a recent introduction to India is gaining popularity among farmers due to its good yield (35-40 t ha^{-1}) and acceptable tuber quality. Compared to native yam species, white yam tuber contains higher dry matter with 20-24 per cent starch. It has excellent cooking quality, novel taste and flavour (Nair *et al.*, 1987; Moorthy and Nair, 1989). Tubers are source of proteins, fats, minerals and vitamins particularly vitamin C and are nutritionally comparable to potato. When compared to other yam species, the tubers of white yam are less slimy. The crop can with stand drought to a certain extent and is almost free from pest and disease infestation (CTCRI,1998a). The crop has good potential as a vegetable, subsidiary food item and industrial raw material. It can be well fitted into the existing tree based cropping systems of South India, especially Kerala. Inspite of all these superior attributes, *D. rotundata* has not yet found an appropriate place in the coconut based cropping system for want of suitable production technologies. Hence there is immense scope to assess its production potential as an intercrop in coconut gardens.

The most serious constraint to yam cultivation is the high production cost due to high requirement of planting material accounting to 25-30 per cent of the total cost of production. Cultural manipulation helps a great deal to minimise production costs. The partial shade prevalent in coconut gardens can provide a moist situation so as to prevent rapid desiccation of yam setts. Hence there is possibility for reducing the sett size. But considerable reduction in sett size could result in severe yield reduction particularly under partial shade as existing in coconut gardens. On the other hand, planting too large setts necessitates deep excavation of the soil to harvest large tubers making yam production difficult, labour intensive and expensive. In this context, it is highly imperative to standardize sett size for economic returns under intercropping situation. Optimum plant population for intercropping white yam in coconut garden also has to be worked out.

In most yams and in particular *D. rotundata,* sprout emergence after planting is slow and staggered, especially where a mixture of tuber portions (head, middle and tail) is planted. Moreover, when the sett size is reduced, due to lesser sprouting loci yam setts take much more time for differentiating sprouts (Onwueme,1973). Improved production technologies should sustain or increase the photosynthetic capacity of the crop by manipulating agronomic factors, such as early emergence. Hence the effect of growth promoting substances on early and uniform sprouting and establishment of yam setts has to be explored.

Yam is a very demanding crop for nutrients and organic matter. Studies conducted mainly in Africa show that yams respond well to nitrogen and potassium but slightly to phosphorus. Fertilization is not a current practice in yams. Nutrient uptake by *D.rotundata* to yield 28.99 t $ha^{-1}$of tuber was 116.52 kg N,17.3 kg P and 122.68 kg K ha^{-1}(Kabeerathumma *et al.*,1987). Due to significant nutrient exports by the crop, fertilizer application becomes inevitable especially when continuously cropped. However, under Indian condition nutritional requirements of white yam has not yet been standardized. The organic manurial recommendation for yam is also slightly high (10 t ha^{-1}). The non availability, high cost and drudgery in transportation and spreading of FYM, the chief organic manure currently used, can discourage many farmers from using it. Hence the feasibility of alternative organic manures viz., coir pith compost, green manuring *in situ* using sunhemp, etc has to be investigated so as to standardize nutrient management practices for intercropping white yam in coconut gardens.

In the light of the above facts, the present investigation was undertaken with the following objectives:

- To assess the agronomic performance and monitor the resource utilization pattern of white yam as an intercrop in coconut garden
- To find out the effect of growth promoting substances on sprouting and establishment of white yam setts
- To optimize plant population and sett size for intercropping white yam in coconut garden
- To develop an effective nutrient management schedule for white yam under intercropping situation
- Economic evaluation of the system.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The study envisages the evaluation of production potential of white yam as an intercrop in coconut garden and standardization of agrotechniques for intercropping .White yam, a recent introduction to India is gaining popularity among farmers at present.

Under Indian condition , Asiatic yams (greater yam (*Dioscorea alata*) and lesser yam (*D. esculenta*)) and to a greater extent, white yam (*D. rotundata*) lack sufficient research attention, particularly in coconut based cropping systems. Hence published work on yams as intercrops is rather limited. This review mostly pertains to the effect of various management strategies on growth, yield and quality of *Dioscorea* spp. viz., *D. alata, D. esculenta* and *D. rotundata* in sole situation. However, available literature relevant to intercropping situation as well as specific to white yam are also cited. Wherever, sufficient information is not available in yams, citations on other related tuber crops are also included.

2.1 Relative performance of white yam

White yam, a recent introduction to India from IITA, Nigeria was tested at CTCRI, Thiruvananthapuram and found to adapt and yield well with acceptable culinary qualities.

Detailed trials conducted by Nair *et al.* (1987) indicated the remarkable yield increase of white yam over the native species as well as the novel taste and flavour of white yam. While the average yield of the best selections of *D. alata* was about 24 t ha^{-1} (CTCRI, 1982) that of Sree Subhra and Sree Priya, the two high yielding selections of white yam was about 36 t ha^{-1} (Nair *et al.*, 1987). Further testings in the different agroclimatic regions of Kerala by the authors also revealed the feasibility of fitting *D. rotundata* into the general cropping pattern of the state as *D. alata.*

Sen and Das (1991) also emphasized the agronomic potential of some cultivars of white yam in the Gangetic plains of West Bengal, under rainfed condition. Under the auspices of All India Co-ordinated Research Project on Tuber Crops (AICRP, 1999) the performance of white yam variety Sree Priya was evaluated at Rajendranagar, Hyderabad and was found promising.

Moorthy and Nair (1989) obtained a starch recovery of 20-24 per cent from white yam with very little loss during extraction. High dry matter accumulation and starch content in white yam tubers has been well established (Egbe and Treche, 1984; Sen and Das, 1991).

Experimental evidences clearly indicate the superior qualities of white yam and scope of introducing it in the existing perennial tree based cropping systems of Kerala.

2.2 Response of yams to shade

The influence of light intensity on yam growth and productivity has not been fully investigated. Onwueme and Charles(1994) suggested that yam is not a shade loving plant. On the other hand, yam not only tolerates but also requires high intensities of sunlight to be maximally productive. Contradicting this report, Johnston and Onwueme (1998) stated that yams appeared to be moderately tolerant to shade.

2.2.1 Growth response

Pushpakumari and Sasidhar (1992a) noticed increased vine length with increase in shade intensity in *D. alata* and *D. esculenta*. Maximum leaf area index was observed at 50 per cent and 25 per cent shade in *D. alata* and *D. esculenta* respectively. According to Johnston and Onwueme (1998) yams compensated for shade by a larger proportional increase in leaf size.

Pushpakumari and Sasidhar (1992a) further elaborated that though shade had no influence on NAR of *D. alata* at any stage, the significant effect of shade on NAR of

D. esculenta was apparent during later stages of growth. Also, shade significantly reduced CGR and dry matter accumulation in *D. alata*, though *D. esculenta* accumulated maximum dry matter at 25 per cent shade.

2.2.2 Effect of shade on photosynthetic pigments

By examining the effect of shade on leaf chlorophyll contents of *D. alata* and *D. esculenta*, Pushpakumari (1989) observed an increasing trend with increasing shade intensities. Johnston and Onwueme (1998) estimated that on an average, shade plants had 1.5 times as much chlorophyll per gram fresh weight as the sun plants in *D. esculenta.*

2.2.3 Yield response

Based on comparative studies at different shade levels, Pushpakumari and Sasidhar (1992b) reported that *D. alata* could be grown in partial shade of up to 50 per cent with 30 per cent yield reduction and *D. esculenta* up to 25 per cent shade with 23 per cent yield reduction.

From the foregoing review it is evident that shade has a profound influence in lowering the tuber yield of yams, though some of the growth attributes are favoured. However, integration of yams in cropping systems will enhance the overall system productivity as the yield reduction under shade is only marginal.

2.3 Performance of yams in cropping systems

The suitability and profitability of intercropping Asiatic yams (*D. alata* and *D. esculenta)* in coconut gardens have been reported by several authors (Nair *et al.*, 1974; Varghese *et al.*, 1978; Ibrahim *et al.*, 1983; Pushpakumari and Sasidhar, 1992c; Ollivier *et al.*, 1994; Inasi *et al.*, 1996)

Investigations carried out at CTCRI also suggested the potentiality and feasibility of intercropping *D. rotundata* and *D. alata* in coconut and banana (Nayar and Nair, 1992; Nayar and Suja, 1996; Nayar and Suja, 1999; Nayar *et al.*, 2000).

Experiments undertaken by CTCRI in collaboration with RRII at Central Experiment Station, Chethackal, Kottayam to test the feasibility of growing *Dioscorea* as an intercrop in immature rubber plantation showed that *D. alata* and *D. rotundata* can be grown as intercrops during the juvenile phase of rubber (CTCRI, 2000a).

2.3.1 Productivity

Nayar and Nair (1992) observed consistently satisfactory performance of *D.alata* in association with Nendran banana, with only 5.23 per cent reduction in tuber yield. In another intercropping experiment conducted by Nayar and Suja (1996) at CTCRI, Thiruvananthapuram with *D. alata, D. esculenta* and *D. rotundata* in Nendran banana, tuber yields were comparable under intercropping, though 9-10 per cent yield reduction was noticed.

Nayar and Suja (1999) obtained tuber yields of more than 12 t ha^{-1} in *D.alata* (variety Sree Keerthi) and *D. rotundata* (variety Sree Priya) when intercropped in coconut.

2.3.2 Profitability

In an intercropping experiment involving *D. alata* and *D. esculenta* in coconut garden at Vellayani, Thiruvananthapuram, Pushpakumari and Sasidhar (1992c) obtained a benefit - cost ratio of 2.44 with *D.alata* and 1.4 with *D. esculenta.* In the reclaimed alluvial soils of Kuttanad tract, intercropping *D.alata* with coconut realized net income to the tune of Rs. 27,709 ha^{-1} and benefit - cost ratio of 2.77. The corresponding figures for D. *esculenta* were Rs. 7849 ha^{-1} and 1.63 respectively (Inasi *et al.*,1996). In Vanuatu, Ollivier *et al.* (1994) estimated profits of $ 5-10 per day for an intercrop of yam in young coconut plantation and stated that the yam crop successfully provided extra income during the first few unproductive years of the new coconut plantation.

At CTCRI, intercropping *D. rotundata* (variety Sree Priya) and *D. alata* (variety Sree Keerthi) in coconut fetched Rs 20,000 ha^{-1} (Nayar and Suja, 1999) and Rs. 20,500 ha^{-1} and Rs. 17,500 ha^{-1} respectively in banana (Nayar and Suja, 1996).

The review points out the popularity and profitability of intercropping yam species as well as the relevance of the present investigation.

2.4 Effect of growth promoting substances on sprouting

Yam tubers exhibited a definite period of dormancy shortly after harvest and the duration varied from two to three months depending on species (Onwueme, 1982) and extended even up to 4- 4.5 months in tropical conditions (Campbell *et al.*, 1962). Dynamics of sprout emergence in *D. rotundata* was studied indepth by Akoroda (1985) at Ibadan, Nigeria and accordingly time to sprout emergence in the field averaged 27-48 days.

Onwueme (1982) further investigated the agricultural implications of yam tuber dormancy and stated that the longer period from planting to field emergence, a consequence of dormancy added to the total crop duration.

Onwueme (1973) noted that large setts sprouted more rapidly than small setts due to the production of more sprouting loci and more sprouts per sett. A number of chemicals or growth regulators have been reported to be effective in breaking dormancy and induce sprouting in yam tubers. Ethrel resulted in earlier sprouting and increased shoot growth in *D. alata* (Bryan and Mcmillan, 1975; Martin and Cabanillas, 1976) and *D. rotundata* (Bala Nambisan and Indira, 1993). But Passam (1977) indicated that ethrel only slightly promoted sprouting in *D. rotundata.*

Recent evidences suggest the pronounced effect of thiourea and potassium nitrate in inducing sprouting in white yam setts and elephant foot yam corm sections (Samarawira, 1983; Dhua *et al.*, 1988; Bala Nambisan and Indira, 1993; Kumar *et al.*, 1998).

Samarawira (1983) claimed that two per cent thiourea treatment was consistently better in inducing satisfactory number of buds by the fourth week in *D. rotundata*. Bala Nambisan and Indira (1993) noticed 77 per cent sprouting with 100 ppm thiourea and 60 per cent sprouting with 100 ppm potassium nitrate treatments in minisetts of *D. rotundata.*

On the contrary, treating the tubers with IAA had no significant effect on the length of dormancy, while maleic hydrazide, 2,4,-D (Passam, 1977; Wickham *et al.*, 1984) or gibberellic acid (Igwilo *et al*; 1988; Nnodu and Alozie, 1992; Girardin *et al.*, 1998;Onjo *et al.*, 1999) delayed sprouting. However, Mozie (1987) observed that auxins (IAA, NAA and IBA) stimulated sprouting, but 2,4-D in general inhibited sprouting.

Available literature throws light on the effect of various growth regulators in inducing sprouting of dormant yam tubers. However the effect of these chemical substances in promoting early and high per cent of sprouting and emergence in the field needs investigation.

2.5 Influence of cultural manipulations on growth, yield and quality

2.5.1 Effect of spacing on growth and yield

Spacing in traditional yam production is variable, depending on sett size, cultivar and the extent of intercropping envisaged (Onwueme and Charles, 1994).

Gurnah (1974) inferred that increase in plant density from 9000 to 36,000 plants ha^{-1} increased tuber yield but decreased average weight of tuber in *D. rotundata.* Similar trend was noticed by Ferguson *et al.* (1984) in *D.alata* on a loamy soil at Trinidad. Accordingly, wider spacing (90 x 60cm) resulted in greater and longer tuber bulking leading to larger tubers, greater total dry matter and tuber dry matter accumulation and higher yield per plant. However, tuber number per unit area was greater for plants at close spacing (90 x 30 cm) resulting in little difference in tuber yield between close and wide spacings.

In the rainforest zone of Nigeria, Kayode (1984) noticed that *D. rotundata* planted at an intra row spacing of 150 cm out yielded others (125 and 100 cm). In general, wider spacings viz., 90x90 cm (George, 1995), 1 x 0.5 m (Onwueme and Fadayomi, 1980) and 1 x 1 m (Onwueme and Charles, 1994) have been advocated in *D. rotundata.* At CTCRI, Thiruvananthapuram, George (1995) observed that, though closer spacing gave comparatively better yield than wider spacing in *D. rotundata* it was not an economical proposition. Hence suggested a wider spacing of 90 x 90 cm as ideal.

At Papua New Guinea, King and Risimeri (1992) found that, though total yield was greatest at the highest density in *D. esculenta*, there was no apparent advantage in increasing density above 4444 plants ha^{-1} (1.5 x 1.5 m) on account of higher planting material requirement.

At Orissa Agricultural University, Singh *et al.* (1994) observed that in *D. alata*, yield increased significantly with closer plant spacing (0.5 m). Wider spacing produced more weight, length and girth of tubers and tuber yield per plant but failed to compensate the loss incurred due to less plant population.

Kerala Agricultural University (KAU, 1996) recommends a spacing of 1 x1 m for *D. alata* and 75x75 cm for *D. esculenta*. Preliminary studies conducted at CTCRI (Nayar and Suja,1999) showed that for intercropping *D. alata* (variety Sree Keerthi) and *D. rotundata* (variety Sree Priya) in coconut garden, a spacing of 90x90 cm accommodating 9000 plants ha^{-1} was promising. Based on another intercropping experiment with *Dioscorea* spp. in Robusta banana, Nayar *et al* .(2000) suggested that 6000 plants of *D. alata* or *D. rotundata* can be intercropped in one hectare without sacrificing the banana plant population.

Available literature reveals that closer spacing results in greater yield per unit area, though higher yield per plant can be obtained from wider spacing. In general, wider spacing is recommended for yam in sole crop situation. Information on this aspect in intercropping situation is scanty. Hence standardization of plant population of *D. rotundata* for intercropping in coconut needs special attention.

2.5.2 Effect of sett size on growth and yield

It is well documented that sett size affects growth and yield in yams. The general trend of yield increase with increasing sett sizes has been repeatedly confirmed in various experiments.

In *D. rotundata,* average tuber weight was highest with 226 g setts (Onwueme, 1972) while further increase in sett size from 203 g to 608 g increased tuber yield and tuber number with no effect on average tuber weight (Gurnah, 1974). However, Kayode (1984) suggested that setts weighing more than 400 g could be used for obtaining maximum tuber yields in *D.rotundata* in forest and Savanna zones of Nigeria, though uneconomical. At Ibadan, Nigeria, Akoroda (1985) observed that sett size of 200-250 g gave optimum sett multiplication ratio for *D. rotundata* under monocrop system. According to Onwueme and Charles (1994) for commercial yam production, setts weighing 150-300 g proved to be optimum.

In *D. alata*, maximum tuber yield per plant was obtained with 255 g setts at Trinidad (Ferguson *et al.*, 1984) and 350 g setts at Nigeria (Onwueme, 1978). For optimum tuber production in *D. alata*, setts of weight 200 g in Orissa (Singh *et al.,* 1994) and 200-250 g in Kerala (KAU, 1996) proved ideal.

In *D. esculenta*, 130 g seed size resulted in significant increase in germination percentage, vine length, leaf area index, number of leaves, length and girth of tubers, number of tubers, dry matter production, utilization index, tuber yield and tuber bulking rate in a study conducted by Nair (1985). However, Pido and Edeo (1988) could not notice any significant difference in tuber yield between sett sizes of 50,100 and 150 g in *D. esculenta.*

Sett size determines the speed of sprouting and vigour of plant growth in edible yams. As sett weight increased, the time to 50 per cent emergence decreased and percentage field emergence increased (Onwueme, 1972; Oriuwa and Onwueme, 1980). Moreover large setts produced more sprouting loci, more sprouts per sett (Onwueme, 1973) and vigorous initial plant growth that was maintained throughout the growing season (Onwueme, 1972; Nwoke *et al.*, 1973; Nwoke *et al.,* 1984). Onwueme and Charles (1994) attributed the rapid and better sprouting of large setts to the presence of greater amount of tuber skin and high skin: cut surface ratio.

Several reports indicate that vine length, vine diameter, number of branches, total leaf area, number of leaves, number of tubers and fresh weight of tubers increased with sett size (Onwuene, 1972; Onwueme and Charles, 1994 and Toyohara *et al.*, 1998).

However, relative growth rate, net assimilation rate, leaf area ratio (Nwoke *et al.*, 1984) and tuber dry matter content (Onwueme, 1972) were unaffected by sett size.

Ferguson *et al.* (1984) and Onwueme and Charles (1994) observed early tuber initiation, early, rapid and longer tuber bulking with large setts. On the contrary, Onwueme (1978) remarked that sett multiplication ratio increased with smaller setts. Toyohara *et al.*(1998) correlated positively the length and weight of the new tuber with seed tuber size.

The direct relationship between sett size and yield in yams is evident from the above discussion. At present, the farmer is forced to reserve one-fifth of his edible harvest for use as future planting material (Onwueme and Charles, 1994). Hence the need for optimization of sett size of *D. rotundata* under intercropping situation is relevant.

2.5.3 Effect of cultural manipulations on tuber quality

Nair (1985) stated that seed size had no influence on starch, sugar, protein and crude fibre contents in *D. esculenta*. This is in conformity to the subsequent report of Maheswarappa *et al.* (1997) in arrow root.

In sweet potato, Sharfuddin and Voican (1984) reported significantly higher contents of starch and crude protein at lower plant density. In cassava - coconut intercropping situation, Nayar and Sadanandan (1991) also obtained significantly higher starch and lower HCN contents in cassava at lower plant density. Maheswarappa *et al.*(1997) noted that population level of 1,11,000 ha^{-1} had significantly higher starch and crude protein contents compared to 1,66,000 ha^{-1} in arrow root when intercropped in coconut.

2.5.4 Combined effect of spacing and sett size

According to Ferguson *et al.* (1984) the effect of sett size and spacing can be jointly considered to be one of seed rate. Quite early, Baker (1964) examined the effect of seed rate on the yield of *D. rotundata* and found that an asymptotic curve for yield at increasing seed rates was only obtained when sett weight was constant and seed rate was proportional to population.

Oriuwa and Onwueme (1980) investigated the combined effect of three within row spacings viz., 30, 60 or 90 cm on ridges 1 m apart, and three sett sizes viz., 100, 200 or 300 g and reported that larger setts planted closely gave more rapid increase in ground cover. They further elaborated that net yield per hectare was highest for the 30 cm spacing with 300 g setts, while net yield per unit weight of planting material was highest with 100 g setts and 90 cm spacing.

Ferguson *et al.* (1984) observed that small setts at the close spacing produced significantly lower yield than large setts at both wide and close spacing. Kayode (1984) also stated that though there was no significant interaction between sett size and spacing, the heaviest yam setts (400 g) gave the largest tuber yield at all spacings.

2.6 Response to organic manures

Incorporation of considerable amount of organic manures at planting is inevitable to achieve higher yields and maintain soil productivity. Usually farmyard manure, cowdung, compost or green manures are used as organic sources.

2.6.1 Effect of organic manures on growth and yield

2.6.1.1 Farmyard manure

Cassava responds to both bulky and concentrated organic manures (Thampan, 1979). Saraswat and Chettiar(1976) recorded an yield of 32 t ha^{-1} in cassava when 66.6 per cent of nitrogen requirement was met by FYM application. Higher efficiency of FYM in producing higher yield and improving chemical properties of soil as compared to castor oil cake and urea was revealed by Gomes *et al.* (1983). Basal application of FYM at 12.5 t ha^{-1} to cassava (Mohankumar *et al.*, 1976; Ashokan and Sreedharan, 1977; Pillai *et al.*, 1987; KAU, 1996) and 5 t ha^{-1} to sweet potato (Ravindran and Bala Nambisan, 1987) was beneficial in enhancing the yield and improving the quality of tubers.

Tyagi *et al.* (1976) recommended 37.5 t ha^{-1} of FYM for yams and suggested application at the rate of 1.5 kg per hill. Of the varying levels of FYM tried by Mohankumar and Nair (1979) in *D. alata*, application of FYM @ 20 t ha^{-1} recorded significantly superior yield, but for economic returns, application of 10 t ha^{-1} of FYM was found to be sufficient. Field experiments in the Cook Islands (Purea and Mataora, 1995) revealed that organic fertilizers compared with NPK generally increased yield in *Dioscorea* species .

According to Patel and Mehta (1987) application of FYM alone resulted in higher yield in *Amorphophallus.*

While studying the effect of different organic manures in arrow root intercropped in coconut garden, Maheswarappa *et al.* (1997) found that application of farmyard manure resulted in significantly higher harvest index, number and length of rhizomes and higher starch and crude protein contents.

2.6.1.2 Green manuring

Studies conducted by Escasinas and Escalada (1984) have shown that legumes can be fitted very well in root crop based rotations.

Cowpea is well adapted to the same ecological conditions as cassava and has been found to be a superior green manure in acid infertile soils of Columbia (CIAT, 1975). Cassava benefitted well by the rotation of cowpea (Sasidhar and Sadanandan,1976) and association of sunhemp (Mattos *et al.*,1980).

Squire (1981) found that a green manure crop of ground nut ploughed in before planting cassava increased cassava root and shoot weight.

Scarcity and higher cost of FYM necessitated studies on low cost soil fertility management practices for cassava. Field experiments conducted at CTCRI revealed that FYM application to cassava can be substituted by green manuring *in situ* with cowpea (Prabhakar and Nair, 1987; Nayar and Mohankumar, 1989; Nayar *et al.*, 1993;

Nayar and Potty, 1996). Nayar *et al.* (1993) emphasized that green manuring *in situ* with cowpea was instrumental in promoting greater dry matter accumulation in the storage roots and sustaining the productivity of cassava.

Similar results of raising cowpea and incorporation in cassava fields under lowland situation has been reported by Mohankumar and Nair (1990).

However, Howeler (1993) reported that normal early season planting of cassava without green manure resulted in higher yield even without fertilizers due to benefit from additional two to three months rainy season which could otherwise be used for growing the green manures.

From the practical viewpoint, Mohankumar *et al.* (2000) suggested the possibility of interplanting green manure crops in between cassava rows and incorporating after 1.5-2 months or alternatively to seed the green manures about 1-2 months before cassava harvest and plant the next crop after incorporation of the green manure. However, this aspect requires thorough investigation.

Sevenorio and Escalada (1983) obtained highest total tuber yield of 9.4 t ha^{-1} when sweet potatoes were planted 21 days after soil incorporation of green manure, *Vigna mungo* or soybean. On Njala upland gravelly soils, green manuring sweet potato with elephant grass and spear grass by Kamara and Lahai (1997) resulted in increased tuber yield and yield components with increasing applications of spear grass upto 10 t ha^{-1} and elephant grass upto 20-30 t ha^{-1}. In another field trial at Rio-de-Janeiro in sweet potato, green manuring with *Crotalaria juncea, Canavalia ensiformis , Cajanus cajan* or *Mucuna aterrima* increased tuber yield compared to fallow, with *Mucuna aterrima* giving the highest yield (Espindola *et al*., 1998).

In an on-farm research trial at Oyo state, Nigeria, Otu and Agboola (1991) obtained 16 per cent yield increase in *D. rotundata* due to addition of three prunings of *Glyricidia sepium.*

2.6.1.3 Compost

Among organic manures tested by Maheswarappa *et al.* (1997) in arrow root intercropped in coconut garden, vermicompost recorded higher rhizome yield and harvest index compared to composted coir pith. The yield components viz., number of rhizomes and length of rhizomes and quality parameters viz., starch and crude protein contents were also favourably influenced by vermicompost application. However, field experiments undertaken at CTCRI (CTCRI, 1998 b) to study the possibility of substituting FYM in cassava production with recently available organic manures viz., press mud (farm boon), a by product from sugar factories and coir pith compost indicated that there was no conspicuous yield variation among the various organic manures suggesting the suitability of press mud or coir pith compost as alternative to FYM in cassava production depending upon availability.

2.6.2 Effect of organic manures on soil properties

The beneficial effects of FYM in conserving soil moisture and maintaining soil fertility in cassava and sweet potato has been confirmed (Mohankumar *et al.*, 1976; Pillai *et al.*, 1987; Ravindran and Bala Nambisan, 1987)

Prabhakar and Nair (1987) noted that incorporation of green manure cowpea in cassava could improve the nitrogen status of the soil from the initial level of 0.075 per cent to 0.083 per cent.

Enhancement in the organic carbon, available N,P and K contents of soil due to green manuring *in situ* was also noticed by Nayar *et al.* (1993). Nayar and Potty (1996) also observed higher uptake of N and K in cassava under green manuring. Hence Nayar *et al.* (1993) and Nayar and Potty (1996) concluded that P application to the green manure cowpea - cassava sequence can be reduced to 50 kg P_2O_5 as indigenous rock phosphate and N dosage by 50 per cent, without hampering cassava root yields.

In an intercropping experiment with arrow root in coconut garden, Maheswarappa *et al.* (1999) studied the effect of organic manures on soil physico-chemical and biological properties. They found that FYM and vermi compost decreased bulk density and improved soil porosity and water holding capacity to a greater extent. Moreover organic carbon, soil pH, microbial population and dehydrogenase activity were also higher under these organic treatments. On the other hand, composted coir pith influenced these parameters to a lesser extent than FYM and vermicompost but to a greater extent than control. However, water holding capacity was highest in plots that received composted coir pith.

The effect of *Glyricidia* prunings on soil properties and performance of white yam was investigated by Otu and Agboola (1991) at Nigeria. The nutrient contribution after decomposition of prunings upgraded the soil nutrient status. There was 14 per cent decrease in soil bulk density and 16 per cent increase in soil moisture content under prunings. This finding is in conformity to the earlier reports of Wilson and Kang (1981).

The review reveals the beneficial effect of organic manures on growth and yield of major tropical tuber crops as well as on soil properties. Investigations on this aspect in minor tuber crops like yams are rather meagre and hence the study is undertaken.

2.7 Response of yams to NPK fertilization

Yams are reported to be highly efficient in the utilization of native and applied nutrients from soils. Hence continuous cropping of yams may lead to severe depletion of essential nutrients from the soil. Supplementing the soil with plant nutrients overcomes this problem to a great extent.

2.7.1 Response to nitrogen

Positive response of yams to nitrogen has been well established.

2.7.1.1 Effect of nitrogen on growth attributes

Nitrogen has been shown to improve the tuber yield in yams probably by increasing the leaf area (Stephens, 1956; Irving, 1956; Enyi, 1972).

Enyi (1972) described that N application encouraged vine growth, increased leaf area index and leaf area duration in *D. esculenta*. Though N application had a favourable effect on dry matter accumulation in the vines and petioles, it tended to increase the proportion of dry matter diverted into tubers at harvest.

Applied N tended to reduce the adverse effect of delayed planting, increased leaf area development, dry matter accumulation, relative growth rate and crop growth rate but decreased tuber bulking rate (Enyi ,1970; Enyi, 1973).

2.7.1.2 Effect of nitrogen on yield attributes and yield

Chapman (1965) obtained 30 per cent increase in tuber yield in *D. alata* when the application of N fertilizers was delayed until three months after planting. Preliminary trials conducted at CTCRI to find out the effect of different levels of nitrogen on the yield of *D. alata* (Singh *et al.*, 1973a) clearly showed that nitrogen levels upto 60 kg ha^{-1} had a significant influence on tuber yield and resulted in highest tuber yield (33.1 t ha^{-1}) and dry matter content (33 per cent).

According to Enyi (1972), N application increased tuber number per plant, mean tuber bulking rate and tuber yield in *D. esculenta*. From three years field experimentation at CTCRI, Singh *et al.* (1973b) confirmed the substantial yield response of *D. esculenta* to N application and arrived at an economic dosage of 80 kg N ha^{-1}. Rao *et al.* (1975) reported that N significantly increased tuber yield linearly upto 300 kg ha^{-1}.

Koli (1973) found that N rates upto 67.2 kg ha^{-1} increased tuber yield by 22.1 per cent in *D. rotundata* at Northern Ghana. At Nigeria, Umanah (1977) recorded significant increase in yield in *D. rotundata* by applying N at the rate of 33.6 kg ha^{-1}, but a higher dose of 67.3 kg ha^{-1} could not increase the yield further.

Though Aduayi (1979) estimated insignificant correlation between tuber yield and leaf N concentration in *D. rotundata,* tuber yield was the highest at 200 kg N ha^{-1} (Aduayi and Okpon, 1980). Significant response of *D. rotundata* to 90 kg N ha^{-1} has been reported at IITA, Nigeria (Kpeglo *et al.*, 1980).

Recent trials indicated that tuber yield increased upto 100 kg N ha^{-1} in *D. alata*, at Orissa (Behura and Swain, 1997) and *D. cayenensis* at Brazil (Macedo and Santos, 1998). In contrast, tuber yield of *D. cayenensis* was unaffected by N levels in subsequent trials at Brazil (Santos and Macedo, 1998).

2.7.1.3 Effect of nitrogen on tuber quality

A few reports indicate that N had no effect on dry matter content of edible yam species viz., *D. esculenta* (Singh *et. al.*, 1973b), *D. alata* (Irizarry *et al.*, 1995) and *D. rotundata* (Umanah, 1977). In contrast, Singh *et al.* (1973a) noticed that dry matter, starch and sugar contents of tubers were appreciably high at 60 kg N ha^{-1} in *D. alata*. Further, additional doses of N had no significant impact on dry matter or starch content of tubers.

Singh *et al.* (1973b) reported maximum crude protein at 80 kg N ha^{-1}, maximum starch and total carbohydrate at 40 kg N ha^{-1} in *D. esculenta.* The protein content of tuber was found to be enhanced by nitrogen application in *D. esculenta* (CTCRI, 1976). On the other hand, Gbedelo (1986) stated that application of N fertilizers resulted in tubers of low organoleptic quality.

2.7.2 Response to phosphorus

Yams can efficiently utilize soil phosphorus and its response to phosphatic fertilization is generally poor (Coursey, 1967; Umanah, 1977; Koli, 1973; Lyonga, 1982). P application resulted in either no response (Irving, 1956) or even depressed tuber yield (Coursey, 1967; Umanah, 1977) in certain instances.

Zaag *et al.* (1980) studied the P requirement of yam in detail and explained that the external P requirement of yams ranged from 0.005 to 0.02 ppm P in solution. All the three species of yams viz., *D. esculenta, D. alata* and *D. rotundata* efficiently utilized P at low concentrations in the soil solution.

In general, the response of yams to P fertilization is reported to be very little, partly because P is not a limiting nutrient to yams in view of its low requirement (Kabeerathumma *et al.*, 1991) and partly due to the association of the mycorrhizal fungi which help yam roots to absorb P effectively from the soil (Potty, 1978; Zaag *et al.* 1980).

2.7.3 Response to potassium

It is a well known fact that potassium is involved in the synthesis of simple sugars and starch and in the translocation of carbohydrate, and as such the potash requirement of root and tuber crops is comparatively higher than other field crops.

Enyi (1972) reported that K application resulted in greater leaf area production and leaf area duration. K exerted profound influence in diverting greater proportion of dry matter into tubers than N and increased dry matter accumulation in tubers, tuber size, tuber number and tuber yield. The increase in tuber yield due to potassium was attributed partly to its effect in bringing about slightly earlier tuber initiation and partly to an increase in bulking rate.

According to Singh *et al.* (1973b), for *D. esculenta,* the economic dose of K_2O was 120 kg ha^{-1}. Maximum starch and total carbohydrate were obtained at 120 kg ha^{-1}. Percentage dry matter content of tuber was not much affected by potash fertilization. Crude protein and sugar contents did not show any regular trend.

Obigbesan(1973) stated that *D. rotundata* continued to respond to additional supply of K upto 78.4 kg ha^{-1}, *D. esculenta* responded highly to K application upto 165.76 kg ha^{-1}, while the yield of *D. alata* was unaffected by K fertilization. K application increased starch and dry matter contents in *D. rotundata,* whereas studies at CTCRI (CTCRI, 1976) could not find any effect of applied K fertilizers on the starch content of *D. alata.*

In contrast, Umanah (1977) noticed that in *D. rotundata*, effect of potash application on yield was inconsistent. Shyu and Chang (1978)observed gradual reduction in crude protein content in *D. alata* with increased K levels.

Investigations on the effect of potassium on tuber yield of three *Dioscorea* species undertaken at University of Ibadan, Nigeria (Obigbesan *et al.*, 1977) revealed that highest tuber yield in *D. cayenensis* and *D. rotundata* (variety Aro) was produced at 30 kg K_2O ha^{-1}, whereas *D. alata* and *D. rotundata* (variety Efuru) gave optimum performance at 60 kg K_2O ha^{-1}. It also appeared that yams will not respond to K fertilizers when the level of exchangeable K was greater than 0.15 meq per 100 g soil on newly cleared land. It was also suggested that K fertilization raised the percentage of marketable tubers. At Orissa, Behura and Swain (1997) indicated that *D. alata* responded upto 60 kg K_2O ha^{-1}.

2.7.4 Combined effect of NPK on growth, yield and quality

It has been demonstrated quite early that yams grown in soils with less than 0.1 per cent N, 10 ppm P and 0.15 meq per 100g exchangeable K responded well to fertilizer application (Young, 1976; Obigbesan *et al.*, 1977). Positive yield response of yams to fertilizer application, particularly in soils where N, P and K levels are low has been reported (Rouanet, 1967; Gooding and Hoad, 1967; Lyonga, 1976; Kpeglo *et al.*,1980.). The magnitude of response to fertilizers was found to vary with *Dioscorea* species (Kabeerathumma and Mohankumar, 1994).

Apparently higher response to applied N and K has also been confirmed (Lyonga, 1982; Kabeerathumma *et al.*, 1987).

2.7.4.1 Effect on growth characters

Comparing the effect of fertilizer levels, viz., 60 : 60: 90, 80: 80: 120, 100: 100: 150 kg NPK ha^{-1} on growth characters of *D. esculenta,* Nair (1985) reported no significant effect of fertilizer levels on vine length, leaf production and total dry matter production.

Experiments undertaken at Kerala Agricultural University by Pushpakumari (1989) to develop fertilizer management practices for *D. alata* and *D. esculenta* in coconut based cropping system revealed that the different fertilizer levels viz., 80:60:80 kg NPK ha^{-1} (full dose as per the package recommendation for sole crop) 60:45:60 kg NPK ha^{-1} (75 per cent of package recommendation) 40:30:40 kg NPK ha^{-1}(50 per cent of package recommendation) significantly increased vine length in *D. alata* but not in *D. esculenta*. But fertilizer levels had no significant impact on leaf production in both species.

Villanueva (1986) explained the inevitable role played by nitrogen and potassium at specific growth stages of yams. When the plant changes from the dependence on the sett to true autotrophy, nitrogen is needed to stimulate larger leaf area. Potassium is particularly needed during tuberization whereas, yams appear to be very efficient in extracting phosphorus from the soil and seldom need added quantities.

2.7.4.2 Effect on growth analysis

Detailed growth analysis studies conducted by Pushpakumari (1989) in *D. alata* and *D. esculenta* intercropped in coconut garden under three fertilizer levels revealed that maximum LAI was obtained in the highest fertilizer level (80:60:80 kg NPK ha^{-1}). On the contrary, lowest CGR and NAR values were recorded in the highest fertilizer level. Highest fertilizer level in *D. alata* and medium fertilizer level in *D. esculenta* resulted in maximum tuber dry weight and total dry matter production. Though fertilizer levels had no influence on tuber bulking rate of *D. esculenta*, highest bulking rate was obtained in the highest fertilizer level in *D. alata*.

At National Root Crops Research Institute, Umudike, Nigeria, Igwilo, (1989) also agreed that NPK application increased tuber yield in *D. alata* by increasing LAI. In contrast, Nair (1985) could not observe any significant effect of fertilizer levels on LAI of *D. esculenta*.

2.7.4.3 Effect on yield attributes and yield

According to Singh *et al.* (1973b) the economic dosage of N and K for *D. esculenta* was found to be 80 and 120 kg ha^{-1} respectively. Gaztambide and Cibes (1975) found that omission of N,P,K, Ca or Mg from yams growing in sand culture restricted growth, caused deformation of tubers and reduced yields. The most consistent and economic fertilizer combination for *D. cayenensis* (yellow yam) was $N_{67.20}$ and $K_{67.20}$ kg ha^{-1} (Azih, 1976). Kang and Wilson (1981) remarked that despite the absence of any significant fertilizer response in *D. rotundata* grown on flats, there was a noticeable effect of fertilizers on tuber yield when planted on large mounds. However, studies by Nwinyi (1983) with *D. rotundata* showed significantly higher yields in fertilized than in unfertilized plants.

Response of *D. alata* to different levels of NPK (40, 80, 120 kg ha^{-1}) was studied at CTCRI and a dosage of 120:80:80 kg ha^{-1} was considered to be optimum for obtaining high yield and good quality tubers (CTCRI, 1973). In a fertilizer trial conducted at Rajendra Agricultural University, yield of *D. esculenta* was found to increase upto 80:40:80 kg NPK ha^{-1}, whereas in Konkan region, application of 40:60:120 kg N, P_2O_5 and K_2O ha^{-1} recorded maximum yield (AICRP, 1983).

Lyonga (1984) observed that nitrogen based and potassium based fertilizers significantly increased yam yields and recommended that nitrogen and potassium in the ratio of 1:1.5 significantly improved yields of *Dioscorea* species.

Taking into consideration of production and economics, Nair (1985) found that fertilization at 80:80:120 kg NPK ha^{-1} was suitable for *D. esculenta* in lateritic soils of Thiruvananthapuram district, on the other hand fertilizer levels were not found to influence the length and girth of tubers in this experiment as observed by Pushpakumari (1989) in *D. esculenta* intercropped in coconut gardens.

According to Irizarry and Rivera (1985) intensively managed *D. rotundata* fertilized with 2240 kg of 10-5-20-3 N P_2O_5 K_2O MgO kg ha^{-1} in an ultisol yielded 51.6 t of marketable tubers equivalent to 18 t edible dry matter. However, in subsequent experiments by Irizarry *et al.* (1995) in *D. alata,* tuber dry matter yield was unaffected by fertilizer treatments.

Contrary to Irizarry's findings, Igwilo (1989) suggested that while application of NPK mixture, 10 : 10: 20 @ 300 kg ha^{-1} enhanced tuber yield of *D. alata*, it had no effect on tuber yield of *D. rotundata.*

Rodriguez *et al.* (1989) proposed that application of 100 kg N, 60 kg P_2O_5 and 200 kg K_2O ha^{-1} resulted in highest tuber yield of 28.64 t ha^{-1} as against 14.97 t ha^{-1} without fertilizers in *D. alata*. At China, Liu (1989) tried different combinations of N (0-120 kg ha^{-1}) and K_2O (0-180 kg ha^{-1}) at constant dose of 60 kg P_2O_5 in two cultivars of *D. alata* and concluded that tuber yield was highest with 90 kg N, 60 kg P_2O_5 and 60 kg K_2O in cv. Coconut Lisbon and 90 kg N, 60 kg P_2O_5 and 120 kg K_2O in local Taitung cultivar. In a field trial at Orissa, Behura and Swain (1997) noted that tuber yield increased upto 100 kg N and 60 kg K_2O in *D. alata.*

Positive and linear response of tuber yield to fertilizer levels in *D. alata* and *D. esculenta* grown as intercrops in coconut garden has also been documented (Pushpakumari and Sasidhar, 1992c). The highest fertilizer level (full dosage) (80:60:80 kg NPK ha^{-1}) recorded maximum yield in *D. alata* (26.55 t ha^{-1}), while medium fertilizer level (75 per cent dose ie., 60:45:60 kg NPK ha^{-1}) produced highest yield (13.18 t ha^{-1}) in *D. esculenta*. Hence they suggested the possibility of reducing fertilizer dose of *D. esculenta* by 25 per cent, but not of *D. alata* under intercropping situation. It is also worth mentioning that in *D. alata*, maximum length and girth of tubers was recorded in the highest fertilizer level (Pushpakumari, 1989).

2.7.4.4 Effect on tuber quality

Singh *et al.* (1973b) obtained maximum crude protein content at 80 kg N ha^{-1}, maximum starch and carbohydrate contents at 40 kg N and 120 kg K_2O ha^{-1} in *D.esculenta.*

At CTCRI, Nair and Mohankumar (CTCRI, 1976) indicated that chemical fertilizers increased protein content of *D. alata* tubers.

Crude protein content was significantly enhanced by the application of 100: 100: 150 kg NPK ha^{-1} in *D. esculenta* (Nair, 1985) and 100:60:200 kg NPK ha^{-1} in *D. alata* (Rodriguez *et al.*, 1989). Nair (1985) noticed maximum starch and sugar contents at 60:60:90 kg NPK ha^{-1} in *D. esculenta*. But crude fibre was unaffected by fertilizer levels.

2.7.5 Nutrient uptake by yams

Different workers have proposed different estimates of NPK uptake by yams. However, all of them agree that uptake varies depending on soil conditions, species and stage of harvest.

Obigbesan and Agboola (1978) stated that for each metric tonne of dry matter produced, yam tubers removed almost the same quantity of nutrients from the soil as that of potato crop, but about four times as much N and twice as much P and K as compared to cassava crop. As per their calculations, two cultivars of *D. rotundata* with an yield of 37.9 t ha^{-1} and dry matter production of 12.17 t ha^{-1} exhausted 148, 18 and 166 kg ha^{-1} of N, P and K respectively.

Sobulo (1972) found that *D. rotundata* grown in an unfertilized soil, yielding 26.96 t ha^{-1} of marketable tubers with a dry matter production of 10.2 t ha^{-1}, removed 205, 13 and 112 kg N, P and K ha^{-1} respectively.

According to Obigbesan *et al.* (1977) nitrogen and potassium constituted the major nutrients removed in large amounts and deposited in the tubers. At the tuber yield level of 13.72 t ha^{-1} on dry weight basis, *D. rotundata* (Variety Efuru) was estimated to remove as much as 175.6 kg N, 20.6 kg P and 198.0 kg K ha^{-1}. The average nutrient removal via the tuber ranged between 128 and 155 kg N, 16.9 and 19.4 kg P and 155 and 184 kg K ha^{-1}.

Intensively managed *D. rotundata* in an ultisol, exported 190 kg N, 25 kg P and 215 kg K ha^{-1} during the eight month crop cycle (Irizarry and Rivera, 1985).

From the practical view point it is more meaningful, simple and useful to express the uptake figures in terms of the quantity of N, P and K utilized to produce one tonne of edible dry matter per hectare. Accordingly a couple of reports indicated the utilization of 15.0 kg N, 1.0 kg P and 8.7 kg K (Sobulo, 1972) or 10.5 kg N, 1.4 kg P and 11.0 kg K (Irizarry and Rivera, 1985) for every tonne of edible dry matter production in *D. rotundata.*

Comparing the relative efficiency of yams with that of taniers, and cassava in terms of the use of NPK, N and K to produce edible dry matter (DM), Irizarry and Rivera (1985) strongly stated that yams were the most efficient and cassava the least in the use of nutrients to produce edible dry matter. Accordingly the ratios, NPK : DM, N : DM and K:DM for yams was worked out as 1:41.9, 1:94.7 and 1:83.7 respectively.

Subsequent studies conducted by Irizarry *et al.* (1995) in *D. alata* (cv.Gunung) grown in an ultisol without vine support indicated that *D. alata* took up 24.7 kg N, 2.2 kg P and 25.7 kg K ha^{-1} for the production of one tonne of edible dry matter. The N and K removal in this experiment was twice of *D. rotundata* (cv. Habanero) plant removal in their earlier experiment (Irizarry and Rivera, 1985).

Detailed studies on uptake conducted at CTCRI by Kabeerathumma *et al.* (1987) indicated that NPK export of *D. rotundata* to yield 28.99 t ha^{-1} of tuber, equivalent to 11.67 t ha^{-1} of dry matter was 116.52, 17.3 and 122.68 kg ha^{-1}. The uptake figures clearly revealed the preference of the crop for both N and K. P requirement was very low, only 15 per cent of N.

The nutrient depletion - recycling by different species of *Dioscorea* worked out from the above study showed that *D. rotundata* was the most soil depleting crop. Yams appeared to have a definite ratio of uptake and the NPK uptake ratio for *D. rotundata* was 1:0.15:1.05 (Kabeerathumma *et al.,* 1987; Kabeerathumma *et al.,* 1991 and Kabeerathumma and Mohankumar, 1994). Similar uptake ratio has been reported earlier (Obigbesan and Agboola, 1978).

2.7.6 Effect of NPK fertilization on nutrient contents and uptake

Investigating the effect of six rates of nitrogen fertilization viz., 0,40, 80, 120, 160 and 200 kg N ha^{-1} on the nutrient composition of *D. rotundata* leaves sampled from different portions on the stake, Aduayi (1979) found that leaf N and P decreased and K increased in the upper portions of the stake at higher rates of 80 kg N ha^{-1}, but were unaffected in the lower and middle portions. The correlation between tuber yield and leaf N and K concentrations was not significant but leaf P showed a significant relationship with tuber yield.

According to Aduayi and Okpon (1980) increasing rates of nitrogen viz., 0, 40, 80, 120, 160 and 200 kg ha^{-1} consistently increased leaf nitrate nitrogen and K, particularly at the vegetative growth stage, while no consistent trend was established for leaf-P in *D. rotundata.* During tuber formation, tuber development and tuber maturation stages, nitrate-N accumulated in the leaf, but K contents in the leaf showed a decreasing trend with increasing N levels.

Kang and Wilson (1981) determined the effect of NPK fertilizers on the nutrient status of the first fully matured leaves in *D. rotundata* and noted an increase in the N level of the index leaves consequent to NPK treatment. However, no distinct effect of fertilizers was seen on the P and K percentages of the index leaves. Nutrient uptake and dry matter production by intensively managed *D. rotundata* in an ultisol was studied by Irizarry and Rivera (1985) and observed maximum uptake of N,P and K at the highest level of fertilization.

The effect of varying fertilizer levels on the NPK uptake of *D. esculenta* was studied by Nair (1985) and found that highest fertilizer level (100:100:150 kg NPK ha^{-1}) increased N uptake during all stages, while P and K uptake remained unaffected. Under intercropping situation in coconut garden, NPK uptake of *D. alata* and *D. esculenta* increased with increasing fertilizer levels ,*D. alata* registered maximum NPK uptake at the highest fertilizer level (80:60:80 kg NPK ha^{-1}), while for *D. esculenta* though N uptake was maximum at the highest fertilizer level, P and K uptake was maximum at the medium fertilizer level (60:45:60) (Pushpakumari, 1989).

2.7.7 Effect of NPK fertilization on soil nutrient status

Nair (1985) reported that post experiment NPK status of the soil was unaffected by the various fertilizer levels tried in *D. esculenta*. In the fertilizer management experiment involving *D. alata* and *D. esculenta* in coconut garden, Pushpakumari (1989) experienced increase in available N and P status of soil with increase in fertilizer levels, while available K status was unaffected.

Results to date indicate that yams respond well to applied N and K, but slightly to phosphorus. It is also obvious that uptake of N and K is also considerably high. Hence the need for N and K supplementation is greatly emphasized in the present investigation.

2.8 Effect of conjoint use of NPK and organic manure

The additive effect of FYM and NPK on tuber production of cassava was reported quite early (Mohankumar *et al.*, 1976). The response to combined application of FYM and NPK on cassava as revealed from long term trials conducted for 13 years indicated that for continuous cultivation of cassava, balanced application of fertilizers with 100 kg each of N and K_2O and 50 kg P_2O_5 ha^{-1} along with 12.5 t ha^{-1} of FYM could be the best to sustain productivity in an acid ultisol (Susan John *et al.*, 1998). Based on confirmatory results in cassava, Mohankumar *et al.* (2000) opined that neither FYM nor any of the nutrients (N, P or K) applied individually could increase yield by more than 4 t ha^{-1} but combined use of NPK and FYM produced a response four times higher.

Application of 5 t ha^{-1} of FYM along with 50:25:50 kg ha^{-1} of N, P_2O_5 and K_2O resulted in better yield in sweet potato (Ravindran and Bala Nambisan, 1987).

Kabeerathumma and George (CTCRI, 1992) reported that application of 25 t ha^{-1} of FYM and 100:50:150 kg NPK ha^{-1} resulted in maximum corm yield, highest dry matter production and highest nutrient uptake in *Amorphophallus*.

For optimum production of *D. alata* and *D. esculenta*, Kerala Agricultural University (KAU, 1996) recommends 80:60:80 kg NPK ha^{-1} along with 10 t ha^{-1} of FYM. Preliminary investigation at CTCRI (CTCRI, 2000b) indicated that for realizing maximum tuber yield in *D. rotundata* (Variety Sree Priya) both organic manure and inorganic fertilizers were highly inevitable. FYM @ 15 t ha^{-1} along with 125:50:125 kg NPK ha^{-1} produced highest yield, which was on par with the yield obtained with FYM @ 10 t ha^{-1} and NPK 75:25:75 kg ha^{-1}. Application of organic manure alone without chemical fertilizers depressed tuber yield significantly.

Maheswarappa *et al.* (1997) reported that in arrow root intercropped in coconut garden, 20 t ha^{-1} FYM and 75:50:50 kg NPK ha^{-1} resulted in significantly higher rhizome yield, rhizome number and rhizome length, starch and crude protein contents. As per the calculations of Maheswarappa *et al.* (1999) the reduction in yield with FYM applied alone, NPK alone, and control was 16.4-17.9, 26.9 and 63.7 per cent respectively compared to conjoint use of NPK and FYM. Veena (2000) also agreed that combined application of 10 t FYM, 120 kg N, 50 kg P_2O_5 and 80 kg K_2O ha^{-1} was the most advantageous for arrow root intercropped in coconut garden in laterite soils of Vellayani.

The foregoing review clearly establishes the superior yield response to combined application of organic manure and fertilizers in tropical tuber crops. However, an effective integrated nutrient management schedule for white yam, especially under Indian condition has not yet been developed. The shortfalls in the available literature strongly substantiates the scope of the present investigation.

A scan of literature indicates that, despite its superior attributes, *D. rotundata* has not yet found an appropriate place in the coconut based cropping systems of Kerala for want of suitable production techniques. Hence the present investigation is undertaken to develop agrotechniques for white yam under intercropping situation.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation programmed as three experiments to assess the agronomic performance of white yam as an intercrop and to develop suitable production techniques for intercropping white yam in coconut garden was undertaken for two consecutive cropping seasons of 1998-99 and 1999-2000. The details of experimental site, season and weather conditions, materials used and methods adopted are presented in this chapter.

3.1 Experimental site

3.1.1 Location

The experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, situated at 8°5' N latitude and 76°9' E longitude, at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental site was red loam and belonged to the order Alfisol suborder Udalf and great soil group Tropudalf. Texturally the soil is classed as clay loam. Initial soil tests indicated acidic soil reaction with low contents of available nitrogen and available potassium, medium test values for organic carbon and high content of available phosphorus. The physico-chemical characteristics of the experimental site are presented in Table 1.

3.1.3 Nature and cropping history of the coconut garden

The coconut palms in the garden selected for the experiments were spaced at 7.5 m and were 25-30 years of age. Prior to the commencement of the investigation, bulk crops of banana and guinea grass were grown in the interspaces of coconut trees.

Table 1. Soil characteristics of the experimental site

Parameters	Unit	Content in soil			Method used
		Exp. I	Exp. II	Exp. III	
A. Mechanical composition					
Coarse sand	%	9.87	9.97	9.20	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand	%	23.03	25.88	24.20	
Silt	%	32.35	30.35	31.15	
Clay	%	34.25	33.25	35.10	
Texture		Clay loam	Clay loam	Clay loam	
B. Chemical properties					
Soil reaction (pH)		5.49	5.60	5.62	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity	dS m^{-1}	0.02	0.022	0.02	Conductivity bridge
Organic carbon	%	0.520	0.532	0.529	Walkley and Black's rapid titration method (Jackson, 1973)
Available N	kg ha^{-1}	261.07	264.04	266.87	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5	kg ha^{-1}	63.41	58.39	61.58	Bray I method (Jackson, 1973)
Available K_2O	kg ha^{-1}	135.70	137.76	137.84	Ammonium acetate method (Jackson,1973)
Total N	%	0.075	0.076	0.078	Modified microkjeldahl method (Jackson, 1973)
Total P_2O_5	%	0.057	0.056	0.056	Vanadomolybdo phosphoric yellow colour method (Jackson, 1973)
Total K_2O	%	0.028	0.030	0.026	Flame photometric method (Jackson,1973)
C. Physical properties					
Bulk density	g cc^{-1}	1.69	1.72	1.68	Core method (Gupta and Dakshinamoorthi, 1980)
Water holding capacity	%	21.65	20.68	22.86	-do-
Particle density	g cc^{-1}	2.47	2.56	2.53	-do-
Porosity	%	32.48	32.17	33.46	-do-
Aggregate stability	%	36.53	38.88	37.65	-do-

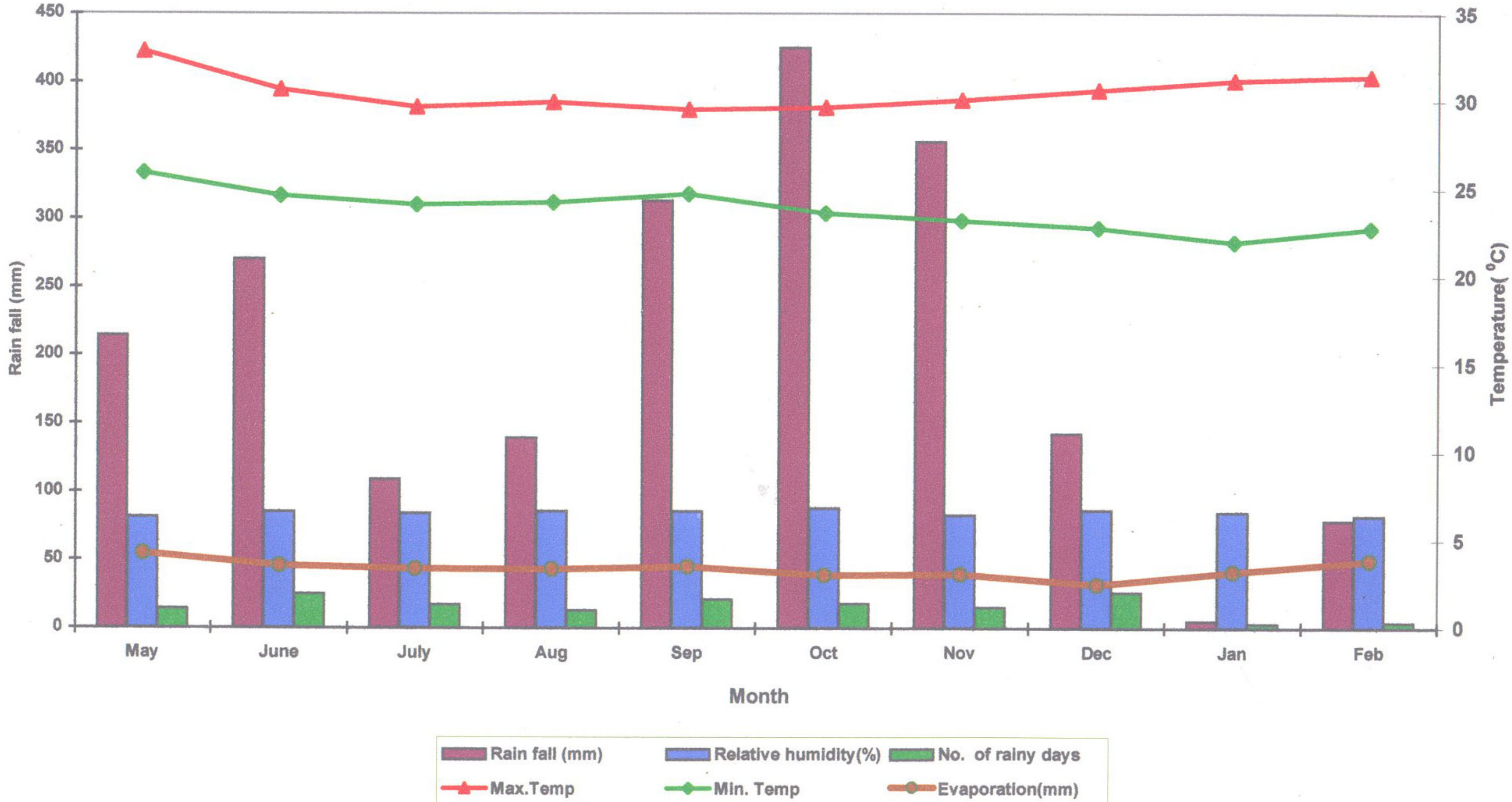


Fig.1a Weather parameters during the crop growth period (1998-99)

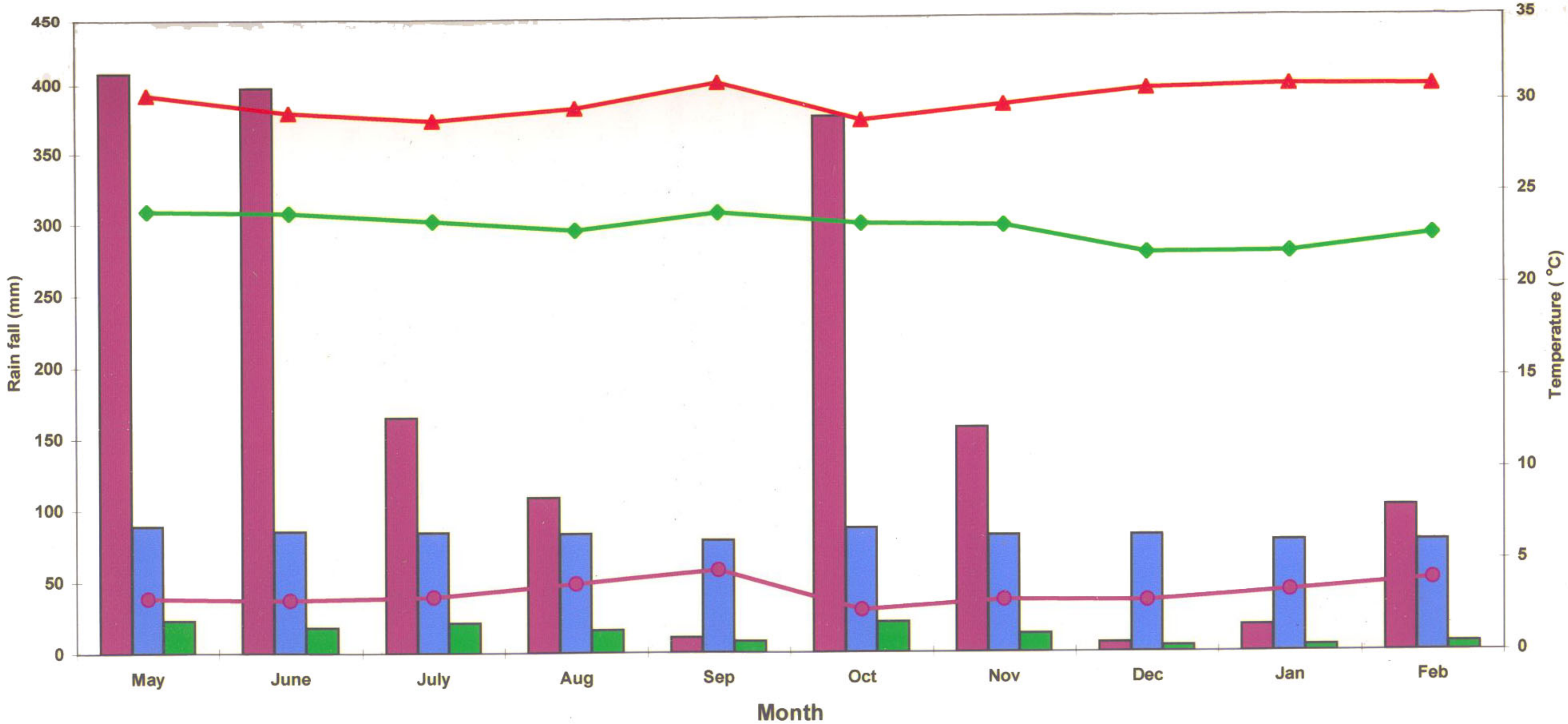


Fig. 1b Weather parameters during the crop growth period (1999-00)

3.2 Season

The field experiments were conducted from May to February in 1998 -99 and 1999-2000. During both the seasons, the microplot experiment was initiated in May and monitored for two months there after.

3.3 Weather

Typical humid tropical climate is experienced by the area. The mean annual rainfall was 1899 mm. The mean annual maximum and minimum temperatures were 30.3^{0}C and 23.4^{0}C respectively. The mean annual relative humidity was 83.5 per cent. Data on weather conditions such as temperature, rainfall and relative humidity obtained from the meteorological observatory, College of Agriculture, Vellayani are given in Appendix I and graphically depicted in Figs.1a and 1b.

3.4 Materials

3.4.1 Planting material and variety

Seed tubers of white yam (*Dioscorea rotundata)* variety Sree Priya were obtained from Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram.

Sree Priya (U - 195 (2)) is a seedling selection developed at Central Tuber Crops Research Institute, Thiruvananthapuram from the white yam variety, "Umudike" received from the International Institute of Tropical Agriculture , Nigeria. Sole crop of Sree Priya yields 35 - 40 t ha^{-1} of highly acceptable quality tubers in 9-10 months. Tuber contains 20-24 per cent starch and has excellent cooking quality. Tubers are cylindrical and smooth with brown skin and white flesh. Vines are spiny, twining to right with dark green glossy leaves. It is capable of withstanding drought to some extent and is free from pest and disease infestation (CTCRI, 1998 a).

3.4.2 Manures and fertilizers

For experiment II, farmyard manure was the only manure applied. For experiment III, alternative organic sources such as coirpith compost and green manuring *in situ* with sunhemp were also tried along with farmyard manure.

Coir pith compost used for the study was obtained from M/s Little way Agri Horti Society, Reg. No.181, Kalavur.P.O, Alappuzha-688 522. For green manuring *in situ* sunhemp (*Crotalaria juncea* L.)seeds were supplied by National Seeds Corporation, Regional Office, Karamana, Thiruvananthapuram-695 002. During both the years sunhemp seeds had a germination percentage of 80 - 85.

The nutrient content of manures used for the experiments were analysed and are given in Table 2. Doses of farmyard manure and coir pith compost were fixed on equivalent nitrogen basis and applied in pits prior to planting.Quantity of major nutrients added through manures and fertilizers are given in Appendix II.

Urea (46% N), Mussoriephos (20% P_2O_5) and muriate of potash (60% K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively.

Table 2. Estimated nutrient content of manures (%)

Organic manures	N	P	K
Farmyard manure	0.5	0.20	0.40
Coir pith compost	1.36	0.06	1.10
Green manure (Sunhemp)	2.63	0.25	2.02

3.4.3 Growth promoting substances

Growth promoting chemicals such as thiourea, potassium nitrate and indole- 3- acetic acid (IAA) and locally available materials preferred by farmers for seed treatment like wood ash and cowdung slurry were used in the microplot experiment for treating tuber pieces (setts) before planting.

3.5 Methods

The research programme consisted of three experiments conducted separately and simultaneously.

3.5.1 Design and layout of experiments

3.5.1.1 Experiment I : Microplot experiment to find out the effect of growth promoting substances on sprouting

Five growth promoting substances and a control were evaluated for their effects on sprouting of yam setts in completely randomised design (CRD). The layout plan of the experiment is given in Fig. 2. The details of the layout are given below.

Design	:	Completely randomised design
Treatments	:	6
Replications	:	3
Sample size	:	10 plants / treatment
Microplot size	:	60 x 60 cm
Sett size used	:	100g

3.5.1.1.1 Treatments

g_1	-	Thiourea 2%
g_2	-	Potassium nitrate 2%
g_3	-	IAA 1000 ppm
g_4	-	Smearing with wood ash
g_5	-	Dipping in cowdung slurry
g_6	-	Untreated control

Fig.2 Layout plan of Experiment I

N

1 g_3	12 g_4	13 g_1
2 g_1	11 g_2	14 g_4
3 g_6	10 g_5	15 g_1
4 g_3	9 g_6	16 g_3
5 g_5	8 g_5	17 g_2
6 g_2	7 g_4	18 g_6

Fig.3 Layout plan of Experiment II

N

R_1

S_1W_3	S_2W_1	S_1W_1
S_3W_3	S_3W_2	S_3W_1
S_2W_2	S_1W_2	S_2W_3

R_2

S_2W_1	S_3W_1	S_3W_2
S_1W_1	S_2W_3	S_1W_3
S_3W_3	S_1W_2	S_2W_2

R_3

S_1W_1	S_2W_1	S_3W_2
S_2W_2	S_1W_2	S_2W_3
S_1W_3	S_3W_3	S_3W_1

3.5.1.2 Experiment II : Optimization of plant population and sett size for intercropping white yam in coconut garden

The experiment was designed as a 3x3 factorial experiment in randomised block design (RBD) with nine treatments, replicated thrice, involving various combinations of three spacings and three sett sizes. The layout plan is given in Fig 3. The details of layout are given below.

Design	:	3x3 factorial experiment in RBD
Treatments	:	3x3 = 9
Replications	:	3
Plot size		
Gross	:	25.92 m^2
Net	:	9.72 m^2
Total number of plots	:	27

3.5.1.2.1 Treatments

(i) **Spacings**

s_1	-	60x60cm	(20,000 plants ha^{-1})
s_2	-	75x75 cm	(13,000 plants ha^{-1})
s_3	-	90x90 cm	(9000 plants ha^{-1})

(ii) **Sett sizes**

w_1	-	100 g
w_2	-	200 g
w_3	-	300 g

3.5.1.2.2 Treatment combinations

s_1w_1	s_2w_1	s_3w_1
s_1w_2	s_2w_2	s_3w_2
s_1w_3	s_2w_3	s_3w_3

3.5.1.3 Experiment III : Nutrient management for intercropping white yam in coconut garden

The experiment was laid out in split plot design with three main plot treatments, ten subplot treatments and two replications. The layout plan is shown in Fig. 4 and detailed below.

Design	:	Split plot
Treatment combinations	:	30
Replications	:	2
Plot size		
Gross	:	25.92 m^2
Net	:	9.72 m^2
Total number of plots	:	60

3.5.1.3.1 Treatments

Main plot

Organic sources

o_1	-	Farmyard manure (FYM) 10 t ha^{-1}
o_2	-	Coir pith compost 5 t ha^{-1}
o_3	-	*In situ* incorporation of green manure (sunhemp) twice during south-west and north-east monsoons

Sub plot

NK combinations and a control = (3 x 3) + 1 = 10

1.	n_1k_1	4.	n_2k_1	7.	n_3k_1
2.	n_1k_2	5.	n_2k_2	8.	n_3k_2
3.	n_1k_3	6.	n_2k_3	9.	n_3k_3
10.	n_0k_0				

Fig.4 Layout plan of Experiment III

N ↑

R1			R2		
$o_1n_2k_1$	$o_3n_1k_3$	$o_2n_2k_1$	$o_3n_3k_3$	$o_1n_3k_1$	$o_2n_0k_0$
$o_1n_3k_1$	$o_3n_3k_3$	$o_2n_0k_0$	$o_3n_2k_2$	$o_1n_1k_3$	$o_2n_2k_2$
$o_1n_1k_1$	$o_3n_2k_2$	$o_2n_1k_1$	$o_3n_1k_2$	$o_1n_1k_2$	$o_2n_1k_2$
$o_1n_3k_3$	$o_3n_1k_2$	$o_2n_2k_3$	$o_3n_3k_2$	$o_1n_2k_1$	$o_2n_2k_1$
$o_1n_1k_2$	$o_3n_3k_2$	$o_2n_1k_2$	$o_3n_2k_1$	$o_1n_2k_2$	$o_2n_1k_3$
$o_1n_2k_3$	$o_3n_2k_1$	$o_2n_3k_2$	$o_3n_3k_1$	$o_1n_3k_3$	$o_2n_3k_2$
$o_1n_3k_2$	$o_3n_0k_0$	$o_2n_3k_1$	$o_3n_0k_0$	$o_1n_3k_2$	$o_2n_3k_1$
$o_1n_0k_0$	$o_3n_1k_1$	$o_2n_1k_3$	$o_3n_1k_1$	$o_1n_2k_3$	$o_2n_2k_3$
$o_1n_1k_3$	$o_3n_3k_1$	$o_2n_2k_2$	$o_3n_2k_3$	$o_1n_0k_0$	$o_2n_3k_3$
$o_1n_2k_2$	$o_3n_2k_3$	$o_2n_3k_3$	$o_3n_1k_3$	$o_1n_1k_1$	$o_2n_1k_1$

(i) Levels of nitrogen

n_1 - 40 kg ha^{-1}

n_2 - 80 kg ha^{-1}

n_3 - 120 kg ha^{-1}

(ii) Levels of potassium

k_1 - 40 kg ha^{-1}

k_2 - 80 kg ha^{-1}

k_3 - 120 kg ha^{-1}

(iii) n_0k_0 - absolute control (without N and K)

3.5.1.3.2 Treatment combinations - 3 [(3x3)+1] = 30

$o_1n_1k_1$	$o_2n_1k_1$	$o_3n_1k_1$
$o_1n_1k_2$	$o_2n_1k_2$	$o_3n_1k_2$
$o_1n_1k_3$	$o_2n_2k_3$	$o_3n_1k_3$
$o_1n_2k_1$	$o_2n_2k_1$	$o_3n_2k_1$
$o_1n_2k_2$	$o_2n_2k_2$	$o_3n_2k_2$
$o_1n_2k_3$	$o_2n_2k_3$	$o_3n_3k_3$
$o_1n_3k_1$	$o_2n_3k_1$	$o_3n_3k_1$
$o_1n_3k_2$	$o_2n_3k_2$	$o_3n_3k_2$
$o_1n_3k_3$	$o_2n_3k_3$	$o_3n_3k_3$
$o_1n_0k_0$	$o_2n_0k_0$	$o_3n_0k_0$

3.5.2 Preparation of growth promoting chemicals

The required concentration of thiourea or potassium nitrate was prepared in water. For preparing 1000 ppm IAA, one gram of IAA was disolved in 5 ml ethyl alcohol, mixed with distilled water, heated to expel the alcohol and the resulting solution was made upto one litre.

Plate 1. General view of experiment II

Plate 2. General view of experiment III

3.5.3 Preparation and treatment of setts

Before planting experiment I, clean and healthy yam tubers weighing about 1000 g were selected and soaked in aqueous solution of the growth promoting chemicals viz., thiourea 2%, potassium nitrate 2% and IAA 1000 ppm for 24 hours. After soaking, the tubers were shade- dried, cut into pieces (setts) of 100 g. Setts weighing 100 g were also smeared with wood ash or dipped in cowdung slurry. An untreated control was also included for comparative assessment.

3.5.4 Microplot / plot preparation, manuring and planting

In experiment I, microplots were prepared by taking small beds of size 60 x 60 cm, 30 cm apart. Treated yam setts were planted in microplots as per the layout plan. Manures or fertilizers were not applied.

For the field experiments, plots were formed in the interspaces of coconut trees leaving an area of two metres radius from the base of the palms. Pit (45 x 45 x 45 cm) reformed into mound was the planting method followed for both the experiments.

In experiment II, pits were dug at different spacings as per the technical programme, filled with farmyard manure @ one kg per pit and mixed with top soil. Setts of different weights were planted at the centre of the pits in accordance with the treatment combinations in the layout.

In experiment III, prior to planting, farmyard manure or coir pith compost was applied in pits in different quantities according to the doses fixed as per the treatments. Setts of 250 g were planted in pits at a spacing of 90 x 90 cm.

3.5.5 Sowing and incorporation of green manure (sunhemp)

In plots designated for green manuring *in situ*, sunhemp seeds were sown @ 35 kg ha^{-1} in the interspaces of pits reformed to mounds on the succeeding day of planting yams. *In situ* incorporation of the green manure crop was undertaken at 60 days after sowing (when about 50 per cent flowering occurred) by opening small basins around the mounds, covering the soil and earthing up. Sunhemp seeds were again sown following the same field techniques and incorporated 45 days thereafter. The green matter obtained from each plot was also quantified before incorporation.

3.5.6 Fertilizer incorporation

For experiment II, fertilizers to provide 80 kg N, 60 kg P_2O_5 and 80 kg K_2O per hectare were applied (KAU, 1996). For experiment III, fertilizers at the calculated amounts to supply the different levels of nitrogen and potassium as per the treatments were applied. Mussoriephos to supply a constant dosage of 60 kg ha^{-1} P_2O_5 was applied. In both the cases, the whole of P_2O_5, half the dose of N and K were given within a week after sprouting of yams. After one month, the remaining doses of nitrogen and potassium were applied along with weeding and earthing up.

Plots assigned for green manuring received full P_2O_5 (60 kg ha^{-1}) at presowing of sunhemp. Half the doses of nitrogen and potassium were applied at the time of first incorporation of green matter, but before the second sowing. The remaining doses of N and K were applied one month later.

3.5.7 Trailing

Trailing was done within 15 days after sprouting of yams using coir ropes tied to G.I wires connecting coconut trees. Observation plants were trailed individually.

3.5.8 Irrigation

The crop was mainly grown as rainfed. However during the first year, two life saving irrigations and in the second year three irrigations were given to avoid prolonged dry spells.

Plate 3. White yam trailed in coconut garden

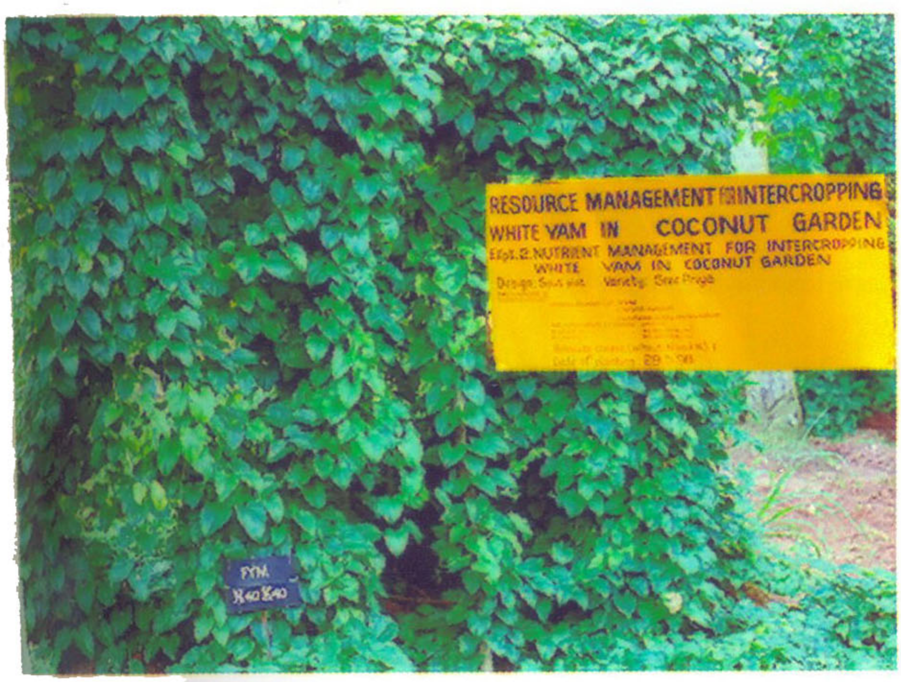


Plate 4. Close view of experiment III

3.5.9 Other cultural operations

Field culture other than the treatment requirement of the experiments were followed as per the package of practices recommendations of the Kerala Agricultural University (KAU,1996).

3.5.10 General condition of the crop

Sprouting and establishment were satisfactory during both the years. Pest and disease incidence were also not apparent.

3.6 Observations

Microplot experiment was observed upto two months after planting. In experiment II, observations were mostly recorded at harvest stage. In experiment III, four plants from each plot were trailed individually for destructive sampling at bimonthly intervals of two, four , six and eight months after planting . At each sampling one plant from each treatment was uprooted to determine vine length, leaf area, number of functional leaves, dry matter production and distribution and tuber bulking rate as well as for growth analysis studies.

3.6.1 Growth characters

3.6.1.1 Days to sprouting

Number of days taken for sprouting of 50 per cent of the total number of setts planted in each plot was noted in experiment I.

3.6.1.2 Sprouting per cent

For experiments I and II sprouting per cent at biweekly intervals upto two months after planting (MAP) was calculated using the formula

$$\text{Sprouting per cent} = \frac{\text{Number of setts sprouted} \times 100}{\text{Total number of setts planted in each plot}}$$

3.6.1.3 Vine length

Vine length was measured from the base of the sprout to the growing tip of the main vine at 15 days interval upto two months after planting in experiment I and II. In experiment III, vine length was measured at bimonthly intervals and expressed as cm.

3.6.1.4 Vigour index

For experiment I, seedling vigour index (VI) was calculated by using the formula suggested by Abdul-Baki and Anderson (1970) and expressed as a number.

$$V\,I = \text{Germination per cent} \times (\text{root length} + \text{shoot length})$$

3.6.1.5 Number of functional leaves

The number of fully opened leaves was counted from the base to the tip of the vine at bimonthly intervals in experiment III.

3.6.2 Physiological parameters

3.6.2.1 Dry matter accumulation and partitioning

At bimonthly intervals, one plant from each plot of experiment III was uprooted and separated into leaves, vines, roots and tubers. After recording the fresh weight of each part, sub samples were taken for estimating the dry weight. The sub samples were first air dried and then oven dried at 70^0C to constant weight. Dry weight of each plant part was computed and recorded.

3.6.2.2 Leaf area index (LAI)

The leaf area of plants in experiment III was calculated following the linear measurement method described by Ravi and Chowdhury (1989). Leaf area index (LAI) at bimonthly intervals was computed by the following formula developed by Watson (1947).

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.6.2.3 Net assimilation rate (NAR)

The procedure suggested by Watson (1958) as modified by Buttery (1970) was followed for calculating NAR and expressed as g m^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)\frac{(A_1 + A_2)}{2}}$$

Where

W_2 = total dry weight of plant at time t_2

W_1 = total dry weight of plant at time t_1

t_2-t_1 = time interval in days

A_2 = leaf area (m^2) at time t_2

A_1 = leaf area (m^2) at time t_1

3.6.2.4 Crop growth rate (CGR)

Crop growth rate (CGR) was calculated using the formula given by Watson (1958) and expressed as g m^{-2} day^{-1}.

$$CGR = NAR \times LAI$$

3.6.2.5 Relative growth rate (RGR)

The formula suggested by Blackman (1919) was used to arrive at RGR, expressed as mg g^{-1} day^{-1}.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

where

W_1 = dry weight of plant at time t_1

W_2 = dry weight of plant at time t_2

3.6.2.6 Tuber bulking rate (TBR)

It is the rate of increase in tuber weight per unit time expressed as g day^{-1} plant^{-1} (dry weight).

$$TBR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where

W_2 = dry weight of tuber at time t_2

W_1 = dry weight of tuber at time t_1

3.6.2.7 Harvest index (HI)

Harvest index was worked out as the ratio of dry weight of tuber to the dry weight of whole plant

$$HI = \frac{\text{tuber dry matter}}{\text{total dry matter}}$$

3.6.2.8 Light infiltration

Light measurements from different plots of experiment III were made using Line Quantum Sensor at bimonthly intervals. The instrument measured the photosynthetically active radiation available at the crop canopies in micro Einsteins per square metre per second (μ E m^{-2} s^{-1})

3.6.2.9 Chlorophyll content

Chlorophyll 'a', 'b' and total chlorophyll contents of plants in each plot of experiment III were estimated at two, four, six and eight months after planting by spectrophotometric method as described by Starnes and Hadley (1965) and expressed as mg g^{-1} tissue.

3.6.2.10 Proline content

Proline content of fully opened leaves at active vegetative growth stage of the crop was estimated by the technique suggested by Bates *et al.* (1973) and expressed in μ g g^{-1} fresh weight.

3.6.3 Yield components and yield

3.6.3.1 Length of tuber

The length of five randomly selected medium sized tubers was measured and the mean values was recorded in cm.

3.6.3.2 Girth of tuber

Girth measurements were made from those tubers from which length was measured. Girth was recorded at three places of the tuber, one at the centre and the other two at half way between the centre and both ends of the tuber. The average of these three was taken as tuber girth and expressed as cm.

3.6.3.3 Tuber weight

Mean tuber weight was computed by dividing the fresh tuber weight in the net plot by the total number of tubers and expressed in kg.

3.6.3.4 Fresh tuber yield

Tubers from the net plot were harvested and fresh weights were recorded and expressed in t ha^{-1}.

3.6.4 Quality attributes

3.6.4.1 Starch content

Starch content of tubers was estimated by potassium ferricyanide method (Aminoff *et al.*, 1970) and expressed as percentage on fresh weight basis.

3.6.4.2 Crude protein content

Total nitrogen content of the tuber was estimated by modified microkjeldahl method (Jackson, 1973). Crude protein content was calculated by multiplying the nitrogen content by the factor 6.25 (Simpson *et. al.*, 1965) and expressed as percentage on fresh weight basis.

3.6.4.3 Crude fibre content

The method suggested by AOAC (A.O.A.C, 1975) was used to determine crude fibre content of the tuber, expressed as percentage on fresh weight basis.

3.6.4.4 Vitamin C content

Vitamin C content of tuber was estimated by titrimetric method (Gyorgy and Pearson, 1967) and expressed in mg 100 mg^{-1}.

3.6.4.5 Organoleptic test

Sensory method suggested by Prema *et al.* (1975) was followed for conducting organoleptic test. Accordingly the cooking quality of the tuber was assessed based on taste, texture, appearance, colour, doneness and flavour by a taste panel on a discrete scale with five points.

3.6.5 Plant analysis

Before termination of experiment III in both years, sample plants were uprooted, separated into leaves, vines, roots and tubers, air dried and then oven dried at 70^0C, dry weights were recorded, powdered and sieved. Nitrogen, phosphorus and potassium contents of the different plant components were analysed separately using standard procedures.

3.6.5.1 Uptake of major nutrients

Modified microkjeldahl method, vanadomolybdo phosphoric yellow colour method and flame photometry (Jackson, 1973) were employed to determine total nitrogen, total phosphorus and total potassium contents respectively in the various plant parts. The contents were calculated and expressed in percentage. The uptake of nitrogen, phosphorus and potassium by the plant was calculated by adding the products of contents of these nutrients in the various plant parts and respective dry weights of plant parts and expressed as kg ha^{-1}.

3.6.5.2 Nutrient use efficiency

Nutrient use efficiency was worked out for nitrogen and potassium based on the equations suggested by Novoa and Loomis (1981).

$$\text{Agronomic efficiency} = \frac{\text{Tuber yield (t ha}^{-1}\text{) in NK fertilized plots - Tuber yield (t ha}^{-1}\text{) in } n_0k_0 \text{ plot}}{\text{Quantity of fertilizer (N) or (K) applied (kg ha}^{-1}\text{)}}$$

$$\text{Physiological efficiency} = \frac{\text{kg tuber}}{\text{kg nutrient absorbed}}$$

3.6.6 Soil moisture content

Soil moisture was monitored gravimetrically in the 0-15 cm surface soil layer at bimonthly intervals in experiment III and contents were expressed as percentage.

3.6.7 Soil analysis

Before the initiation of the experiments, composite soil samples were collected separately from the sites of experiment I and II and analysed for various physico-chemical properties (Table 1). Plotwise analysis of soil samples from experiment III for physical and chemical properties was done before the establishment of the experiment in 1998 and after the termination of the experiment in each season. The following physical and chemical parameters were investigated.

3.6.7.1 Soil physical properties

Physical characters of soil such as bulk density, particle density, water holding capacity and porosity were determined by the core method (Gupta and Dakshinamoorthy, 1980). Aggregate stability was calculated based on wet sieving technique developed by Yoder (1936).

3.6.7.2 Soil chemical properties

3.6.7.2.1 Organic carbon (%)

Organic carbon content (%) of soil was estimated by Walkley and Black's rapid titration method (Jackson, 1973).

3.6.7.2.2 Total nitrogen (%)

Modified microkjeldahl method (Jackson, 1973) was employed for the estimation of total nitrogen content of the soil.

3.6.7.2.3 Total phosphorus (P_2O_5%)

Total phosphorus content of soil was determined by the vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and read in a spectrophotometer.

3.6.7.2.4 Total potassium (K_2O%)

Total potassium content of soil was estimated by using flame photometer (Jackson, 1973).

3.6.7.2.5 Available nitrogen (kg ha^{-1})

Available nitrogen in soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

3.6.7.2.6 Available phosphorus (P_2O_5 kg ha^{-1})

Available phosphorus was determined by Bray I method as described by Jackson (1973) and readings were taken in spectrophotometer.

3.6.7.2.7 Available potassium (K_2O kg ha^{-1})

Available potassium was analysed by using flame photometer (Jackson, 1973).

3.6.7.2.8 Nutrient balance sheet

Nutrient balance sheets were worked out for available N, P_2O_5 and K_2O in each year for experiment III as per the procedure outlined by Sadanandan and Mahapatra (1973 a).

The following parameters were investigated

(i) Initial status of nutrient in soil (Y) (kg ha^{-1})

(ii) Total amount of nutrient added through manures and fertilizers (A) (kg ha^{-1})

(iii) Amount of nutrient removed by the crop or uptake (B) (kg ha^{-1})

(iv) Expected nutrient balance (C) = (A-B) +Y (kg ha^{-1})

(v) Actual nutrient balance or available nutrient status of soil after the experiment (D) (kg ha^{-1})

(vi) Net loss (-) or gain (+) = D-C (kg ha^{-1})

3.6.8 Economics of cultivation

Total cost of cultivation and gross return were calculated from average input cost and average market price of the produce during the period of investigation, given in Appendix.III The following parameters were computed from these

Net return (Rs ha^{-1}) = Gross income - cost of cultivation

$$\textbf{Benefit - Cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

Added profit and marginal benefit cost ratio

Added profit and marginal benefit cost ratio of inputting N and K fertilizers in experiment III were computed using the procedure suggested by Gomez and Gomez (1984).

3.6.9 Statistical analysis

Data relating to various characters of experiment I were analysed by applying analysis of variance technique (ANOVA) for completely randomised design, that of experiment II by the analysis of variance technique for 3 x 3 factorial experiment in randomised block design and for the analysis of experiment III , ANOVA technique for split plot design was adopted (Cochran and Cox, 1965). Wherever significant differences between treatments were detected through ANOVA, critical differences (CD) are provided for effective comparison of means.

RESULTS

RESULTS

The results of the investigation conducted as three separate experiments during 1998-99 and 1999-2000 to assess the agronomic performance of white yam and to formulate agrotechniques for intercropping white yam in coconut garden are presented in this chapter.

4.1 Experiment I

Effect of growth promoting substances on sprouting

4.1.1 Days taken for sprouting

The effect of various sett treatments on the number of days taken for 50% sprouting was significant during both the years of experimentation (Table 3). Among the sett treatments, thiourea 2% (g_1) recorded less number of days for 50% sprouting in both the years (48.67 and 45.33 days respectively). However, in 98-99 , potassium nitrate (g_2), wood ash (g_4) and untreated control (g_6) and in the subsequent year, potassium nitrate (g_1), wood ash (g_4) and cowdung slurry (g_5) proved equally effective as thiourea. Sett treatment with IAA (g_3) delayed 50% sprouting considerably in both the years (72.00 and 54.33 days respectively).

4.1.2 Sprouting per cent

As depicted in Table 4, highest sprouting was observed with thiourea treatment (g_1) at 30 and 45 DAP in 98-99 (16.67% and 33.33% respectively)and the remaining treatments either showed a low response or did not respond. In the succeeding year, g_1 was significantly superior at 30 DAP, but at 45 DAP, g_1 was on par with g_2, g_5 and g_6. However, better sprouting was observed for all the treatments (30 to 46.67%) at this stage in 99-00 as compared to 98-99 . By 60 DAP, g_1 was similar to g_2 and g_6 in 98-99 and to all other sett treatments in 99-00 in inducing sprouts.

4.1.3 Vine length

It is evident from Table 5 that effect of thiourea (g_1) in increasing vine length at 60 DAP was significant in both the years of experimentation (174.99 cm and 169.00 cm in 98-99 and 99-00 respectively). The remaining sett treatments were on par during both the years.

Table 3. Effect of sett treatments on number of days taken for 50% sprouting

Sett treatments		Days taken for 50% sprouting (number)	
		98-99	99-00
g_1	Thiourea 2%	48.67	45.33
g_2	KNO_3 2%	55.00	45.67
g_3	IAA 1000 ppm	72.00	54.33
g_4	Wood ash	59.33	49.00
g_5	Cowdung slurry	66.00	47.00
g_6	Control	53.00	49.67
$F_{5,12}$		5.16**	6.04**
SE_m		3.80	1.36
CD (0.05)		11.710	4.191

** Significant at 1% level

Table 4. Effect of sett treatments on sprouting

		Sprouting %					
		98 -99			99-00		
		30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
g_1	Thiourea 2 %	16.67	33.33	83.33 (70.07)	30.00 (33.21)	46.67 (43.08)	86.67 (72.79)
g_2	KNO_3 2 %	0.00	0.00	70.00 (57.78)	0.00 (0.00)	46.67 (43.08)	70.00 (57.70)
g_3	IAA 1000 ppm	0.00	0.00	30.00 (32.21)	6.66 (12.29)	30.00 (33.21)	70.00 (57.70)
g_4	Wood ash	3.33	6.67	53.33 (47.00)	10.00 (18.43)	30.00 (33.21)	80.00 (67.86)
g_5	Cowdung slurry	0.00	0.00	40.00 (39.15)	6.66 (12.29)	40.00 (39.15)	83.33 (66.14)
g_6	Control	3.33	10.00	83.33 (66.14)	3.33 (6.14)	36.67 (37.22)	80.00 (67.86)
$F_{5, 12}$		-	-	5.14**	6.91**	3.49**	0.50
SE_m		-	-	6.67	4.34	2.38	8.57
CD (0.05)		-	-	20.554	13.374	7.334	-

** Significant at 1 % level
Figures in paranthesis are transformed means in angles
-Statistical analysis not performed

4.1.4 Vigour index

Treatments significantly influenced the vigour of sprouts in 98-99 but not in 99-00. As depicted in Table 5, highest vigour index values at 60 DAP was obtained due to thiourea treatment (g_1) in both the years. In 98-99, g_3, g_4 and g_5 treated plots registered low vigour index values in comparison with control (g_6) which was on par with g_1 and g_2. Pooled analysis of the data revealed that thiourea was significantly superior to all other treatments in producing vigorous sprouts at 60 DAP. IAA had the least effect in this regard.

4.2. Experiment II

Optimization of plant population and sett size for intercropping white yam

4.2.1 Growth characters

4.2.1.1 Sprouting per cent

Table 6 depicts the main effect of spacing and sett size on sprouting of yam setts . Spacing had no significant influence on sprouting at different sampling times during the period of experimentation except at 60 DAP in 99-00. In general, it appeared that the widest spacing (s_3) (90x90cm) resulted in the highest sprouting per cent, though its significant influence was seen at 60 DAP in 99-00.

On the other hand, sett size had significant influence on sprouting at most of the stages of observation in both the years except at 45 DAP in 98-99. The largest sett size (w_3) (300 g) resulted in significantly highest sprouting per cent . However, at 60 DAP in 98-99, differences in sprouting per cent between w_3 and w_2 (200 g) and w_2 and w_1 (100 g) were not significant.

The interaction between spacing and sett size (SxW) could not significantly affect the sprouting per cent at any of the stages in 98 -99 and 99 -00 (Table 7).

4.2.1.2 Vine length

Perusal of the data in Table 8 clearly indicates that the main effect of spacing and sett size had profound influence on vine length at most of the stages during both the years.

Table 5. Effect of sett treatments on vine length and vigour index

Sett treatments		Vine length (cm)		Vigour index		
		60 DAP		60 DAP		
		98-99	99-00	98-99	99-00	Mean
g_1	Thiourea 2 %	174.99	169.00	19940.37	20833.33	20386.85
g_2	KNO_3 2 %	115.64	126.24	12354.33	13195.80	12775.07
g_3	IAA 1000 ppm	122.47	113.32	5704.83	12074.50	8889.75
g_4	Wood ash	106.58	135.33	8526.50	15880.00	12203.33
g_5	Cowdung slurry	103.93	128.95	5883.33	15741.00	10812.17
g_6	Control	128.53	112.41	15487.97	13042.07	14265.02
$F_{(5, 12)}$		12.01**	4.45**	10.02**	3.04	10.03**
SE_m		7.51	9.83	1795.96	1829.84	1249.05
CD (0.05)		23.143	30.292	5534.378	-	3684.759

** Significant at 1% level

Table 6. Effect of spacing and sett size on sprouting

Treatments	Sprouting %					
	98- 99			99 - 00		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
Spacing						
s_1 (60X60cm)	18.52 (23.45)	82.03 (65.47)	92.18 (75.44)	9.88 (16.63)	56.05 (48.63)	79.58 (64.29)
s_2(75X75cm)	19.78 (25.21)	84.89 (68.01)	90.67 (75.07)	12.08 (17.46)	54.67 (47.95)	71.78 (58.60)
s_3(90X90cm)	26.39 (30.64)	87.50 (70.95)	93.75 (77.49)	13.95 (19.64)	59.11 (50.49)	82.61 (67.44)
$F_{2, 16}$	2.96	1.25	0.23	1.02	0.59	4.03*
$S E_m$	2.18	2.45	2.72	1.54	1.71	2.23
CD (0.05)	-	-	-	-	-	6.693
Sett size						
w_1 (100g)	11.02 (17.65)	78.45 (62.92)	87.08 (69.26)	2.76 (7.69)	38.96 (38.51)	64.15 (53.57)
w_2 (200g)	21.45 (27.32)	87.07 (69.64)	92.03 (76.12)	8.32 (16.31)	55.61 (48.26)	79.09 (63.23)
w_3 (300g)	32.21 (34.34)	88.90 (71.87)	97.49 (82.63)	24.82 (29.72)	75.26 (60.29)	90.73 (73.52)
$F_{2, 16}$	14.78**	3.61	6.02**	51.99**	40.68**	19.97**
$S E_m$	2.18	2.45	2.72	1.54	1.71	2.23
CD (0.05)	6.535	-	8.169	4.614	5.131	6.693

** Significant at 1 % level

* Significant at 5 % level

Figures in paranthesis are transformed means in angles

Table 7. Interaction effect of spacing and sett size on sprouting

Spacing X sett size	Sprouting %					
	98-99			99-00		
	Days after planting (d)			Days after planting (d)		
	30	45	60	30	45	60
s_1w_1	5.56 (11.04)	72.03 (58.24)	87.67 (69.46)	2.78 (9.59)	42.04 (40.21)	65.04 (53.76)
s_1w_2	19.44 (26.12)	87.03 (69.19)	91.66 (76.45)	4.63 (12.28)	53.73 (47.17)	81.11 (64.39)
s_1w_3	30.56 (33.20)	87.03 (69.19)	97.22 (80.40)	22.22 (28.01)	72.38 (58.51)	92.59 (74.72)
s_2w_1	6.67 (14.80)	80.00 (63.57)	84.00 (66.53)	1.33 (3.85)	37.33 (37.66)	58.67 (50.06)
s_2w_2	22.00 (27.41)	86.67 (70.03)	90.67 (76.38)	12.00 (20.09)	49.33 (44.62)	68.67 (56.01)
$s_2 w_3$	30.67 (33.42)	88.00 (70.43)	97.33 (82.31)	22.92 (28.44)	77.33 (61.59)	88.00 (69.73)
$s_3 w_1$	20.83 (27.11)	83.33 (66.94)	89.58 (71.79)	4.17 (9.65)	37.50 (37.66)	68.75 (56.90)
$s_3 w_2$	22.92 (28.44)	87.50 (69.72)	93.75 (75.52)	8.33 (16.55)	63.75 (53.00)	87.50 (69.29)
$s_3 w_3$	35.42 (36.39)	91.67 (76.19)	97.92 (85.17)	29.33 (32.71)	76.08 (60.80)	91.58 (76.12)
SXWXD						
F Value	0.34			1.07		
S E_m	3.98			3.08		
CD (0.05)	-			-		

Figures in paranthesis are transformed means in angles.

Table 8. Effect of spacing and sett size on vine length

Treatments	Vine length (cm)					
	98-99			99-00		
	Days after planting (d)			Days after planting (d)		
	30	45	60	30	45	60
Spacing (s)						
s_1 (60X60cm)	132.14	165.13	393.14	128.61	170.80	398.79
s_2 (75X75cm)	87.27	186.21	404.74	68.47	179.99	412.42
s_3 (90X90cm)	85.11	201.64	454.82	76.79	199.08	478.89
Sett size (w)						
w_1 (100g)	54.82	99.81	153.09	38.58	107.30	162.66
w_2 (200g)	108.57	201.83	464.22	95.55	192.50	462.12
w_3 (300g)	141.14	251.34	635.39	139.73	250.08	665.32

	98-99			99-00		
	F Value	SE_m	CD (0.05)	F Value	SE_m	CD (0.05)
SXD	17.65 **	7.02	20.141	6.69*	13.29	38.139
WXD	235.13**	7.02	20.141	69.22**	13.29	38.139

** Significant at 1 % level

* Significant at 5 % level

Plate 5. Canopy growth at closest spacing (60 X 60 cm)

Plate 6. Canopy growth at widest spacing (90 X 90 cm)

At 30 DAP, the closest spacing (s_1) (60 x 60 cm) resulted in significantly longest vines in both the years. The other spacings, (s_2) (75 x 75 cm) and (s_3) (90 x 90 cm) did not vary each other. At 45 DAP in 98-99, s_3 resulted in longest vines that did not differ from s_2 but varied significantly from s_1, while in the next year spacings had similar effects on vine length at 45 DAP. In both the years at 60 DAP, s_3 was significantly superior to s_2, though s_2 and s_1 did not differ.

At all stages of observation in 98-99 and 99-00, sett size, w_3 resulted in significantly longest vines. Mean vine lengths at 60 DAP for this sett size were 635.39 cm and 665.32 cm in 98-99 and 99-00 respectively.

It is clear from Table 9 that the effect of SxW interaction on vine length was significant only in 98 -99. In 98-99, at 30 DAP, s_1w_3 was significantly superior, at 45 DAP, s_3w_3 and s_2w_3 had similar effects and at 60 DAP, s_3w_3, s_2w_3 and s_1w_3 were equally effective in producing significantly longer vines. This result obviously indicates the superior effect of the largest sett size (w_3) in producing longer vines.

4.2.2 Pattern of dry matter distribution

4.2.2.1 Tuber dry matter production

Mean tuber dry matter production during 98-99 and 99-00 are presented in Table 10. Tuber dry matter production was significantly influenced by spacing and sett size during both the years of experimentation.

In 98-99 and 99-00, plants spaced at s_1 produced significantly highest tuber dry matter (6.72 and 6.00 t ha^{-1} respectively). With increase in spacings to s_2 and s_3 there was significant decrease in tuber dry matter production in the first year. While in the succeeding year, the decrement in tuber dry matter yield with increment in spacing from s_2 to s_3 was not significant.

The variation in tuber dry matter production due to different sett sizes was significant in both the years. In 98-99 and 99-00, sett size, w_3 yielded significantly highest tuber dry matter (6.53 and 6.24 t ha^{-1} respectively). As in the case of fresh tuber yield, the tuber dry matter yield was also significantly low in the smallest sett size (w_1).

Table 9. Interaction effect of spacing and sett size on vine length

Spacing X sett size	Vine length (cm)					
	98-99			99-00		
	Days after planting (d)			Days after planting (d)		
	30	45	60	30	45	60
$s_1 w_1$	54.33	91.33	126.76	67.75	103.13	150.08
$s_1 w_2$	151.00	183.33	431.75	137.67	177.13	425.25
$s_1 w_3$	191.08	220.72	620.92	180.42	232.13	621.00
$s_2 w_1$	54.67	95.08	162.95	16.00	93.78	169.25
$s_2 w_2$	90.81	198.83	416.92	63.14	189.24	383.69
$s_2 w_3$	116.34	264.70	634.34	126.26	256.93	684.31
$s_3 w_1$	55.42	113.00	169.55	32.00	124.97	168.64
$s_3 w_2$	83.92	223.33	544.00	85.83	211.11	577.42
$s_3 w_3$	115.98	268.60	650.90	112.53	261.17	690.64
	98-99			99-00		
SXWXD	F Value	SE_m	CD (0.05)	F Value	SE_m	CD (0.05)
	4.54*	12.16	34.885	1.92	23.02	-

* Significant at 5 % level

Table 10. Effect of spacing, sett size and their interaction on dry matter production and harvest index

Treatments	Dry matter production (t ha^{-1})				Harvest index	
	Tuber dry matter		Total dry matter			
	98-99	99-00	98-99	99-00	98-99	99-00
Spacing						
s_1 (60X60cm)	6.72	6.00	14.06	13.23	0.47	0.45
s_2 (75X75cm)	5.13	4.96	10.35	10.29	0.49	0.48
s_3 (90X90cm)	4.42	4.46	7.92	7.82	0.56	0.57
$F_{2, 16}$	44.35**	17.81**	140.66**	206.36**	22.74**	19.52**
S E_m	0.18	0.19	0.26	0.19	0.01	0.01
CD (0.05)	0.529	0.559	0.782	0.565	0.028	0.042
Sett size						
w_1(100g)	3.94	3.83	9.16	9.07	0.43	0.43
w_2 (200g)	5.79	5.34	11.32	10.69	0.52	0.51
w_3 (300g)	6.53	6.24	11.85	11.59	0.57	0.55
$F_{2,16}$	57.07**	42.93**	29.79**	46.21**	52.59**	20.72**
SE_m	0.18	0.19	0.26	0.19	0.01	0.01
CD (0.05)	0.529	0.559	0.782	0.565	0.028	0.042
Interaction						
$s_1 w_1$	4.75	4.29	11.49	11.11	0.41	0.39
$s_1 w_2$	6.93	6.31	14.51	13.53	0.47	0.47
$s_1 w_3$	8.47	7.39	16.17	15.06	0.53	0.49
$s_2 w_1$	3.85	3.92	8.75	8.92	0.44	0.44
$s_2 w_2$	5.63	4.98	11.26	10.62	0.50	0.47
$s_2 w_3$	5.90	5.97	11.05	11.33	0.54	0.52
$s_3 w_1$	3.24	3.26	7.24	7.17	0.45	0.46
$s_3 w_2$	4.79	4.74	8.18	7.91	0.59	0.60
$s_3 w_3$	5.23	5.37	8.33	8.39	0.63	0.64
$F_{4, 16}$	2.74	1.02	4.51*	4.52*	3.10*	1.81
S E_m	0.31	0.32	0.45	0.33	0.02	0.02
CD (0.05)	-	-	1.354	0.979	0.048	-

**Significant at 1% level

* Significant at 5% level

The interaction, SxW could not impart any significant variation in tuber dry matter production either in 98-99 or 99-00.

4.2.2.2 Total dry matter production

The significant effect of spacing and sett size, individually and in combination on total dry matter production in 98-99 and 99-00 is presented in Table 10.

In both the years, plants spaced at s_1 yielded significantly highest total dry matter (14.06 and 13.23 t ha^{-1} respectively). Widening of spacings to s_2 and s_3 resulted in significant reduction in total dry matter production during both the years of experimentation. Lowest dry matter was obtained from plants at s_3 spacing .

In 98-99 and 99-00, largest sett size (w_3) produced plants with greatest total dry matter (11.85 and 11.59 t ha^{-1} respectively). The total dry matter of plants raised from w_2 and w_3 sett sizes did not vary each other in 98-99 but differed significantly during 99-00. In both the years the smallest sett size (w_1) resulted in significantly lowest dry matter.

Considering the interaction between spacing and sett size, in both the years, in the closest spacing (s_1) an increase in total dry matter was observed with an increase in sett size. But with s_2, no significant difference in total dry matter was seen between w_2 and w_3. In s_3 spacing, sett sizes were not significantly different in 98-99 but in 99-00 total dry matter production was significantly low in w_1 as compared to w_3, which was on par with w_2. Thus s_1w_3 resulted in plants of significantly highest total dry matter of 16.17 t ha^{-1} in 98-99 and 15.06 t ha^{-1} in 99-00. The interaction s_3 w_1 had the least effect in this regard.

4.2.2.3 Harvest index

The effect of treatments on harvest index during 98-99 and 99-00 are presented in Table 10.

The influence of spacing on harvest index was significant during both the years. The harvest index was significantly highest for the spacing, s_3 (0.56 in 98-99 and 0.57 in 99-00). With decrease in spacing there was significant reduction in harvest index. Significantly lowest harvest index was recorded for the treatment, s_1 which did not vary from that of s_2. The above trend was observed during both the years.

Sett size significantly influenced harvest index during both the years and the largest sett size (w_3) resulted in highest harvest index (0.57 and 0.55 respectively). Significantly lowest harvest index was obtained from the smallest sett size (w_1). The difference in harvest index between w_2 and w_3 was significant in 98-99 but not in 99-00 and the treatment, w_2 registered lower harvest index.

Interaction between spacing and sett size was significant in 98-99, but not in 99-00. During 98-99, in closer spacing (s_1), with increase in sett size there was significant increase in harvest index. While in the wider spacings, w_2 and w_3 were on a par each other and w_1 resulted in significantly lower values. On the whole, s_3w_3 registered significantly highest harvest index, on a par with s_3w_2 in 98-99.

4.2.3 Yield components and yield

4.2.3.1 Length of tuber

The data pertaining to length of tuber at harvest during 98-99 and 99-00 are presented in Table 11.

During both the years, length of tuber was significantly influenced by spacing. The widest spacing, s_3 produced significantly longest tubers in 98-99 and 99-00 (45.39 cm and 44.18 cm respectively). Significantly lowest length of tuber was recorded from plants at s_1 spacing that did not vary significantly from that of s_2 in both the years.

The effect of sett size on length of tuber was significant in 98-99 and 99-00. Increase in sett size resulted in significant increase in length of tuber in both the years with the largest sett size (w_3) producing significantly longest tuber (47.89 cm in 98-99 and 48.71 cm in 99-00).

The interaction, SxW had significant effect on length of tuber only in 98-99. In closer spacing (60x60cm) no significant difference in length of tuber was observed between sett sizes, w_1 and w_2, but w_3 produced significantly longer tubers. With wider spacings (75x75cm and 90x90cm), there was no significant difference in tuber length between w_2 and w_3. However, SxW interaction was not significant in 99-00. In both the years, s_3w_3 resulted in longest tubers(53.50 cm and 53.17 cm in 98-99 and 99-00 respectively).

Table 11. Yield attributes as influenced by spacing, sett size and their interaction

Treatments	Tuber length (cm)		Tuber girth (cm)		Mean tuber weight (kg)	
	98-99	99-00	98-99	99-00	98-99	99-00
Spacing						
s_1 (60X60cm)	40.11	39.34	20.62	21.63	1.23	1.11
s_2 (75X75cm)	41.64	39.51	23.84	23.95	1.39	1.39
s_3 (90X90cm)	45.39	44.18	24.21	24.86	1.71	1.74
$F_{2, 16}$	9.05**	5.95**	14.18**	27.06**	56.04**	34.26**
SE_m	0.19	1.13	0.52	0.32	0.03	0.05
CD (0.05)	2.713	3.377	1.573	0.962	0.097	0.161
Sett size						
w_1 (100g)	35.86	33.54	18.46	21.13	1.15	1.11
w_2 (200g)	43.39	40.78	23.32	23.44	1.53	1.49
w_3 (300g)	47.89	48.71	26.89	25.88	1.66	1.65
$F_{2, 16}$	45.15**	45.35**	64.97**	54.84**	68.28**	26.73**
SE_m	0.91	1.13	0.52	0.32	0.03	0.05
CD (0.05)	2.713	3.377	1.573	0.962	0.097	0.161
Interaction						
$s_1 w_1$	35.63	31.67	16.08	19.04	0.95	0.84
$s_1 w_2$	38.58	40.63	21.22	21.25	1.26	1.18
$s_1 w_3$	46.10	45.71	24.56	24.58	1.48	1.33
$s_2 w_1$	38.67	33.96	19.05	22.54	1.14	1.13
$s_2 w_2$	42.17	37.33	24.92	23.51	1.49	1.43
$s_2 w_3$	44.08	47.25	27.55	25.79	1.56	1.60
$s_3 w_1$	33.28	35.00	20.25	21.79	1.35	1.36
$s_3 w_2$	49.42	44.38	23.83	25.54	1.82	1.85
$s_3 w_3$	53.50	53.17	28.55	27.25	1.95	2.02
$F_{4, 16}$	8.16**	1.07	0.50	2.33	1.08	0.41
SE_m	1.57	1.95	0.91	0.56	0.06	0.09
CD (0.05)	4.699	-	-	-	-	-

** Significant at 1% level

60 X 60 (100g) 60 X 60 (200g) 60 X 60 (300g)

90 X 90 (100g) 90 X 90 (200g) 90 X 90 (300g)

Plate 7. Tuber size influenced by spacing and sett size

4.2.3.2 Girth of tuber

The significant influence of spacing and sett size on girth of tuber during the period of experimentation is evident from Table 11. However, the effect of spacing and sett size was independent on tuber girth.

Tuber girth was significantly greatest in the widest spacing (s_3) in 98-99 (24.21cm) and 99-00 (24.86 cm) which was on par with s_2. Planting at closest spacing (s_1) produced significantly thinnest tubers in both the years.

In both the years, increase in sett size resulted in significant increase in tuber girth. The tuber girth was maximum with w_3 (26.89cm and 25.88 cm respectively).

4.2.3.3 Tuber weight

The data on mean weight of tuber at harvest during 98-99 and 99-00 are given in Table 11. The effect of spacing on mean weight of tuber was significant during both the years. There was significant increase in mean weight of tuber with increase in spacing and s_3 produced tubers with significantly greatest weight (1.71kg in 98-99 and 1.74 kg in 99-00).

Sett size also had profound influence on mean weight of tuber in 98-99 and 99-00. Increasing the sett size from w_1 to w_3 resulted in significant increase in mean weight of tuber from 1.15 to 1.66 kg in 98-99 and from 1.11 to 1.65 kg in 99-00. Sett size, w_2 also resulted in tubers of significantly greater weight than that of w_1.

The interaction S x W did not occur in either of the years.

4.2.3.4 Tuber yield

Spacing and sett size significantly affected fresh tuber yield in both the years (Table 12).

Planting at s_1 spacing resulted in significantly highest tuber yield in both the years (24.62 t ha^{-1} and 22.29 t ha^{-1} in 98-99 and 99-00 respectively) with mean yield of 23.46 t ha^{-1}. In both the years, with increase in spacings to s_2 and s_3 there was significant reduction in tuber yield. However, the tuber production in s_2 was significantly higher than that of s_3. The pooled analysis also showed similar trends.

Table 12. Effect of spacing, sett size and their interaction on tuber yield

Treatments	Tuber yield (t ha^{-1})		
	98-99	99-00	Mean
Spacing			
s_1 (60X60cm)	24.62	22.29	23.46
s_2 (75X75cm)	18.19	18.03	18.11
s_3 (90X90cm)	15.38	15.67	15.53
$F_{2, 16}$	89.36**	28.58**	101.47**
S E_m	0.50	0.63	0.40
CD (0.05)	1.503	1.881	1.157
Sett size			
w_1 (100g)	15.33	14.54	14.94
w_2 (200g)	20.37	19.59	19.98
w_3 (300g)	22.49	21.84	22.16
$F_{2, 16}$	53.73**	35.49**	85.18**
S E_m	0.50	0.63	0.40
CD (0.05)	1.503	1.881	1.157
Interaction			
s_1 w_1	19.00	16.73	17.87
s_1 w_2	25.27	23.60	24.43
s_1 w_3	29.60	26.53	28.07
s_2 w_1	14.82	14.69	14.76
s_2 w_2	19.46	18.55	19.00
s_2 w_3	20.28	20.84	20.56
s_3 w_1	12.18	12.21	12.19
s_3 w_2	16.38	16.65	16.52
s_3 w_3	17.58	18.15	17.87
F Value	3.05*	1.09	3.44**
S E_m	0.868	1.087	0.70
CD (0.05)	2.602	-	2.004

** Significant at 1% level

* Significant at 5% level

Among sett sizes, largest sett size (w_3) resulted in significantly highest tuber yield in both the years (22.49 and 21.84 t ha^{-1} respectively). In contrast to spacing, with increase in sett size there was significant increase in tuber yield . The pooled analysis also revealed the same trend with mean tuber yields of 22.16, 19.98 and 14.94 t ha^{-1} respectively for w_3, w_2 and w_1 sett sizes.

The interaction between spacing and sett size was significant on tuber yield in 98-99 but not in 99-00.

Pooled analysis indicates that yield trends were consistent between years due to the absence of treatment x year interaction , but the interaction between spacing and sett size had a significant effect on tuber yield.

The analysis of yield data for 98-99 as well as the pooled analysis reveals that, at s_1 spacing, with increase in sett size there was significant increase in tuber yield. Planting setts of 200 g (w_2) and 300 g (w_3) in wider spacings of 75x75 cm or 90x90 cm proved equally effective. But w_1 was significantly inferior.

Largest sett planted at the closest spacing (s_1w_3) resulted in highest tuber yield in both the years (29.60 and 26.53 t ha^{-1} respectively). The pooled analysis of the data also clearly indicates the significant effect of s_1w_3 interaction on tuber yield (28.07 t ha^{-1}). The interaction s_3w_1 resulted in lowest yield in both the years.

4.2.4 Quality attributes

4.2.4.1 Dry matter content

As presented in Table 13, during both the years, spacing and sett size had significant effect on tuber dry matter content with the widest spacing (s_3) accumulating highest dry matter in tuber (28.54% and 28.29% in 98-99 and 99-00 respectively). The variation in tuber dry matter content between s_2 and s_3 was not significant in the first year, while in the second year, s_2 and s_3 differed significantly. Significantly lowest dry matter content was noticed in the tubers obtained from s_1.

The largest sett size accumulated significantly highest tuber dry matter in both the years (29.15% and 28.69% respectively). In 98-99, w_3 and w_2 did not vary significantly while their variation was significant in the succeeding year. In both the years, the smallest sett size (w_1) produced tubers with significantly lowest dry matter content.

Table 13. Effect of spacing, sett size and their interaction on tuber quality

Treatments	Dry matter (%)		Starch (%) fresh weight basis		Crude protein (%) fresh weight basis	
	98-99	99-00	98-99	99-00	98-99	99-00
Spacing						
s_1 (60X60cm)	26.99	26.76	22.05	22.13	1.79	1.77
s_2 (75X75cm)	28.02	27.43	23.52	23.20	1.79	1.77
s_3 (90X90cm)	28.54	28.29	24.12	23.28	1.79	1.78
$F_{2,16}$	5.62**	8.05**	21.05**	5.54**	0.00	0.00
SE_m	0.33	0.27	0.23	0.27	0.00	0.00
CD (0.05)	0.996	0.808	0.696	0.821	-	-
Sett size						
w_1 (100g)	25.86	26.37	22.81	22.49	1.78	1.77
w_2 (200g)	28.54	27.42	23.44	22.71	1.79	1.77
w_3 (300g)	29.15	28.69	23.44	23.41	1.79	1.77
$F_{2,16}$	27.73**	18.60**	2.51	3.05	0.00	0.00
SE_m	0.33	0.27	0.23	0.27	0.00	0.00
CD (0.05)	0.996	0.808	-	-	-	-
Interaction						
$s_1 w_1$	24.99	25.68	22.01	21.52	1.80	1.79
$s_1 w_2$	27.38	26.78	22.41	21.92	1.79	1.76
$s_1 w_3$	28.59	27.82	21.72	22.94	1.79	1.76
$s_2 w_1$	25.99	26.67	22.66	22.86	1.79	1.79
$s_2 w_2$	28.95	26.97	23.55	23.09	1.79	1.76
$s_2 w_3$	29.10	28.64	24.36	23.66	1.79	1.76
$s_3 w_1$	26.59	26.75	23.75	23.12	1.76	1.74
$s_3 w_2$	29.28	28.50	24.36	23.12	1.80	1.80
$s_3 w_3$	29.75	29.62	24.25	23.63	1.80	1.80
$F_{4,16}$	0.22	0.67	1.69	0.24	0.00	0.00
SE_m	0.58	0.47	0.40	0.47	0.00	0.00
CD (0.05)	-	-	-	-	-	-

** Significant at 1% level

The interaction between spacing and sett size could not significantly influence this attribute in either of the years.

4.2.4.2 Starch content

The effect of treatments on starch content of tuber is given in Table 13.

Spacing had significant influence on starch content of tuber in both the years. Plants spaced at s_3 produced tubers with highest starch content (24.12% in 98-99 and 23.28% in 99-00) which was on a par with s_2. Starch content was low in tubers from plants spaced at s_1 in both the years.

The main effect of sett size as well as interaction effect of spacing and sett size were not significant in both the years of field experimentation.

4.2.4.3 Crude protein content

Spacing and sett size either individually or in combination had no significant impact on crude protein content of tubers in either of the years (Table 13).

4.2.5 Economic analysis

4.2.5.1 Net return

It is evident from Table 14 that planting setts of 300 g at a spacing of 90 x 90 cm so as to accommodate 9000 plants ha^{-1} (s_3 w_3) resulted in maximum net return to the tune of Rs.21,613 ha^{-1} besides generating additional employment of 318 man days ha^{-1}. Maintaining the same plant population by planting a slightly lesser sett size of 200 g (s_3w_2) also fetched higher net income (Rs.19,363 ha^{-1}). However, the returns were either less or even negative when 100g setts were used as planting material at any of the spacings during both the years.

4.2.5.2 Benefit - Cost Ratio (BCR)

Highest benefit-cost ratio was realized from s_3 w_3 (1.32) very closely followed by s_3 w_2 (1.31). Setts of 100 g planted at closer spacings of either 60 x 60 cm or 75 x 75 cm registered benefit -cost ratios of less than one. In general, BCR of more than one was obtained from setts of 200g or 300g regardless of the spacings adopted (Table 14).

Table 14. Economics of cultivation as influenced by plant population and sett size

Treatments	Tuber yield (t ha^{-1})	Gross return (Rs ha^{-1})	Total cost (Rs ha^{-1})	Net return (Rs. ha^{-1})	Benefit - cost ratio
s_1w_1	17.87	89325.00	119010.00	-29685.00	0.75
s_1w_2	24.44	122175.00	129010.00	-6835.00	0.95
s_1w_3	28.07	140325.00	139010.00	1315.00	1.01
s_2w_1	14.76	73775.00	82255.00	-8480.00	0.90
s_2w_2	19.01	95.025.00	88755.00	6270.00	1.07
s_2w_3	20.56	102800.00	95255.00	7545.00	1.08
s_3w_1	12.20	60975.00	58712.50	2262.50	1.04
s_3w_2	16.52	82575.00	63212.50	19362.50	1.31
s_3w_3	17.87	89325.00	67712.50	21612.50	1.32

Experiment III

Nutrient management for intercropping white yam in coconut garden

4.3.1 Growth characters

4.3.1.1 Vine length

The main and interaction effects of treatments on vine length at various stages of crop growth during 98-99 and 99-00 are furnished in Tables 15 a and 15 b respectively.

Significant difference in vine length was observed throughout the crop growth in both the years with organic manure application. Plots that received o_2(coir pith compost) resulted in longest vines at all growth stages . The other manures ,o_3(*in situ* green manuring) and o_1 (FYM) had similar effects at most stages except at 2nd and 8th months in 98-99 and 6th month in 99-00. At these stages, o_3 was significantly superior to o_1. The effect of nitrogen on vine length was significant at all sampling times in both the years. With increase in levels of nitrogen there was significant increase in vine length. The effect of potassium was significant during both the years, with k_2 (80 kg ha^{-1}) producing significantly longest vines. Significant reduction in vine length was noticed with further addition of potassium.

The interaction effect, OxN was significant throughout the period of experimentation, with o_2n_3 producing significantly longest vines. The general trend of significant increase in vine length with increase in nitrogen dose from n_1(40 kg ha^{-1}) to n_3 (120 kg ha^{-1}) was conspicuous in o_1, o_2 and o_3 applied plots at almost all stages in both the years. However, at the final stage in 99-00, in o_3 treated plots, n_2(80 kg ha^{-1}) resulted in significantly longer vines than $n_1$and n_3, which were on par (Table 15 b).

The interaction, OxK was significant only at 6th month in 98-99, significant increase in vine length was observed upto k_2 with all the organic manures. Plots treated with o_2k_2 registered highest values. The interaction, NxK was also significant only at the above stage. At all levels of N, vine length was significantly promoted upto k_2. Longest vines were observed with n_3k_2 .

Table 15a. Effect of organic manures, nitrogen and potassium on vine length

Main effect of factors	Vine length (cm)							
	98-99				99-00			
	2 MAP	4 MAP	6MAP	8MAP	2MAP	4MAP	6MAP	8MAP
o_1	362.30	568.95	741.90	823.20	359.20	578.65	748.40	828.45
o_2	412.00	637.35	803.45	886.55	413.55	639.15	793.85	885.20
o_3	373.00	555.30	744.65	841.00	368.45	559.80	758.85	839.60
$F_{2,2}$	551.83**	111.30**	85.89*	206.64**	118.00**	76.50*	1487.96**	31.83*
SE_m	1.114	4.167	3.752	2.273	2.677	4.740	0.617	5.329
CD(0.05)	6.779	25.356	22.832	13.832	16.291	28.845	3.754	32.429
n_1	363.78	587.22	766.17	856.78	363.00	596.56	765.83	861.61
n_2	393.72	605.28	788.17	885.06	389.56	610.72	800.44	887.94
n_3	413.00	628.67	821.94	903.00	409.94	629.89	827.17	897.44
$F_{2,27}$	295.79**	203.40**	275.41**	90.47**	181.33**	75.10**	329.80**	33.24**
SE_m	1.442	1.457	1.693	2.450	1.748	1.930	1.693	3.220
CD(0.05)	4.185	4.228	4.913	7.110	5.073	5.601	4.913	9.344
k_1	391.17	605.00	776.44	863.00	389.22	606.78	782.56	867.94
k_2	390.11	610.61	805.72	894.72	386.61	618.28	815.89	895.56
k_3	389.22	605.57	794.11	887.11	386.67	612.11	795.00	883.50
$F_{2,27}$	0.46	4.50*	75.84**	45.69**	0.73	8.89**	98.95**	18.48**
SE_m	1.442	1.457	1.693	2.450	1.748	1.930	1.693	3.220
CD(0.05)	_	4.228	4.913	7.110	_	5.601	4.913	9.344
Controls								
$o_{1\ alone}$	300.00	362.00	480.50	545.00	310.00	367.00	445.00	551.00
$o_{2\ alone}$	321.00	431.00	529.00	590.50	324.50	430.50	508.00	588.00
$o_{3\ alone}$	317.50	432.50	504.00	568.50	315.00	444.00	517.00	570.50

** Significant at 1% level
* Significant at 5% level

Table 15b. Interaction effect of organic manures, nitrogen and potassium on vine length

Interaction effects	Vine length (cm)							
	98-99				99-00			
	2 MAP	4MAP	6MAP	8MAP	2MAP	4MAP	6 MAP	8 MAP
o_1n_1	350.67	568.67	756.67	842.17	350.33	583.83	760.00	847.00
o_1n_2	368.67	593.50	764.83	846.83	355.17	596.17	785.17	853.00
o_1n_3	388.33	613.67	791.33	873.33	388.50	626.50	801.17	877.83
o_2n_1	387.50	637.33	791.83	877.33	388.00	645.17	793.17	876.33
o_2n_2	430.83	651.00	835.83	930.67	433.83	661.50	824.50	928.17
o_2n_3	448.00	692.50	874.17	950.33	448.50	680.33	859.17	950.17
o_3n_1	353.17	555.67	750.00	850.83	350.67	560.67	744.33	861.50
o_3n_2	381.67	571.33	763.83	877.67	379.67	574.50	791.67	882.67
o_3n_3	402.67	579.83	800.33	885.33	392.83	582.83	821.17	864.33
$F_{4,27}$	7.91**	14.79**	19.42**	11.34**	12.60**	3.47*	10.82**	12.90**
$S E_m$	2.498	2.524	2.932	4.243	3.028	3.344	2.933	5.577
CD (0.05)	7.249	7.325	8.509	12.313	8.787	9.704	8.512	16.184
o_1k_1	370.67	586.00	757.00	838.33	369.33	597.17	766.83	848.50
o_1k_2	366.50	597.83	789.83	863.33	364.33	608.83	799.50	865.17
o_1k_3	370.50	592.00	766.00	860.67	360.33	600.50	780.00	864.17
o_2k_1	423.83	660.67	818.67	898.67	424.17	655.67	815.50	901.00
o_2k_2	421.33	661.67	847.00	935.67	423.17	668.83	843.00	929.67
o_2k_3	421.17	658.50	836.17	924.00	423.00	662.50	818.33	924.00
o_3k_1	379.00	568.33	753.67	852.00	374.17	567.50	765.33	854.33
o_3k_2	382.50	572.33	780.33	885.17	372.33	577.17	805.17	891.83
o_3k_3	376.00	566.17	780.17	876.67	376.67	573.33	786.67	862.33
$F_{4,27}$	1.25	1.47	4.41**	0.56	1.03	0.17	2.62	2.14
$S E_m$	2.498	2.524	2.932	4.243	3.028	3.344	2.933	5.577
CD (0.05)	–	–	8.509	–	–	–	–	–
n_1k_1	366.00	586.00	749.17	840.17	366.33	590.83	751.50	840.33
n_1k_2	362.00	589.83	772.00	866.33	364.17	600.17	782.67	880.00
n_1k_3	363.33	585.83	777.33	863.83	358.50	598.67	763.33	864.50
n_2k_1	393.67	598.67	772.50	866.33	391.50	604.17	787.33	877.17
n_2k_2	391.17	612.50	801.83	900.50	387.33	617.33	820.67	899.00
n_2k_3	396.33	604.67	790.17	888.33	389.33	610.67	793.33	887.67
n_3k_1	413.83	630.33	807.67	882.50	409.83	625.33	808.83	886.33
n_3k_2	417.17	629.50	843.33	917.33	408.33	637.33	844.33	907.67
n_3k_3	408.00	626.17	814.83	909.17	411.67	627.00	828.33	898.33
$F_{4,27}$	2.37	2.31	8.48**	0.49	0.92	0.51	1.64	0.94
$S E_m$	2.498	2.524	2.932	4.243	3.028	3.344	2.933	5.577
CD(0.05)			8.509					

** Significant at 1% level

* Significant at 5% level

4.3.1.2 Number of functional leaves

Perusal of the data in Table 16 a clearly indicates that the main effects of organic manures, levels of nitrogen and potassium had significant influence on the number of functional leaves at most stages during both the years. However at 2nd month in 98-99, the effect of organic manures was not significant.

Among the organic sources, o_2 retained significantly highest number of functional leaves almost throughout. In general, o_1 was significantly superior to o_3. However, at the initial and final stages during 99-00, o_1 and o_3 were on a par each other. Increasing levels of nitrogen, significantly enhanced the number of functional leaves, with maximum number of functional leaves at n_3. The highest level of potassium (k_3) (120 kg ha^{-1}) also promoted significant leaf retention at all stages of crop growth in both the years, except at the final stage. At this stage, k_2 (80 kg ha^{-1}) in 98-99 and k_1(40 kg ha^{-1}) in 99-00 favoured leaf retention.

Interaction effects presented in Table 16 b indicate that OxN interaction was present at all stages. In combination with any of the organic source, increasing levels of nitrogen resulted in an increase in the number of functional leaves, with n_3 recording the significantly highest number at most stages, in both the years. However at the initial stages in both the years in o_3 applied plots, n_2 and n_3 exerted similar effects. On the whole, o_2 n_3 retained maximum leaves .The interaction, OxK was significant only at the final stage in both the years.During 98-99, in o_1 and o_2 applied plots significantly higher leaf retention was observed at k_2. In o_3 applied plots, all levels of K imparted similar effects on leaf retention. In the subsequent year, at this stage in o_1 applied plots, k_2 and k_3 and in o_2 and o_3 treated plots all K levels showed similar effects. The interaction between nitrogen and potassium was significant only at 4th and 8th months in the second year .At 4th month , k_3 retained significantly highest number of leaves at all levels of nitrogen. At the subsequent stage, in n_1 and n_2 applied plots, k_1 retained more leaves and in n_3 applied plots, k_3 showed more leaf retention.At these stages, n_3k_3 registered highest values .

Table 16a. Effect of organic manures, nitrogen and potassium on number of functional leaves

Main effect of factors	Number of functional leaves							
	98-99				99-00			
	2 MAP	4MAP	6MAP	8MAP	2MAP	4MAP	6MAP	8MAP
o_1	100.55	341.30	640.45	505.15	96.50	348.85	686.00	554.20
o_2	119.60	372.30	705.30	570.50	121.00	383.35	746.00	650.20
o_3	102.15	326.40	602.15	525.30	102.00	326.35	631.65	567.55
$F_{2,2}$	14.06	163.19**	158.75**	1003.69**	20.24*	76.29*	930.10**	266.53**
SE_m	2.818	1.833	4.138	1.056	2.857	3.287	1.875	3.185
CD(0.05)	–	11.154	2.518	6.426	17.384	20.000	11.409	19.381
n_1	99.94	298.89	606.06	480.56	98.56	312.56	656.94	556.33
n_2	110.72	364.89	652.89	560.22	110.22	373.28	706.33	613.22
n_3	118.56	411.78	731.17	597.83	118.94	411.56	751.00	650.61
$F_{2,27}$	139.91**	2201.66**	1211.62**	3960.34**	86.47**	3745.86**	965.09**	832.16**
SE_m	0.790	1.209	1.816	0.952	1.100	0.816	1.514	1.646
CD(0.05)	2.293	3.509	5.270	2.763	3.192	2.368	4.394	4.777
k_1	105.39	349.94	656.22	541.56	105.83	358.72	694.33	610.44
k_2	110.56	359.72	663.61	548.33	109.28	364.72	704.94	606.06
k_3	113.28	365.89	670.28	548.72	112.61	373.94	715.00	603.67
$F_{2,27}$	25.73**	44.25**	14.99**	17.94**	9.49**	88.37**	46.57**	4.36*
SE_m	0.790	1.209	1.816	0.952	1.100	0.816	1.514	1.646
CD(0.05)	2.293	3.509	5.270	2.763	3.192	2.368	4.394	4.777
Controls								
$o_{1\,alone}$	80.00	230.00	509.50	410.50	78.00	226.00	520.00	439.00
$o_{2\,alone}$	90.00	259.50	550.50	431.50	88.50	266.00	560.00	455.00
$o_{3\,alone}$	90.00	230.50	508.00	420.00	79.00	217.00	528.00	444.00

** Significant at 1% level

* Significant at 5% level

Table 16b . Interaction effect of organic manures, nitrogen and potassium on number of functional leaves

Interaction effects	Number of functional leaves							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1n_1	91.83	315.00	588.00	434.33	85.67	323.00	645.50	501.00
o_1n_2	102.00	356.33	639.50	528.67	98.50	366.67	713.50	585.33
o_1n_3	114.67	389.67	737.50	584.00	111.50	397.83	754.33	614.67
o_2n_1	112.17	318.33	666.17	546.67	110.67	346.83	725.50	614.33
o_2n_2	123.50	390.33	727.33	590.67	126.17	398.50	765.67	680.83
o_2n_3	133.00	445.83	774.00	620.50	137.00	443.83	808.83	720.50
o_3n_1	95.83	263.33	564.00	460.67	99.33	267.83	599.83	553.67
o_3n_2	106.67	348.00	591.83	561.33	106.00	354.67	639.83	573.50
o_3n_3	108.00	399.83	682.00	589.00	108.33	393.00	689.83	616.67
$F_{4,27}$	5.94**	66.69**	25.79**	167.52**	6.87**	101.36**	11.08**	39.16**
S E_m	1.368	2.093	3.145	1.648	1.905	1.413	2.623	2.850
CD (0.05)	3.970	6.074	9.127	4.782	5.528	4.101	7.612	8.271
o_1k_1	99.83	346.50	646.33	507.83	94.67	355.67	694.00	576.67
o_1k_2	102.83	355.17	656.33	519.83	98.17	362.50	705.67	562.00
o_1k_3	105.83	359.33	662.33	519.33	102.83	369.33	713.67	562.33
o_2k_1	117.83	373.67	715.00	579.50	121.50	390.33	755.50	675.33
o_2k_2	124.17	387.67	724.33	587.50	125.67	394.67	768.00	672.33
o_2k_3	126.67	393.17	728.17	590.83	126.67	404.17	776.50	668.00
o_3k_1	98.50	329.67	607.33	537.33	101.33	330.17	633.50	579.33
o_3k_2	104.67	336.33	610.17	537.67	104.00	337.00	641.17	583.83
o_3k_3	107.33	345.17	620.33	536.00	108.33	348.33	654.83	580.67
$F_{4,27}$	0.56	1.19	0.49	5.90**	0.32	1.15	0.42	3.30*
S E_m	1.368	2.093	3.145	1.648	1.905	1.413	2.623	2.850
CD (0.05)	–	–	–	4.782	–	–	–	8.271
n_1k_1	95.67	291.67	598.00	473.50	94.33	306.00	649.33	565.50
n_1k_2	99.67	301.33	606.17	484.33	99.00	312.83	656.33	555.17
n_1k_3	104.50	304.17	614.00	483.83	102.33	318.83	665.17	548.33
n_2k_1	105.50	358.33	644.67	557.67	107.17	364.00	693.33	616.83
n_2k_2	112.33	364.83	653.67	560.67	110.50	373.33	707.00	612.17
n_2k_3	114.33	371.50	660.33	562.33	113.00	382.50	718.67	610.67
n_3k_1	115.00	400.33	726.00	593.50	116.00	406.17	740.33	649.00
n_3k_2	119.67	413.00	731.00	600.00	118.33	408.00	751.50	650.83
n_3k_3	121.00	422.00	736.50	600.00	122.50	420.50	761.17	652.00
$F_{4,27}$	0.74	1.67	0.26	1.54*	0.15	2.82*	0.87	3.192*
S E_m	1.368	2.093	3.145	1.648	1.905	1.413	2.623	2.850
CD(0.05)	–	–	–		–	4.101	–	8.271

** Significant at 1% level

* Significant at 5% level

Effect of nutrient management practices on canopy growth

Plate 8. FYM alone

Plate 9. FYM + $n_{80}k_{120}$

Plate 10. Coir pith compost alone

Plate 11. Coir pith compost + $n_{80}k_{80}$

Plate 12. Green manure sunhemp

Plate 13. Plot incorporated with green manure sunhemp alone

Plate 14. Sunhemp+ n_{120} k_{120}

4.3.2 Physiological parameters

4.3.2.1 Dry matter accumulation and partitioning

4.3.2.1.1 Total dry matter

Various organic manures, levels of nitrogen and potassium had profound influence on total dry matter at almost all stages in both the years. However, the effect of organic manures was not significant at 4th month in 98-99 and at 6th month in 99-00 (Table 17 a).

Application of o_2 resulted in significantly highest total dry matter at most of the stages in both the years. Increased rates of nitrogen application significantly enhanced total dry matter production at most stages. However, at 6th and 8th months in 98-99, n_2 proved superior. At most of the stages, k_3 recorded significantly highest total dry matter accumulation. However, k_3 and k_2 proved equally effective at 8th month in 98-99.

The interaction, OxN was significant at all stages in both the years. Incremental doses of nitrogen enhanced total dry matter production in o_1, o_2 or o_3 applied plots at most of the growth stages in both the years. However, towards the final stages in both the years, o_2 responded significantly upto n_2 and indicated a trend of decline at n_3 (Table 17 b). A similar trend was observed in o_3 applied plots after 6th month in 98-99.

The interaction, OxK was significant throughout except at 2nd month in both the years. At these stages, in o_1 and o_2 applied plots, increasing rates of potassium resulted in an increase in total dry matter production. However, in o_3 applied plots, though similar trends were observed upto 4-6 months, towards the final stages maximum response was obtained at k_2 in 98-99 and at k_1 in 99-00.

Significant difference in total dry matter due to NxK interaction was observed at 2nd and 6th months in 98-99 and 4th and 8th months in 99-00. At all levels of N, increasing rates of applied K resulted in an increase in total dry matter content with k_3 producing maximum dry matter. However, at 4th and 8th months in 99-00, n_2 promoted dry matter production upto k_2 (Table 17 b).

Table 17a. Effect of organic manures, nitrogen and potassium on total dry matter

Main effect of factors	Total dry matter (g $plant^{-1}$)							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	38.89	203.32	558.52	688.29	33.69	126.95	555.98	648.63
o_2	40.25	230.38	697.33	844.01	34.49	133.07	610.87	746.78
o_3	38.49	207.72	604.27	733.69	31.73	119.14	554.51	661.10
$F_{2,2}$	23.58*	3.52	357.83**	39.25*	40.09*	196.49**	7.19	20.78*
SE_m	0.191	7.762	3.739	12.784	0.224	0.498	11.983	11.720
CD(0.05)	1.162	–	22.752	77.791	1.363	3.030	–	71.316
n_1	36.48	177.28	566.79	709.72	30.09	102.44	516.06	633.97
n_2	39.93	233.11	710.98	846.28	34.06	131.39	595.29	714.36
n_3	43.70	260.84	658.89	814.75	38.30	157.31	668.44	779.02
$F_{2,27}$	491.85**	107.40**	178.16**	50.79**	515.42**	4485.46**	46.53**	51.67**
SE_m	0.163	4.038	5.470	10.033	0.181	0.410	11.172	10.110
CD(0.05)	0.473	11.718	15.873	29.116	0.525	1.190	32.421	29.339
k_1	37.88	171.39	585.85	723.03	32.22	124.35	531.81	653.06
k_2	40.19	213.77	662.51	809.36	34.26	130.05	588.15	708.36
k_3	42.03	276.06	688.30	838.36	35.97	136.75	659.84	765.93
$F_{2,27}$	163.57**	170.00**	94.90**	35.76**	107.74**	229.14**	32.99**	31.17**
SE_m	0.163	4.038	5.470	10.033	0.181	0.410	11.172	10.110
CD(0.05)	0.473	11.718	15.873	29.116	0.525	1.190	32.421	29.399
Controls								
$o_{1\,alone}$	29.63	148.74	374.55	431.99	24.99	90.70	376.51	446.86
$o_{2\,alone}$	33.43	162.71	397.94	445.60	27.16	92.80	409.00	498.55
$o_{3\,alone}$	32.25	150.84	398.85	445.44	25.00	87.75	409.89	473.50

** Significant at 1% level
* Significant at 5% level

Table 17b. Interaction effect of organic manures, nitrogen and potassium on total dry matter

Interaction effects	Total dry matter(g plant^{-1})							
	98-99				99-00			
	2 MAP	4MAP	6 MAP	8 MAP	2 MAP	4MAP	6 MAP	8 MAP
o_1n_1	35.75	147.81	513.87	616.08	30.28	103.75	507.55	616.26
o_1n_2	39.95	232.19	624.29	738.29	35.39	129.27	567.20	658.60
o_1n_3	44.06	247.85	598.73	795.91	38.30	159.92	653.02	738.30
o_2n_1	37.71	207.17	615.73	775.70	30.86	106.10	495.29	640.45
o_2n_2	40.84	227.17	777.99	967.81	35.54	144.26	677.99	849.53
o_2n_3	44.49	279.37	798.08	921.33	39.53	162.26	726.62	833.08
o_3n_1	35.99	176.85	570.78	737.38	29.13	97.48	545.35	645.21
o_3n_2	39.00	209.98	730.65	832.75	31.25	120.64	540.69	634.95
o_3n_3	42.56	255.30	579.85	727.01	37.07	149.76	625.69	765.69
$F_{4,27}$	2.97*	5.95**	30.14**	10.83**	8.39**	38.92**	6.79**	11.09**
S E_m	0.282	6.994	9.474	17.377	0.314	0.710	19.351	17.510
CD (0.05)	0.818	20.297	27.494	50.428	0.911	2.060	56.157	50.814
o_1k_1	37.99	174.03	467.68	570.49	32.67	122.98	474.19	552.59
o_1k_2	39.92	203.31	607.51	751.58	34.83	127.17	555.91	657.88
o_1k_3	41.85	250.50	661.71	828.22	36.47	142.79	697.67	802.69
o_2k_1	38.62	168.09	671.43	820.35	33.48	127.65	564.46	685.87
o_2k_2	41.23	233.39	744.50	915.01	35.20	141.97	646.29	821.53
o_2k_3	43.19	312.34	775.87	929.49	37.25	143.00	689.15	815.67
o_3k_1	37.03	172.06	618.45	778.25	30.51	122.43	556.78	720.72
o_3k_2	39.44	204.62	635.51	761.51	32.74	121.00	562.26	645.69
o_3k_3	41.07	265.45	627.31	757.39	34.19	124.44	592.69	679.44
$F_{4,27}$	0.62	6.44**	24.79**	17.14**	0.30	69.69**	6.44	22.02**
S E_m	0.282	6.994	9.474	17.377	0.314	0.710	19.351	17.510
CD (0.05)	–	20.297	27.494	50.428	–	2.060	56.157	50.814
n_1k_1	34.83	137.46	498.93	621.41	28.23	98.93	452.87	565.80
n_1k_2	36.72	172.50	577.35	718.71	30.19	102.46	488.24	596.34
n_1k_3	37.89	221.87	624.09	783.05	31.84	105.94	607.08	739.78
n_2k_1	37.34	168.45	670.61	805.31	32.22	123.36	540.98	652.19
n_2k_2	40.08	216.50	730.16	872.71	34.18	137.28	598.54	760.30
n_2k_3	42.38	284.38	732.16	860.83	35.78	133.53	646.36	730.59
n_3k_1	41.47	208.26	588.01	736.37	36.21	150.77	601.58	741.20
n_3k_2	43.79	352.31	680.01	836.67	38.41	150.40	677.68	768.45
n_3k_3	45.84	321.94	708.64	871.21	40.29	170.76	726.07	827.42
$F_{4,27}$	3.26*	1.64	3.77*	2.51	0.21	83.79**	1.20	6.74**
S E_m	0.282	6.994	9.474	17.377	0.314	0.710	19.351	17.510
CD(0.05)	0.818	–	27.494	–	–	2.060	–	50.814

** Significant at 1% level

* Significant at 5% level

4.3.2.1.2 Leaf dry matter

The effect of treatments on leaf dry matter production at different growth stages during the two years are presented in Tables 18 a and 18 b.

In general, o_2 recorded significantly highest leaf dry matter at most of the growth stages, except at 2nd month in both the years and 4th month in 98-99. At all stages except at the final stages in both the years, o_1 registered significantly higher values than o_3. Incremental doses of nitrogen significantly enhanced the leaf dry matter production at all phases in both the years with n_3 producing maximum dry matter. The effect of potassium was significant during the initial phase upto 4 months in 98-99 and at all stages in 99-00. Significant response was obtained upto k_3 during the initial phase in both the years and upto k_2 during the subsequent phases in 99-00 (Table 18a).

The interaction, OxN was significant at 4th month in 98-99 and at all stages except at 2nd month in 99-00. It is evident from Table 18 b that increasing levels of nitrogen enhanced leaf dry matter production significantly when combined with any of the organic sources. In general, o_2n_3 registered highest values at most stages. The interaction effect, OxK was not significant in either of the years. Significant effect of NxK interaction was observed only during the final phases of crop growth in 99-00. At the lowest and highest levels of N, higher leaf dry matter could be obtained in combination with higher levels of K. But the medium level of N (n_2) responded upto k_2. Highest leaf dry matter was recorded at n_3k_3.

4.3.2.1.3 Vine dry matter

Organic manures, nitrogen and potassium had significant influence on vine dry matter in both the years (Table 19a). At all stages except at 4th month in 98-99, o_2 produced significantly highest vine dry matter. During the initial phases, o_1 proved significantly superior to o_3 but towards the later phases, o_1 and o_3 had similar effects. Increasing rates of nitrogen and potassium enhanced vine dry matter significantly at all stages of crop growth in both the years.

Table 18a Effect of organic manures, nitrogen and potassium on leaf dry matter

Main effect of factors	Leaf dry matter (g plant^{-1})							
	98 - 99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	14.88	76.50	156.00	128.99	13.11	76.20	160.58	130.43
o_2	15.38	77.82	164.48	145.13	13.28	78.28	173.29	153.31
o_3	14.49	73.26	148.56	136.52	12.75	73.31	150.08	141.45
$F_{2,2}$	5.23	92.47**	3402.19**	2283.94**	1.36	421.07**	953.06**	621.42**
SE_m	0.195	0.244	0.137	0.169	0.233	0.124	0.377	0.459
CD(0.05)	–	1.485	0.834	1.028	–	0.755	2.294	2.793
n_1	13.91	64.67	145.36	125.67	11.45	65.76	149.69	130.40
n_2	15.10	76.45	156.61	137.15	13.34	77.72	162.19	142.27
n_3	17.10	91.96	174.26	155.24	15.56	90.40	175.30	155.82
$F_{2,27}$	199.13**	3363.33**	384.03**	382.84**	378.18**	6399.40**	717.02**	844.76**
SE_m	0.114	0.236	0.744	0.762	0.106	0.154	0.478	0.438
CD(0.05)	0.331	0.685	2.159	2.211	0.308	0.447	1.388	1.271
k_1	14.33	75.48	157.24	137.97	12.49	76.12	160.74	140.88
k_2	15.42	77.66	159.21	139.72	13.59	77.72	162.61	143.26
k_3	16.35	79.93	159.79	140.32	14.27	80.04	163.82	144.35
$F_{2,27}$	78.83**	88.82**	3.22	2.60	71.67**	164.06**	10.54**	16.41**
SE_m	0.114	0.236	0.744	0.762	0.106	0.154	0.478	0.438
CD(0.05)	0.331	0.685	–	–	0.308	0.447	1.388	1.271
Controls								
o_1 alone	10.88	58.63	132.18	120.95	8.75	59.95	150.85	132.00
o_2 alone	10.93	60.39	131.18	111.13	10.00	60.55	152.75	133.00
o_3 alone	10.75	59.03	140.85	112.00	9.50	57.75	151.34	130.50

** Significant at 1% level

Table 18b. Interaction effect of organic manures, nitrogen and potassium on leaf dry matter

Interaction effects	Leaf dry matter(g plant^{-1})							
	98-99				99-00			
	2 MAP	4MAP	6 MAP	8 MAP	2 MAP	4MAP	6 MAP	8 MAP
o_1n_1	13.68	63.69	144.35	116.67	11.48	65.78	148.07	118.92
o_1n_2	15.12	77.39	157.07	126.79	13.65	80.68	161.88	127.75
o_1n_3	17.19	94.37	174.52	146.21	15.67	89.29	175.04	144.08
o_2n_1	14.21	67.28	155.01	135.46	11.51	67.89	163.46	143.96
o_2n_2	15.63	78.65	166.61	147.11	13.66	78.37	176.84	156.61
o_2n_3	17.78	93.33	182.91	164.17	15.76	94.50	186.42	166.13
o_3n_1	13.86	63.05	136.73	124.87	11.36	63.62	137.54	128.31
o_3n_2	14.54	73.31	146.14	137.54	12.71	74.10	147.83	142.45
o_3n_3	16.31	88.16	165.37	155.33	15.25	87.40	164.43	157.25
$F_{4,27}$	2.68	13.59**	0.64	0.37	1.69	56.04**	5.17**	9.22**
SE_m	0.197	0.409	1.288	1.320	0.183	0.267	0.828	0.758
CD (0.05)	–	1.187	–	–	–	0.775	2.403	2.200
o_1k_1	14.35	76.62	157.55	128.88	12.80	76.64	160.68	128.88
o_1k_2	15.39	78.35	159.12	130.50	13.71	78.25	160.86	130.67
o_1k_3	16.25	80.48	159.27	130.29	14.29	80.86	163.46	131.21
o_2k_1	14.72	77.38	166.03	146.82	12.72	78.57	172.63	153.03
o_2k_2	16.06	79.54	168.26	149.04	13.70	80.09	176.29	156.08
o_2k_3	16.83	82.34	170.24	150.88	14.50	82.10	177.81	157.58
o_3k_1	13.93	72.45	148.14	138.21	11.95	73.14	148.93	140.74
o_3k_2	14.83	75.10	150.24	139.74	13.37	74.82	150.67	143.03
o_3k_3	15.96	76.97	149.85	139.79	14.00	77.16	150.21	144.25
$F_{4,27}$	0.42	0.75	0.38	0.34	0.82	0.51	2.26	0.55
SE_m	0.197	0.409	1.288	1.320	0.183	0.267	0.828	0.758
CD (0.05)	–	–	–	–	–	–	–	–
n_1k_1	13.12	62.85	143.30	123.67	10.39	64.16	146.54	127.06
n_1k_2	13.87	64.69	145.37	125.62	11.67	65.70	150.78	130.75
n_1k_3	14.76	66.48	147.42	127.71	12.29	67.43	151.76	133.38
n_2k_1	13.90	74.04	155.29	136.11	12.60	76.02	160.59	140.87
n_2k_2	15.27	76.07	157.27	137.75	13.58	77.48	163.02	143.11
n_2k_3	16.12	79.23	157.26	137.58	13.84	79.64	162.94	142.83
n_3k_1	15.97	89.56	173.13	154.13	14.48	88.17	175.10	154.71
n_3k_2	17.13	92.23	174.98	155.92	15.53	89.98	174.01	155.92
n_3k_3	18.17	94.08	174.68	155.68	16.67	93.04	176.78	156.83
$F_{4,27}$	0.93	1.39	0.36	0.38	2.24	2.81	3.14*	2.83*
SE_m	0.197	0.409	1.288	1.320	0.183	0.267	0.828	0.758
CD(0.05)	–	–	–	–	–	–	2.403	2.200

** Significant at 1% level

* Significant at 5% level

Table 19a. Effect of organic manures, nitrogen and potassium on vine dry matter

Main effect of factors	Vine dry matter (g $plant^{-1}$)							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	24.01	46.36	125.51	105.48	20.58	46.88	125.08	105.29
o_2	24.88	48.05	134.83	114.80	21.22	48.79	135.88	115.76
o_3	24.00	45.06	125.85	105.83	18.20	44.62	124.96	105.76
$F_{2,2}$	50.67*	18.68	880.98**	745.58**	375.83**	178.93**	27.39*	23.24*
SE_m	0.071	0.347	0.178	0.194	0.059	0.156	1.197	1.227
CD(0.05)	0.432	–	1.083	1.180	0.359	0.949	7.284	7.466
n_1	22.57	36.52	120.26	100.22	18.64	36.68	121.35	101.56
n_2	24.83	48.49	131.83	111.81	20.72	48.69	130.59	110.33
n_3	26.61	59.86	138.74	118.71	22.74	60.17	138.29	119.41
$F_{2,27}$	209.40**	3157.82**	350.78**	347.37**	179.82**	4299.06**	113.83**	166.98**
SE_m	0.140	0.208	0.499	0.501	0.153	0.179	0.795	0.691
CD(0.05)	0.406	0.604	1.448	1.454	0.444	0.519	2.307	2.005
k_1	23.55	46.27	127.60	107.58	19.73	46.89	127.01	107.45
k_2	24.77	48.46	130.37	110.36	20.67	48.60	129.55	109.98
k_3	25.69	50.14	132.85	112.79	21.71	50.04	133.68	113.86
$F_{2,27}$	58.64**	87.38**	27.80**	27.06**	41.76**	77.49**	17.92**	21.83**
SE_m	0.140	0.208	0.499	0.501	0.153	0.179	0.795	0.691
CD(0.05)	0.406	0.604	1.448	1.454	0.444	0.519	2.307	2.005
Controls								
o_1 alone	18.75	29.81	113.63	93.63	16.24	30.75	114.91	94.50
o_2 alone	22.50	31.83	116.83	96.98	17.15	32.25	116.13	95.88
o_3 alone	21.50	29.31	114.00	93.87	15.50	30.00	116.05	95.88

** Significant at 1% level

* Significant at 5% level

Table 19b. Interaction effect of organic manures, nitrogen and potassium on vine dry matter

Interaction effects	Vine dry matter(g plant^{-1})							
	98-99				99-00			
	2 MAP	4MAP	6 MAP	8 MAP	2 MAP	4MAP	6 MAP	8 MAP
o_1n_1	22.07	37.01	117.04	97.02	18.80	37.98	118.36	99.25
o_1n_2	24.83	48.25	128.62	108.63	21.74	48.58	125.69	105.58
o_1n_3	26.87	59.34	134.83	114.75	22.64	59.46	134.58	114.63
o_2n_1	23.50	37.58	125.72	105.67	19.35	38.21	125.95	106.00
o_2n_2	25.21	50.69	138.03	117.96	21.88	50.95	140.54	120.21
o_2n_3	26.71	61.28	146.73	126.71	23.77	62.72	147.72	127.69
o_3n_1	22.13	34.97	118.03	97.97	17.77	33.86	119.73	99.42
o_3n_2	24.46	46.52	128.83	108.83	18.54	46.54	125.55	105.21
o_3n_3	26.25	58.94	134.66	114.67	21.82	58.33	132.58	115.91
$F_{4,27}$	2.77*	3.45*	1.83	1.82	6.75**	8.25**	3.80*	4.21**
SE_m	0.242	0.359	0.864	0.868	0.265	0.310	1.378	1.197
CD (0.05)	0.702	1.042	–	–	0.769	0.900	3.999	3.474
o_1k_1	23.65	45.31	124.38	104.35	19.87	46.33	122.82	102.83
o_1k_2	24.53	48.74	127.02	107.04	21.13	48.92	126.11	106.04
o_1k_3	25.60	50.55	129.08	109.00	22.17	50.77	129.70	110.58
o_2k_1	23.90	47.91	134.57	114.56	20.75	49.08	135.49	115.40
o_2k_2	25.17	49.80	137.74	117.65	21.50	50.71	138.08	117.96
o_2k_3	26.35	51.85	138.18	118.13	22.75	52.08	140.64	120.54
o_3k_1	23.11	45.58	123.85	103.83	18.56	45.27	122.71	104.13
o_3k_2	24.61	46.83	126.35	106.39	19.38	46.18	124.46	105.95
o_3k_3	25.11	48.02	131.31	111.25	20.19	47.28	130.69	110.46
$F_{4,27}$	0.87	4.38**	2.09	1.99	0.55	4.02	0.55	0.40
SE_m	0.242	0.359	0.864	0.868	0.265	0.310	1.378	1.197
CD (0.05)	–	1.042	–	–	–	0.900	–	–
n_1k_1	21.72	34.15	118.00	98.03	17.84	34.77	119.19	99.13
n_1k_2	22.85	37.03	119.88	99.92	18.52	36.77	121.09	100.96
n_1k_3	23.13	38.37	122.90	102.71	19.56	38.51	123.75	104.58
n_2k_1	23.44	46.71	129.64	109.58	19.62	47.33	127.48	107.25
n_2k_2	24.80	48.65	131.68	111.63	20.60	48.63	129.25	108.92
n_2k_3	26.26	50.10	134.16	114.21	21.93	50.12	135.05	114.83
n_3k_1	25.50	57.94	135.16	115.13	21.72	58.58	134.35	115.98
n_3k_2	26.65	59.69	139.56	119.54	22.89	60.42	138.30	120.08
n_3k_3	27.67	61.94	141.50	121.46	23.62	61.51	142.23	122.17
$F_{4,27}$	2.47	1.04	0.72	0.70	0.58	0.89	0.65	0.78
SE_m	0.242	0.359	0.863	0.868	0.265	0.310	1.378	1.197
CD(0.05)	–	–	–	–	–	–	–	–

** Significant at 1% level

* Significant at 5% level

The interaction, OxN was significant at 2nd and 4th months in 98-99 and at all growth stages in 99-00. In combination with increasing levels of nitrogen, the different organic manures produced significantly higher vine dry matter. At most stages in both the years, o_2n_3 resulted in highest vine dry matter. The various organic manures interacted significantly with increasing levels of potassium only at 4th month in 98-99 and 99-00 and k_3 in combination with any of the organic manure resulted in highest dry matter. Interaction NxK was not significant throughout the crop growth in both the years (Table 19b).

4.3.2.1.4 Tuber dry matter

The data on tuber dry matter at various growth stages in 98-99 and 99-00 are furnished in Tables 20 a and 20 b. It is to be noted that tuberisation was considerably late during 99-00. Hence tuber development was not appreciable at 4th month in 99-00 for any recording and analysis. Hence data pertaining to subsequent stages is provided for that year.

The difference in tuber dry matter between the organic sources was significant at 6th and 8th months in 98-99. Application of o_2 resulted in significantly highest tuber dry matter. The organic source, o_3 was significantly superior to o_1 at 6th month, but o_3 and o_1 were on par at the subsequent stage.

The effect of nitrogen was significant in both the years. In general, significant positive response was obtained upto n_2 in 98-99 and upto n_3 in 99-00. However, at 4th month in 98-99 significantly highest dry matter was produced at n_3. Increments in K levels also significantly promoted tuber dry matter, with k_3 producing highest dry matter. But k_2 and k_3 were on par at 8th month in 98-99.

As depicted in Table 20 b, OxN and OxK interactions were significant at various stages in both the years. Significantly higher response was obtained due to application of o_1 or o_3 in combination with n_2 in 98-99 and with n_3 in 99-00 and in the case of o_2 in combination with n_2 at most stages during the period of experimentation. With o_1 and o_2, higher potassium nutrition resulted in significantly higher tuber dry matter production at most stages in both the years.

Table 20a Effect of organic manures, nitrogen and potassium on tuber dry matter

Main effect of factors	Tuber dry matter (g plant^{-1})				
	98-99			99-00	
	4 MAP	6 MAP	8 MAP	6 MAP	8 MAP
o_1	80.36	277.01	453.81	270.32	412.92
o_2	104.53	398.03	584.08	301.70	477.71
o_3	89.41	329.96	490.34	287.63	413.90
$F_{2,2}$	2.69	283.53**	26.54*	4.27	9.29
SE_m	7.445	3.603	13.018	7.610	12.181
CD(0.05)	–	21.924	79.214	–	–
n_1	76.08	301.28	483.84	245.03	402.02
n_2	98.18	422.55	597.33	302.51	461.76
n_3	109.04	345.87	540.81	363.92	503.80
$F_{2,27}$	18.16**	130.31**	33.14**	52.55**	26.87**
SE_m	3.941	5.373	9.858	8.202	9.867
CD(0.05)	11.437	15.592	28.608	23.802	28.634
k_1	49.63	301.12	477.48	253.13	404.73
k_2	87.66	372.93	559.24	295.99	455.12
k_3	145.99	395.64	585.25	362.33	507.72
$F_{2,27}$	151.64**	84.32**	32.55**	44.99**	27.25**
SE_m	3.941	5.373	9.858	8.202	9.867
CD(0.05)	11.437	15.592	28.608	23.802	28.634
Controls					
$o_{1\ alone}$	60.30	128.75	217.45	110.75	220.36
$o_{2\ alone}$	70.50	149.94	237.50	140.13	269.67
$o_{3\ alone}$	62.50	144.00	239.57	142.50	247.12

** Significant at 1% level
* Significant at 5% level

Table 2ob. Interaction effect of organic manures ,nitrogen and potassium on tuber dry matter

Interaction effects	Tuber dry matter (g plant^{-1})				
	98-99			99-00	
	4 MAP	6 MAP	8 MAP	6 MAP	8 MAP
o_1n_1	47.08	252.48	402.40	241.13	398.09
o_1n_2	106.53	338.61	502.88	279.63	425.26
o_1n_3	94.13	289.35	534.95	343.40	479.59
o_2n_1	102.32	335.00	534.57	205.88	390.50
o_2n_2	97.83	473.35	702.74	360.61	572.72
o_2n_3	124.78	468.43	630.46	392.48	539.27
o_3n_1	78.83	316.36	514.55	288.08	417.47
o_3n_2	90.16	455.68	586.37	267.31	387.29
o_3n_3	108.20	279.83	457.01	355.89	492.53
$F_{4,27}$	6.06**	30.91*	11.04**	10.33**	10.65**
S E_m	6.827	9.307	17.075	14.207	17.090
CD (0.05)	19.812	27.009	49.551	41.229	49.595
o_1k_1	52.07	185.74	337.27	190.70	320.89
o_1k_2	76.22	321.38	514.03	268.94	421.17
o_1k_3	119.47	373.32	588.93	404.51	560.89
o_2k_1	42.80	370.83	558.97	256.34	417.44
o_2k_2	104.08	438.50	648.32	331.92	547.49
o_2k_3	178.05	467.45	660.49	370.70	537.55
o_3k_1	54.03	346.79	536.21	312.36	475.85
o_3k_2	82.69	358.92	515.38	287.13	396.71
o_3k_3	140.47	346.15	506.35	311.79	424.72
$F_{4,27}$	6.69*	26.48**	18.04**	15.39**	22.98**
S E_m	6.827	9.307	17.075	14.207	17.090
CD (0.05)	19.812	27.009	49.551	41.229	49.595
n_1k_1	40.43	237.97	405.71	187.13	339.61
n_1k_2	70.78	312.11	493.17	216.38	364.63
n_1k_3	117.02	353.77	552.63	331.57	501.82
n_2k_1	47.70	385.68	559.61	252.92	404.07
n_2k_2	91.78	441.22	623.34	306.25	508.28
n_2k_3	155.05	440.74	609.04	348.37	472.93
n_3k_1	60.77	279.73	467.12	319.35	470.50
n_3k_2	100.43	365.47	561.22	365.37	492.46
n_3k_3	165.92	392.41	594.09	407.06	548.42
$F_{4,27}$	1.63	3.58*	2.46	2.39	7.01**
S E_m	6.827	9.307	17.075	14.207	17.090
CD(0.05)	_	27.009	_	_	49.595

** Significant at 1% level

* Significant at 5%level

Significantly higher response was obtained at k_3 in o_1 and at k_2 in o_2. In plots that received o_3, k_1 was sufficient for enhancing tuber dry matter at the active and final growth stages in both the years and a tendency for reduced rate of dry matter production was observed at higher levels.

The interaction between nitrogen and potassium was significant only at certain stages (6th month in 98-99 and 8th month in 99-00). The trend was similar to that of leaf dry matter. At the lowest and highest doses of nitrogen, significantly higher response was obtained at k_3 while the medium level of nitrogen enhanced tuber dry matter significantly at k_2.

4.3.2.2 Leaf area index (LAI)

As depicted in Table 21 a, organic manures significantly influenced LAI at most stages during the period of experimentation , except at 2nd month in both the years and 8th month during 99-00. In general, o_2 produced significantly highest LAI. At peak growth stages, o_1 was significantly superior to o_3, though their effects were similar towards final stages in both the years. Incremental doses of nitrogen significantly enhanced LAI at most stages of growth, with highest values obtained at n_3. Potassium nutrition profoundly influenced LAI at most stages in both the years except at the final stage in 99-00. Significantly higher LAI values was attained at k_2 during the initial stages (2nd and 4th months) and at k_3 during the subsequent stage (6th month).

Interaction effects furnished in Table 21 b indicated that OxN interaction was significant at most stages except at 2nd month in 98-99 and 6th month in 99-00. During 98-99, incremental levels of nitrogen in combination with organic manures enhanced LAI significantly with maximum values at n_3. In the subsequent year, though an increasing trend was observed, during most stages, n_2 and n_3 recorded almost same LAI values. Throughout the crop growth in both the years, o_2n_3 recorded maximum LAI values. The interaction between organic manures and potassium was significant, except at 4th and 6th months in 98-99 and at 4th month in 99-00. In general, all the organic manures responded favourably upto k_2 level. The effect of N x K

Table 21a Influence of organic manures, nitrogen and potassium on leaf area index

Main effect of factors	Leaf area index							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	0.49	1.84	4.09	1.52	0.44	1.93	4.07	1.51
o_2	0.55	1.93	4.12	1.58	0.45	1.99	4.07	1.57
o_3	0.53	1.79	3.99	1.52	0.45	1.87	3.92	1.52
$F_{2,2}$	0.53	100.00**	197.00**	48.00*	1.00	145.00**	19.43*	19.00
SE_m	0.042	0.007	0.005	0.005	0.005	0.005	0.019	0.007
CD(0.05)	–	0.043	0.030	0.030	–	0.030	0.116	–
n_1	0.47	1.81	3.76	1.49	0.44	1.92	3.69	1.48
n_2	0.53	1.89	4.11	1.57	0.46	1.95	4.07	1.57
n_3	0.61	1.99	4.58	1.60	0.46	2.05	4.52	1.59
$F_{2,27}$	21.08*	116.65**	1522.6**	559.50**	7.56**	39.79**	1059.46**	86.94**
SE_m	0.015	0.008	0.011	0.003	0.006	0.011	0.013	0.006
CD(0.05)	0.044	0.023	0.032	0.009	0.017	0.032	0.038	0.017
k_1	0.50	1.87	4.03	1.55	0.44	1.95	3.98	1.54
k_2	0.56	1.92	4.16	1.56	0.47	2.01	4.11	1.55
k_3	0.55	1.89	4.25	1.56	0.45	1.96	4.18	1.55
$F_{2,27}$	3.56*	11.19**	107.37**	8.17*	6.72**	7.91**	62.75**	0.73
SE_m	0.015	0.008	0.011	0.003	0.006	0.011	0.013	0.006
CD(0.05)	0.044	0.023	0.032	0.009	0.017	0.032	0.038	–
Controls								
$o_{1\,alone}$	0.38	1.48	3.29	1.33	0.40	1.59	3.33	1.38
$o_{2\,alone}$	0.48	1.53	3.38	1.44	0.39	1.59	3.38	1.40
$o_{3\,alone}$	0.46	1.43	3.28	1.38	0.40	1.48	3.38	1.38

** Significant at 1% level

* Significant at 5% level

Table 21b **Interaction effect of organic manures, nitrogen and potassium on leaf area index**

Interaction effects	Leaf area index							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1n_1	0.43	1.84	3.81	1.45	0.46	1.89	3.75	1.45
o_1n_2	0.49	1.87	4.16	1.56	0.45	1.94	4.14	1.56
o_1n_3	0.60	1.93	4.57	1.62	0.45	2.09	4.55	1.58
o_2n_1	0.47	1.84	3.84	1.56	0.44	1.99	3.76	1.55
o_2n_2	0.58	1.96	4.10	1.60	0.46	1.98	4.10	1.60
o_2n_3	0.64	2.12	4.67	1.62	0.47	2.12	4.57	1.61
o_3n_1	0.52	1.74	3.63	1.45	0.41	1.87	3.55	1.45
o_3n_2	0.51	1.84	4.08	1.56	0.48	1.93	3.96	1.56
o_3n_3	0.59	1.91	4.50	1.58	0.47	1.94	4.45	1.58
$F_{4,27}$	1.97	11.78**	9.96**	44.92**	4.62**	5.35**	1.84	4.38**
S E_m	0.026	0.014	0.018	0.005	0.010	0.019	0.022	0.011
CD (0.05)	–	0.041	0.052	0.015	0.029	0.055	–	0.032
o_1k_1	0.48	1.84	4.08	1.52	0.44	1.98	4.04	1.52
o_1k_2	0.53	1.90	4.20	1.55	0.46	2.04	4.19	1.53
o_1k_3	0.52	1.90	4.25	1.55	0.45	1.90	4.21	1.53
o_2k_1	0.54	1.91	4.11	1.59	0.44	1.96	4.06	1.58
o_2k_2	0.59	2.02	4.20	1.60	0.49	2.07	4.14	1.59
o_2k_3	0.56	1.98	4.30	1.60	0.45	2.07	4.24	1.59
o_3k_1	0.50	1.85	3.91	1.53	0.45	1.91	3.84	1.53
o_3k_2	0.55	1.85	4.08	1.53	0.47	1.92	4.01	1.53
o_3k_3	0.57	1.79	4.21	1.53	0.45	1.90	4.10	1.53
$F_{4,27}$	0.32	6.19**	4.73**	2.04	1.26	7.79**	2.34	0.00
S E_m	0.026	0.014	0.018	0.005	0.010	0.019	0.022	0.011
CD (0.05)	–	0.041	0.052	–	–	0.055	–	–
n_1k_1	0.44	1.80	3.60	1.47	0.41	1.90	3.55	1.47
n_1k_2	0.51	1.83	3.79	1.49	0.46	1.93	3.71	1.49
n_1k_3	0.47	1.79	3.89	1.49	0.44	1.93	3.80	1.49
n_2k_1	0.49	1.87	4.02	1.57	0.45	1.95	3.98	1.57
n_2k_2	0.55	1.92	4.09	1.58	0.49	1.98	4.07	1.58
n_2k_3	0.55	1.88	4.22	1.58	0.45	1.93	4.15	1.58
n_3k_1	0.58	1.94	4.48	1.59	0.46	2.01	4. 42	1.59
n_3k_2	0.62	2.02	4.61	1.61	0.46	2.11	4.56	1.59
n_3k_3	0.62	2.00	4.65	1.61	0.45	2.02	4.60	1.59
$F_{4,27}$	0.25	1.40	5.23**	0.00	2.52	1.75	1.42	0.00
S E_m	0.026	0.014	0.018	0.005	0.010	0.019	0.022	0.011
CD(0.05)	–	–	0.052	–	–	–	–	-

** Significant at 1% level

interaction was significant only at 6th month in 98-99. Increasing levels of K resulted in significantly higher LAI values at all levels of N except at n_3 wherein k_2 and k_3 were at par. Almost throughout the crop growth period in both the years, n_3k_3 recorded highest LAI values.

4.3.2.3 Net assimilation rate (NAR)

The NAR computed at various growth phases in 98-99 and 99-00 are presented in Tables 22 a and 22 b.

As shown in Table 22 a, organic manures influenced NAR significantly only at the second phase (4 - 6 months) in 98-99, with highest values obtained due to application of o_2. The treatment, o_3 was significantly superior to o_1. Different levels of nitrogen affected NAR significantly at the first phase (2 - 4 months) in both the years and only at the second phase (4 - 6 months) in the first year. During the first phase in both the years, n_3 favoured NAR. At the subsequent phase in 98-99, n_2 resulted in significantly highest NAR values. Similarly higher rates of potassium also significantly enhanced the values of NAR at the first and second phase in 98-99 and 99-00.

It is evident from Table 22b that the effect of the interaction, OxN was significant at most stages in both the years except at the final phase (6 - 8 months) in the second year. In combination with any of the organic manure, either n_2 or n_3 resulted in significantly higher NAR at the first and second phases in both the years. However, o_3 promoted NAR highly in combination with n_1 at the second phase in 99-00. While during the final phases, higher doses of nitrogen (n_2 or n_3) depressed the NAR values in most cases. The difference in NAR values due to OxK interactions was also significant at all stages in both the years. Combination of o_1 or o_2 with higher levels of K (k_2 or k_3) resulted in higher NAR during the first two phases. However, o_3 in combination with lowest level of K promoted NAR at most stages. At the final phase, in the case of o_1, though an increasing trend in NAR was observed at higher levels of K, with o_2 and o_3 NAR values were found to be depressed at k_3. Interaction between nitrogen and potassium was significant only at the second phase in the first year and at the first

Table 22a. Influence of organic manures, nitrogen and potassium on net assimilation rate

Main effect of factors	Net assimilation rate (g m^{-2} day^{-1})					
	98-99			99-00		
	Phase1	Phase2	Phase3	Phase1	Phase2	Phase3
	2-4MAP	4-6MAP	6-8MAP	2-4MAP	4-6MAP	6-8MAP
o_1	2.88	2.61	0.93	1.61	2.93	0.69
o_2	3.12	3.35	1.06	1.65	3.22	1.00
o_3	2.98	2.99	0.97	1.55	3.10	0.81
$F_{2,2}$	0.55	91.90*	1.22	12.78	3.62	1.61
SE_m	0.165	0.039	0.061	0.015	0.076	0.123
CD(0.05)	–	0.237	–	–	–	–
n_1	2.54	3.06	1.12	1.27	3.04	0.94
n_2	3.12	3.54	0.98	1.66	3.17	0.87
n_3	3.44	2.65	1.04	1.96	3.20	0.75
$F_{2,27}$	48.78**	65.03**	1.22	945.62**	1.34	2.49
SE_m	0.065	0.055	0.065	0.011	0.072	0.135
CD(0.05)	0.189	0.160	–	0.032	–	–
k_1	2.30	3.07	1.02	1.58	2.82	0.91
k_2	2.87	3.24	1.06	1.58	3.07	0.88
k_3	3.93	2.94	1.07	1.72	3.51	0.77
$F_{2,27}$	160.52**	7.66**	0.19	49.28**	22.96**	0.90
SE_m	0.065	0.055	0.065	0.011	0.072	0.078
CD(0.05)	0.189	0.160	–	0.032	0.209	–
Controls						
o_1 alone	2.65	2.02	0.51	1.37	2.40	0.62
o_2 alone	2.67	2.01	0.41	1.36	2.62	0.77
o_3 alone	2.60	2.20	0.41	1.38	2.73	0.55

** Significant at 1% level

* Significant at 5% level

Table 22b. Interaction effect of organic manures,nitrogen and potassium on net assimilation rate

Interaction effects	Net assimilation rate (g m^{-2} day^{-1})					
	98-99			99-00		
	Phase 1	Phase 2	Phase3	Phase 1	Phase 2	Phase 3
	2-4MAP	4-6MAP	6-8MAP	2-4MAP	4-6MAP	6-8MAP
o_1n_1	2.03	2.86	0.80	1.29	2.94	0.86
o_1n_2	3.35	2.83	0.82	1.62	2.96	0.66
o_1n_3	3.33	2.34	1.31	1.99	3.06	0.57
o_2n_1	3.02	3.12	1.22	1.28	2.78	1.13
o_2n_2	3.02	3.98	1.37	1.83	3.61	1.24
o_2n_3	3.48	3.40	0.81	1.95	3.46	0.71
o_3n_1	2.58	3.19	1.35	1.23	3.40	0.83
o_3n_2	2.98	3.82	0.75	1.53	2.94	0.71
o_3n_3	3.51	2.21	1.00	1.93	3.07	0.97
$F_{4,27}$	9.51**	18.20**	9.75**	19.14**	7.57**	2.49
S E_m	0.113	0.096	0.113	0.020	0.125	0.135
CD (0.05)	0.328	0.279	0.328	0.058	0.363	–
o_1k_1	2.40	2.19	0.74	1.53	2.40	0.60
o_1k_2	2.76	2.90	1.02	1.52	2.82	0.73
o_1k_3	3.56	2.93	1.18	1.86	3.74	0.76
o_2k_1	2.15	3.64	1.10	1.61	2.96	0.90
o_2k_2	3.03	3.62	1.22	1.72	3.33	1.27
o_2k_3	4.34	3.24	1.08	1.72	3.55	0.90
o_3k_1	2.36	3.38	1.21	1.59	3.11	1.23
o_3k_2	2.82	3.21	0.94	1.52	3.07	0.63
o_3k_3	3.89	2.64	0.95	1.58	3.23	0.64
$F_{4,27}$	5.33**	16.61**	3.05*	31.24**	6.73**	4.28**
S E_m	0.113	0.096	0.113	0.020	0.125	0.135
CD (0.05)	0.328	0.279	0.328	0.058	0.363	0.392
n_1k_1	1.89	2.93	1.04	1.27	2.68	0.93
n_1k_2	2.39	3.16	1.10	1.24	2.83	0.86
n_1k_3	3.35	3.08	1.22	1.29	3.61	1.03
n_2k_1	2.30	3.70	0.99	1.56	2.90	0.83
n_2k_2	2.94	3.73	1.03	1.72	3.14	1.18
n_2k_3	4.11	3.18	0.91	1.69	3.47	0.61
n_3k_1	2.73	2.58	1.01	1.91	2.89	0.98
n_3k_2	3.27	2.83	1.04	1.79	3.25	0.61
n_3k_3	4.34	2.54	1.07	2.17	3.45	0.67
$F_{4,27}$	0.60	3.46*	0.40	36.30**	1.62	3.10*
S E_m	0.113	0.096	0.113	0.020	0.125	0.135
CD(0.05)	–	0.279	–	0.058	–	0.392

** Significant at 1% level

* Significant at 5% level

and last phases in 99-00. At active growth phases in both the years, at all levels of N, higher NAR values were noted at k_1 or k_2. Further increments of K had a depressing effect, at all levels of N, especially at the last phase.

4.3.2.4 Crop growth rate (CGR)

The main and interaction effects of treatments on CGR during the different growth phases in both the years are presented in Tables 23a and 23b respectively.

Significantly highest CGR value was observed in o_2 applied plots at the second phase in 98-99 and initial phase in 99-00. Different levels of N also had significant effect on CGR at all phases except at the last phase in both the years. Highest dose of N (n_3) resulted in significantly higher CGR during the initial phase in both the years as well as the second phase in 99-00. At the second phase in 98-99, the medium level of this nutrient favoured CGR. Similar results were obtained for the effect of potassium in both the years.

It is clear from Table 23 b that interaction between organic manures and nitrogen was significant at all phases in both the years except at the final phase in 99-00. During the first two phases in both the years, organic manures in combination with higher levels of nitrogen enhanced CGR. However, at the second phase in 99-00, o_3 in combination with lowest level, n_1 resulted in higher CGR values. In the last phase in 98-99, except in plots that received o_1, mostly a declining trend was observed at higher levels of N. Interaction between organic manures and potassium was also significant except at the last phase in 98-99. At the active growth phases (2 - 4 and 4 - 6 months) in both the years, higher levels of K resulted in an increase in the CGR in combination with any of the organic manure. As in the case of N, the depressing effect of higher rates of potassium nutrition was conspicuous when combined with o_2 or o_3 at the final phase in both the years.

The significant effect of NxK interaction was evident at the second phase in 98-99 and first and last phases in 99-00. In general, at all levels of N, higher CGR values were obtained at highest or medium levels of K, except at the last phase in 99-00. At the last phase in 99-00, at n_3, the lowest dose of potassium (k_1) promoted CGR.

Table 23a. Influence of organic manures, nitrogen and potassium on crop growth rate

Main effect of factors	Crop growth rate (g m^{-2} day^{-1})					
	98-99			99-00		
	Phase 1	Phase 2	Phase3	Phase 1	Phase 2	Phase3
	2-4MAP	4-6MAP	6-8MAP	2-4MAP	4-6MAP	6-8MAP
o_1	3.38	7.31	2.67	1.92	8.83	1.91
o_2	3.91	9.61	3.02	2.03	9.83	2.80
o_3	3.48	8.16	2.66	1.80	8.96	2.19
$F_{2,2}$	3.29	111.99**	1.18	58.33*	5.22	1.77
S E_m	0.156	0.110	0.186	0.015	0.239	0.341
CD(0.05)	–	0.669	–	0.091	–	–
n_1	2.90	8.02	2.94	1.49	8.51	2.43
n_2	3.77	10.04	2.78	2.00	9.54	2.45
n_3	4.47	8.19	3.21	2.45	10.52	2.28
$F_{2,27}$	98.74**	54.49**	1.27	2900.90**	19.64**	0.18
S E_m	0.079	0.152	0.190	0.009	0.226	0.221
CD(0.05)	0.229	0.441	–	0.026	0.656	–
k_1	2.75	8.53	2.82	1.90	8.38	2.49
k_2	3.57	9.23	3.02	1.97	9.43	2.47
k_3	4.82	8.48	3.09	2.07	10.76	2.18
$F_{2,27}$	172.42**	7.69**	0.53	99.98**	27.78**	0.62
S E_m	0.079	0.152	0.190	0.009	0.226	0.221
CD(0.05)	0.229	0.441	–	0.026	0.656	–
Controls						
o_1 alone	2.45	4.65	1.18	1.35	5.88	1.45
o_2 alone	2.66	4.84	0.98	1.35	6.51	1.85
o_3 alone	2.44	5.10	0.96	1.29	6.63	1.31

** Significant at 1% level

* Significant at 5% level

Table 23b. Interaction effect of organic manures, nitrogen and potassium on crop growth rate

Interaction effects	Crop growth rate (g m^{-2} day^{-1})					
	98-99			99-00		
	Phase1	Phase2	Phase3	Phase1	Phase2	Phase3
	2-4MAP	4-6MAP	6-8MAP	2-4MAP	4-6MAP	6-8MAP
o_1n_1	2.31	7.53	2.10	1.51	8.31	2.24
o_1n_2	3.96	8.07	2.34	1.93	9.01	1.88
o_1n_3	4.19	7.22	4.06	2.50	10.15	1.76
o_2n_1	3.49	8.41	3.29	1.55	8.01	2.99
o_2n_2	3.84	11.33	3.91	2.24	10.98	3.53
o_2n_3	4.84	10.67	2.53	2.53	11.61	2.19
o_3n_1	2.90	8.11	3.43	1.41	9.21	2.05
o_3n_2	3.52	10.71	2.10	1.84	8.64	1.94
o_3n_3	4.38	6.68	3.03	2.32	9.79	2.88
$F_{4,27}$	6.32**	21.37**	8.93**	31.70**	6.09**	2.56
S E_m	0.137	0.263	0.329	0.016	0.392	0.382
CD (0.05)	0.398	0.763	0.955	0.046	1.138	–
o_1k_1	2.80	6.04	2.11	1.86	7.22	1.61
o_1k_2	3.36	8.32	2.96	1.90	8.82	2.10
o_1k_3	4.29	8.46	3.43	2.19	11.42	2.16
o_2k_1	2.67	10.36	3.06	1.94	8.99	2.50
o_2k_2	3.96	10.52	3.51	2.20	10.38	3.61
o_2k_3	5.54	9.54	3.16	2.18	11.24	2.60
o_3k_1	2.78	9.19	3.29	1.89	8.94	3.37
o_3k_2	3.39	8.87	2.59	1.82	9.08	1.72
o_3k_3	4.62	7.45	2.68	1.86	9.64	1.78
$F_{4,27}$	6.96**	17.60	2.69	63.75**	5.30**	4.28**
S E_m	0.137	0.263	0.329	0.016	0.392	0.382
CD (0.05)	0.398	0.763	–	0.046	1.138	1.109
n_1k_1	2.11	7.44	2.64	1.45	7.28	2.32
n_1k_2	2.80	8.33	2.91	1.49	7.94	2.22
n_1k_3	3.79	8.28	3.27	1.53	10.31	2.73
n_2k_1	2.70	10.33	2.77	1.88	8.59	2.29
n_2k_2	3.63	10.57	2.93	2.12	9.49	3.33
n_2k_3	4.98	9.21	2.65	2.01	10.55	1.73
n_3k_1	3.43	7.81	3.05	2.36	9.28	2.87
n_3k_2	4.29	8.80	3.22	2.31	10.85	1.87
n_3k_3	5.68	7.96	3.35	2.69	11.43	2.08
$F_{4,27}$	1.61	3.81*	0.39	72.29**	1.54	3.13*
S E_m	0.137	0.263	0.329	0.016	0.392	0.382
CD(0.05)	–	0.763	–	0.046	–	1.109

** Significant at 1% level
* Significant at 5% level

4.3.2.5 Relative growth rate (RGR)

Variation in RGR due to organic manures was not significant during the various growth phases in 98-99 and 99-00 (Table 24a). The effect of different levels of nitrogen on RGR was significant at all phases in both the years, except at the final phase in 99-00. Increasing levels of nitrogen significantly enhanced RGR with maximum values at n_3 at the first phase in both the years. However in the subsequent phases, highest values were obtained at n_1 and at higher levels of nitrogen a declining trend was observed. Potassium also exerted marked influence on RGR at the first and second phases in both the years. During the first phase in 98-99 and second phase in 99-00, incremental doses of potassium was found to enhance RGR significantly . At the other phases, k_1 recorded higher RGR values than the other levels.

Significant OxN interaction occurred at all stages, except at the last phase in 99-00. During the first two phases in 98-99, application of organic manures at higher rates of nitrogen tended to enhance RGR. Similar trend was observed at the first phase in the subsequent year. Towards the last phases in both the years, organic manures indicated favourable effects at n_1 itself. The interaction between organic manures and potassium was significant during the first and second phases in both the years. In 98-99, at the first phase, at the highest level of K, all organic manures resulted in significantly highest RGR. In the second phase, even k_1 promoted RGR in combination with any of the organic manure. At the last phase a depressing effect of higher levels of K was evident particularly with o_2 and o_3, though the effects were not significant. On the other hand, at the first phase in the second year, k_3 , k_2 or k_1 favoured RGR in combination with o_1 o_2 and o_3 respectively. At the next phase, higher levels of potassium in combination with organic manures tended to promote RGR (Table 24b).The interaction effect was not significant at the last phase in 99-00 also.

Interaction between nitrogen and potassium was significant only at the first two phases in 99-00. In general, at all levels of nitrogen, higher doses of potassium (k_2 or k_3) resulted in higher RGR.

Table 24a. Influence of organic manures, nitrogen and potassium on relative growth rate

Main effect of factors	Relative growth rate (mg g^{-1} day^{-1})					
	98-99			99-00		
	Phase1	Phase2	Phase3	Phase1	Phase2	Phase3
	2-4MAP	4-6MAP	6-8MAP	2-4MAP	4-6MAP	6-8MAP
o_1	26.96	17.22	3.39	21.91	24.55	2.63
o_2	28.42	18.83	3.15	22.27	25.38	3.40
o_3	27.67	18.04	3.22	21.89	25.77	2.90
$F_{2,2}$	1.37	1.52	0.48	1.27	4.49	0.82
SE_m	0.625	0.650	0.182	0.189	0.295	0.434
CD(0.05)	–	–	–	–	–	–
n_1	25.77	19.85	3.70	20.43	26.78	3.44
n_2	28.27	19.62	2.84	22.47	25.08	2.99
n_3	29.46	15.45	3.62	23.52	24.01	2.56
$F_{2,27}$	26.53**	34.94**	4.54*	215.09**	24.00**	2.19
SE_m	0.366	0.418	0.224	0.107	0.285	0.298
CD(0.05)	1.062	1.213	0.650	0.311	0.827	–
k_1	24.89	20.47	3.52	22.36	24.24	3.41
k_2	27.60	18.96	3.34	22.06	25.18	3.07
k_3	31.02	15.50	3.30	22.00	26.45	2.50
$F_{2,27}$	70.32**	37.14**	0.28	3.37*	15.22**	2.35
SE_m	0.366	0.418	0.224	0.107	0.285	0.298
CD(0.05)	1.062	1.213	–	0.311	0.827	–
Controls						
$o_{1\ alone}$	26.90	15.40	2.37	21.50	23.73	2.85
$o_{2\ alone}$	26.37	14.92	1.89	20.48	24.73	3.29
$o_{3\ alone}$	25.71	16.21	1.85	20.93	25.70	2.40

** Significant at 1 % level
* Significant at 5% level

Table 24b. Interaction effect of organic manures, nitrogen and potassium on relative growth rate

Interaction effects	Relative growth rate (mg g^{-1} day^{-1})					
	98-99			99-00		
	Phase1	Phase2	Phase3	Phase1	Phase2	Phase3
	2-4MAP	4-6MAP	6-8MAP	2-4MAP	4-6MAP	6-8MAP
o_1n_1	23.30	21.01	2.98	20.54	26.09	3.23
o_1n_2	28.87	16.85	2.72	21.61	24.43	2.59
o_1n_3	28.74	14.42	4.82	23.73	23.39	1.99
o_2n_1	27.63	18.90	3.86	20.61	25.58	4.30
o_2n_2	28.20	20.93	3.64	23.27	25.82	3.69
o_2n_3	30.12	17.95	2.37	23.52	24.95	2.26
o_3n_1	26.38	19.63	4.28	20.16	28.66	2.78
o_3n_2	27.75	21.10	2.16	22.53	24.99	2.68
o_3n_3	29.53	14.00	3.69	23.30	23.69	3.42
$F_{4,27}$	4.51**	8.69**	8.23**	8.14**	5.86**	1.99
S E_m	0.634	0.725	0.388	0.185	0.494	0.517
CD (0.05)	1.840	2.104	1.126	0.537	1.434	–
o_1k_1	24.89	16.95	3.31	21.95	22.62	2.60
o_1k_2	26.73	18.61	3.49	21.51	24.48	2.88
o_1k_3	29.29	16.72	3.72	22.41	26.81	2.33
o_2k_1	24.28	23.24	3.34	22.19	24.70	3.39
o_2k_2	28.84	19.30	3.47	23.02	25.33	3.97
o_2k_3	32.84	15.24	3.05	22.18	26.33	2.89
o_3k_1	25.51	21.22	3.92	22.94	25.39	4.23
o_3k_2	27.22	18.97	3.06	21.64	25.73	2.37
o_3k_3	30.92	14.53	3.14	21.41	26.22	2.28
$F_{4,27}$	3.25*	8.69**	0.90	14.62**	3.20*	1.80
S E_m	0.634	0.725	0.388	0.185	0.494	0.517
CD (0.05)	1.840	2.104	–	0.537	1.434	–
n_1k_1	22.76	21.53	3.71	20.90	25.29	3.69
n_1k_2	25.53	20.33	3.62	20.36	25.99	3.33
n_1k_3	29.02	17.67	3.77	20.04	29.06	3.30
n_2k_1	25.04	22.88	2.93	22.40	24.55	3.10
n_2k_2	28.08	20.24	2.95	23.06	24.48	3.82
n_2k_3	31.70	15.76	2.65	21.95	26.21	2.04
n_3k_1	26.87	16.99	3.93	23.79	22.87	3.43
n_3k_2	29.18	16.31	3.45	22.75	25.07	2.07
n_3k_3	32.34	13.06	3.49	24.01	24.08	2.16
$F_{4,27}$	0.23	1.70	0.21	12.32**	5.09**	1.49
S E_m	0.634	0.725	0.388	0.185	0.494	0.517
CD(0.05)	–	–	–	0.537	1.434	–

** Significant at 1% level

* Significant at 5% level

4.3.2.6 Tuber bulking rate (TBR)

Tuber development was not appreciable at 4th month in 99-00, due to delayed tuberisation. Hence tuber bulking rates for the peak tuber enlargement phase (6-8 months) in 98-99 and 99-00 are furnished in Table 25a. Organic manures, nitrogen and potassium had no significant impact on tuber bulking rate at this phase in either of the years.

As depicted in Table 25b, the variation in tuber bulking rates due to OxN interaction was significant, in 98-99 at the peak tuber growth phase. Higher bulking rates were observed in o_1 applied plots upto n_3, in o_2 upto n_2 and in o_3 at n_1. The interaction, OxK was significant at this phase in both the years. Bulking rates were favoured at k_1 in o_1 or o_3 applied plots, and at k_2 in o_2 treated plots. The interaction between nitrogen and potassium was significant in 99-00. Response was noticed upto k_3 at lowest level of nitrogen, upto k_2 at medium dose of nitrogen and only at k_1 with highest level of nitrogen.

4.3.2.7 Harvest index (HI)

The main effect of treatments on harvest index during the two years of experimentation are summarised in Table 26a.

Organic manures had no significant influence on harvest index during both the years. However, o_2 registered highest values (0.68 and 0.63 respectively). Significantly highest HI was obtained at the medium level of nitrogen (0.70) in 98-99. However, the difference in HI between the levels of nitrogen was not significant in the subsequent year. Highest value for HI was recorded at k_3 in both the years (0.70 and 0.66 respectively). In 98-99, the difference in HI between k_2 and k_1 was significant, whereas k_2 and k_3 were on par. However in the subsequent year, incremental rates of potassium significantly enhanced HI, with maximum values attained at k_3.

Table 25a. Influence of organic manures, nitrogen and potassium on tuber bulking rate at peak tuber enlargement phase

Main effect of factors	Tuber bulking rate (g day^{-1}) Phase 3 (6-8 MAP)	
	98-99	99-00
o_1	2.95	2.38
o_2	3.10	2.94
o_3	2.69	2.11
$F_{2,2}$	1.76	4.40
SE_m	0.157	0.202
n_1	3.04	2.62
n_2	2.91	2.65
n_3	3.25	2.33
$F_{2,27}$	1.25	1.65
SE_m	0.151	0.137
k_1	2.94	2.53
k_2	3.11	2.65
k_3	3.16	2.42
$F_{2,27}$	0.58	0.7
SE_m	0.151	10.137
Controls		
$o_{1\ alone}$	1.48	1.83
$o_{2\ alone}$	1.46	2.16
$o_{3\ alone}$	1.60	1.75

Table 25b. Interaction effect of organic manures,nitrogen and potassium on tuber bulking rate

Interaction effects	Tuber bulking rate (g day^{-1}) Phase 3 (6-8 MAP)	
	98-99	99-00
o_1n_1	2.50	2.62
o_1n_2	2.74	2.43
o_1n_3	4.09	2.27
o_2n_1	3.33	3.08
o_2n_2	3.83	3.54
o_2n_3	2.70	2.45
o_3n_1	3.30	2.16
o_3n_2	2.18	2.00
o_3n_3	2.95	2.28
$F_{4,27}$	9.50**	2.25
S E_m	0.262	0.238
CD (0.05)	0.760	–
o_1k_1	2.53	2.17
o_1k_2	3.21	2.54
o_1k_3	3.59	2.61
o_2k_1	3.14	2.69
o_2k_2	3.50	3.60
o_2k_3	3.22	2.78
o_3k_1	3.16	2.73
o_3k_2	2.61	1.83
o_3k_3	2.67	1.88
$F_{4,27}$	2.77*	4.61**
S E_m	0.262	0.238
CD (0.05)	0.760	0.691
n_1k_1	2.80	2.54
n_1k_2	3.02	2.47
n_1k_3	3.32	2.84
n_2k_1	2.90	2.52
n_2k_2	3.04	3.37
n_2k_3	2.81	2.08
n_3k_1	3.12	2.52
n_3k_2	3.26	2.12
n_3k_3	3.36	2.36
$F_{4,27}$	0.41	4.17**
S E_m	0.262	0.238
CD(0.05)	–	0.691

** Significant at 1% level
*Significant at 5% level

Table 26a . Effect of organic manures ,nitrogen and potassium on harvest index

Main effect of factors	Harvest index	
	98-99	99-00
o_1	0.65	0.62
o_2	0.68	0.63
o_3	0.66	0.62
$F_{2,2}$	13.00	1.00
$S\,E_m$	0.001	0.005
CD(0.05)	–	–
n_1	0.68	0.63
n_2	0.70	0.64
n_3	0.66	0.64
$F_{2,27}$	23.31**	2.12
$S\,E_m$	0.005	0.005
CD(0.05)	0.015	–
k_1	0.65	0.61
k_2	0.69	0.64
k_3	0.70	0.66
$F_{2,27}$	24.60**	21.15**
$S\,E_m$	0.005	0.005
CD(0.05)	0.015	0.015
Controls		
o_1 alone	0.51	0.49
o_2 alone	0.54	0.54
o_3 alone	0.54	0.52

** Significant at 1% level

Table 26b . Interaction effect of organic manures ,nitrogen and potassium on harvest index

Interaction effects	Harvest index	
	98-99	99-00
o_1n_1	0.65	0.63
o_1n_2	0.67	0.64
o_1n_3	0.66	0.64
o_2n_1	0.69	0.61
o_2n_2	0.73	0.67
o_2n_3	0.68	0.65
o_3n_1	0.70	0.65
o_3n_2	0.70	0.61
o_3n_3	0.63	0.64
$F_{4,27}$	8.42**	7.93**
SE_m	0.008	0.009
CD (0.05)	0.023	0.026
o_1k_1	0.59	0.58
o_1k_2	0.68	0.64
o_1k_3	0.71	0.70
o_2k_1	0.68	0.61
o_2k_2	0.71	0.66
o_2k_3	0.71	0.66
o_3k_1	0.69	0.66
o_3k_2	0.67	0.61
o_3k_3	0.67	0.63
$F_{4,27}$	20.72**	20.62**
SE_m	0.008	0.009
CD (0.05)	0.023	0.026
n_1k_1	0.64	0.60
n_1k_2	0.68	0.61
n_1k_3	0.71	0.68
n_2k_1	0.68	0.62
n_2k_2	0.71	0.66
n_2k_3	0.71	0.65
n_3k_1	0.63	0.63
n_3k_2	0.66	0.64
n_3k_3	0.67	0.66
$F_{4,27}$	1.94	5.82**
SE_m	0.008	0.009
CD(0.05)	–	0.026

** Significant at 1% level
* Significant at 5% level

Interaction effects are furnished in Table 26b. The variation in HI due to OxN interaction was significant during both the years. Plots that received o_1 or o_2 had higher values of HI at medium levels of nitrogen in both the years. But o_3 attained maximum values at n_1. Influence of OxK interaction on HI was significant in both the years. In the case of o_1, maximum value was registered at k_3, in o_2 and o_3 significantly higher values were obtained at k_2 and k_1 respectively in both the years. The interaction, NxK was significant only in the second year. Higher levels of K (k_2 or k_3) resulted in higher HI values irrespective of the levels of applied nitrogen.

4.3.2.8 Light infiltration

The effect of organic manures, levels of nitrogen and potassium on the interception of photosynthetically active radiation (PAR) at the crop canopy was not significant at almost all stages in both the years. However, at 4th month in 99-00, levels of nitrogen imparted significant influence and incremental doses of nitrogen resulted in significant increase in the interception of PAR with maximum values at n_3 (501.28 $\mu E\ m^{-2}\ s^{-1}$) (Table 27 a).

As depicted in Table 27b, the interactions, OxN, OxK, or NxK also could not significantly affect the interception rates at all the stages during the two years of experimentation, except OxN interaction effect which was significant at 4th month in 99-00. At this stage, in the case of o_1, medium level of nitrogen resulted in higher interception and with o_3, all the levels of nitrogen had similar effects. In the case of o_2, increasing levels of nitrogen significantly enhanced the interception of PAR, with maximum interception attained at n_3.

4.3.2.9 Chlorophyll content

4.3.2.9.1 Chlorophyll 'a'

It is clear from Table 28a that organic manures and potassium could not profoundly influence the chlorophyll 'a' content at various growth stages in 98-99 and 99-00. The effect of nitrogen was significant at the active growth stages in both the years (4th and 6th months in 98-99 and 6th month in 99-00). At these stages, higher rates of applied nitrogen (n_2 or n_3) was found to enhance chlorophyll 'a' content. However at 6th month in both the years, no significant difference was observed between n_2 and n_3 levels.

Table 27a. Interception of photosynthetically active radiation as influenced by organic manures, nitrogen and potassium

Main effect of factors	Photosynthetically active radiation (μ $Em^{-2}s^{-1}$)							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	379.50	230.25	229.25	270.05	460.45	406.40	268.70	268.05
o_2	569.30	231.35	266.35	320.20	775.00	394.85	257.80	275.90
o_3	454.05	218.55	245.85	226.25	524.70	386.55	178.20	298.05
$F_{2,2}$	0.81	0.13	1.12	6.47	3.83	0.23	0.52	0.61
SE_m	106.240	19.757	17.581	18.479	84.909	20.958	68.563	19.962
n_1	479.00	204.11	244.94	261.28	618.67	283.67	249.50	273.17
n_2	580.61	246.06	242.17	330.17	697.67	390.00	256.39	301.67
n_3	354.67	264.78	249.17	262.22	498.61	501.28	167.00	283.89
$F_{2,27}$	4.32	1.50	0.03	0.78	1.95	9.89**	0.58	0.54
SE_m	54.450	25.369	20.971	44.712	71.790	34.597	65.087	19.677
CD(0.05)	–	–	–	–	–	100.400	–	–
k_1	365.28	206.39	234.61	259.00	568.61	345.22	287.39	267.50
k_2	514.06	210.33	260.56	293.00	610.00	370.67	203.67	289.00
k_3	534.94	298.22	241.11	301.67	636.33	459.06	181.83	302.22
$F_{2,27}$	2.89	4.19	0.41	0.25	0.23	2.98	0.73	0.79
SE_m	54.450	25.369	20.971	44.712	71.790	34.597	65.087	19.677
Controls								
o_1 alone	270.50	128.50	277.00	158.00	376.50	318.00	517.00	230.50
o_2 alone	511.50	134.50	234.00	128.50	411.00	634.50	257.00	196.00
o_3 alone	518.00	104.00	277.00	195.50	479.50	351.00	217.00	265.00

**Significant at 1% level

Table 27b. Interaction effect of organic manures, nitrogen and potassium on photosynthetically active radiation

Interaction effects	Photosynthetically active radiation ($\mu E m^{-2} s^{-1}$)							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1n_1	403.67	199.50	205.67	338.83	458.67	263.33	284.83	290.00
o_1n_2	383.33	276.50	249.33	385.33	590.83	423.17	305.83	321.50
o_1n_3	387.83	248.67	216.83	123.34	359.83	562.17	132.67	205.17
o_2n_1	661.00	210.50	277.83	262.67	826.17	186.67	333.67	247.83
o_2n_2	705.00	194.67	254.50	306.67	935.83	367.17	285.50	268.17
o_2n_3	361.17	321.17	277.50	455.17	684.33	550.83	154.50	338.33
o_3n_1	372.33	202.33	251.33	182.33	571.17	401.00	130.00	281.67
o_3n_2	653.50	267.00	222.67	298.50	566.33	379.67	177.83	315.33
o_3n_3	315.00	224.50	253.17	208.17	451.67	390.83	213.83	308.17
$F_{4,27}$	1.66	1.15	0.36	2.40	0.12	2.80*	0.47	2.40
SE_m	94.310	43.940	36.324	77.444	124.344	59.924	112.735	34.081
CD (0.05)	–	–	–	–	–	173.900	–	–
o_1k_1	264.00	192.00	230.67	270.34	484.50	346.83	283.00	256.67
o_1k_2	378.83	241.83	236.00	270.00	463.83	373.50	243.67	270.67
o_1k_3	532.00	290.83	205.17	307.17	461.00	528.33	196.67	289.33
o_2k_1	504.50	163.17	226.83	334.17	751.17	376.50	275.17	255.17
o_2k_2	534.50	200.50	308.17	411.17	824.00	330.50	266.33	312.67
o_2k_3	688.17	362.67	274.83	279.17	871.17	397.67	232.17	286.50
o_3k_1	327.33	264.00	246.33	172.50	470.17	312.33	304.00	290.67
o_3k_2	628.83	188.67	237.50	197.83	542.17	408.00	101.00	283.67
o_3k_3	384.67	241.17	243.33	318.67	576.83	451.17	116.67	330.83
$F_{4,27}$	1.56	1.84	0.54	0.79	0.11	0.71	0.23	0.36
SE_m	94.310	43.940	36.324	77.444	124.344	59.924	112.735	34.081
CD (0.05)	–	–	–	–	–	–	–	–
n_1k_1	397.33	174.67	284.00	218.67	581.33	261.17	383.17	257.00
n_1k_2	389.50	184.83	257.33	232.33	639.83	299.50	214.67	282.00
n_1k_3	650.17	252.83	193.50	332.83	634.83	290.33	150.67	280.50
n_2k_1	483.67	251.83	234.67	298.67	677.00	390.67	238.00	304.83
n_2k_2	771.00	241.67	259.17	431.67	713.50	367.67	281.83	301.33
n_2k_3	487.17	244.67	232.67	260.17	702.50	411.67	249.33	298.83
n_3k_1	214.83	192.67	185.17	259.67	447.50	383.83	241.00	240.67
n_3k_2	381.67	204.50	265.17	215.00	476.67	444.83	114.50	283.67
n_3k_3	467.50	397.17	297.17	312.00	571.67	675.17	145.50	327.33
$F_{4,27}$	2.25	1.79	1.96	1.07	0.07	1.92	0.39	0.50
SE_m	94.310	43.940	36.324	77.444	124.344	59.924	112.735	34.081
CD(0.05)	–	–	–	–	–	–	–	–

* Significant at 5% level

Table28a. Effect of organic manures, nitrogen and potassium on chlorophyll a content

Main effect of factors	Chlorophyll a (mg g^{-1})							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	1.78	1.88	2.07	1.26	1.61	1.90	2.06	1.27
o_2	1.80	1.93	2.13	1.32	1.67	1.95	2.18	1.31
o_3	1.78	1.88	1.96	1.31	1.61	1.93	2.13	1.28
$F_{2,2}$	1.40	5.00	2.51	9.25	0.07	0.14	3.28	8.00
S E_m	0.011	0.012	0.055	0.010	0.134	0.070	0.034	0.009
CD(0.05)	–	–	–	–	–	–	–	–
n_1	1.79	1.89	2.02	1.29	1.67	2.00	2.07	1.27
n_2	1.81	1.92	2.08	1.29	1.60	1.97	2.21	1.27
n_3	1.82	1.95	2.17	1.34	1.71	1.99	2.27	1.32
$F_{2,27}$	2.09	10.89**	4.69*	2.36	0.48	0.12	6.94**	0.84
S E_m	0.013	0.010	0.036	0.021	0.074	0.050	0.041	0.022
CD(0.05)	–	0.030	0.104	–	–	–	0.119	–
k_1	1.79	1.92	2.08	1.33	1.75	1.99	2.19	1.32
k_2	1.81	1.92	2.08	1.29	1.64	1.99	2.16	1.27
k_3	1.83	1.92	2.12	1.30	1.58	1.97	2.21	1.28
$F_{2,27}$	2.44	0.00	0.37	0.61	1.39	0.09	0.44	0.66
S E_m	0.013	0.010	0.036	0.021	0.074	0.050	0.041	0.022
CD(0.05)	–	–	–	–	–	–	–	–
Controls								
$o_{1\ alone}$	1.58	1.65	1.70	1.20	1.14	1.35	1.57	1.22
$o_{2\ alone}$	1.55	1.65	1.70	1.30	1.44	1.36	1.61	1.28
$o_{3\ alone}$	1.65	1.66	1.65	1.20	1.59	1.49	1.60	1.25

** Significant at 1% level
* Significant at 5% level

Table 28b. Interaction effect of organic manures, nitrogen and potassum on chlorophyll a contents

Interaction effects	Chlorophyll a (mg g^{-1})							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1n_1	1.73	1.86	2.09	1.23	1.68	1.89	1.96	1.24
o_1n_2	1.83	1.93	2.10	1.28	1.63	1.99	2.16	1.28
o_1n_3	1.85	1.92	2.14	1.30	1.69	1.99	2.23	1.29
o_2n_1	1.83	1.88	2.03	1.28	1.74	1.96	2.18	1.31
o_2n_2	1.82	1.93	2.15	1.29	1.64	1.98	2.27	1.25
o_2n_3	1.83	2.05	2.34	1.40	1.73	2.10	2.29	1.39
o_3n_1	1.80	1.92	1.93	1.35	1.59	2.15	2.07	1.28
o_3n_2	1.78	1.90	2.00	1.29	1.54	1.92	2.21	1.30
o_3n_3	1.79	1.89	2.04	1.34	1.70	1.88	2.31	1.29
$F_{4,27}$	3.05	9.57**	1.22	1.15	0.07	2.18	0.39	0.33
SE_m	0.022	0.018	0.061	0.037	0.127	0.083	0.070	0.037
CD (0.05)	–	0.052	–	–	–	–	–	–
o_1k_1	1.78	1.90	2.11	1.29	1.88	1.95	2.07	1.31
o_1k_2	1.82	1.91	2.14	1.29	1.75	2.02	2.10	1.27
o_1k_3	1.81	1.90	2.08	1.23	1.38	1.89	2.18	1.23
o_2k_1	1.81	1.96	2.19	1.31	1.84	2.00	2.28	1.30
o_2k_2	1.84	1.96	2.09	1.29	1.54	1.98	2.30	1.29
o_2k_3	1.84	1.95	2.24	1.37	1.73	2.05	2.17	1.36
o_3k_1	1.77	1.91	1.93	1.38	1.54	2.02	2.23	1.34
o_3k_2	1.78	1.89	2.00	1.31	1.64	1.98	2.07	1.26
o_3k_3	1.83	1.91	2.04	1.29	1.64	1.96	2.28	1.25
$F_{4,27}$	0.52	0.40	1.09	1.49	2.19	0.44	1.89	0.33
SE_m	0.022	0.018	0.061	0.037	0.127	0.083	0.070	0.037
n_1k_1	1.77	1.89	2.08	1.30	1.66	1.95	2.17	1.30
n_1k_2	1.80	1.89	1.95	1.29	1.81	2.00	2.02	1.27
n_1k_3	1.79	1.88	2.03	1.27	1.54	2.05	2.02	1.25
n_2k_1	1.79	1.93	2.04	1.28	1.82	2.05	2.21	1.29
n_2k_2	1.81	1.92	2.09	1.30	1.50	1.93	2.16	1.30
n_2k_3	1.84	1.92	2.12	1.28	1.50	1.92	2.27	1.23
n_3k_1	1.80	1.95	2.13	1.39	1.79	1.98	2.19	1.37
n_3k_2	1.83	1.95	2.19	1.30	1.62	2.06	2.29	1.25
n_3k_3	1.84	1.96	2.20	1.35	1.71	1.93	2.34	1.35
$F_{4,27}$	0.26	0.27	0.76	0.67	1.14	0.81	1.48	0.42
SE_m	0.022	0.018	0.061	0.037	0.127	0.083	0.070	0.037

** Significant at 1% level

As shown in Table 28 b, except OxN interaction which was significant at 4^{th} month in 98-99, the other interactions were not significant throughout the period of experimentation. In the case of OxN interaction, o_1 and o_2 registered significantly higher chlorophyll 'a' content at medium (n_2) and highest levels of nitrogen (n_3) respectively at the above stage. However, in the case of o_3, n_1 recorded the highest content, and was found to be equally effective as the higher levels, n_2 and n_3.

4.3.2.9.2 Chlorophyll 'b'

The main and interaction effects of treatments on chlorophyll 'b' content at different growth stages in 98-99 and 99-00 are presented in Tables 29a and 29b respectively.

The different organic manures had similar effects on chlorophyll 'b' content in both the years. The variation in chlorophyll 'b' content due to different levels of nitrogen was significant at 2^{nd} month in 98-99 and at 8^{th} month in 98-99 and 99-00. In the 2^{nd} month in 98-99, a significant increase in chlorophyll 'b' content was seen with an increase in N upto n_2 level. Increasing rates of N resulted in higher chlorophyll 'b' content at 8^{th} month in both the years, though no significant difference in chlorophyll 'b' content was observed between n_2 and n_3 levels in 99-00. The effect of potassium was not significant in both the years, except at the final stage in 99-00. At this stage, k_1 and k_2 were on a par each other but superior to k_3.

Considering OxN interaction, at 8^{th} month in 98-99, significantly higher response was observed at n_1 in o_1 applied plots, n_2 in o_2 applied plots and at n_3 in o_3 treated plots. At this stage in the subsequent year, in o_1 and o_2 applied plots, higher rates of N nutrition (n_2 or n_3) tended to enhance chlorophyll 'b' content, but in o_3 applied plots, maximum values were obtained even at n_1. The interaction between organic manures and potassium had significant impact on chlorophyll 'b' content only at the final stage in the second year, higher chlorophyll 'b' content was noticed at k_1 level when combined with any of the organic manure. The interaction between nitrogen and potassium could not profoundly influence the chlorophyll 'b' content throughout the period of experimentation.

Table 29a. Effect of organic manures, nitrogen and potassium on chlorophyll b content

Main effect of factors	Chlorophyll b (mg g^{-1})							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	0.57	0.74	0.88	0.59	0.65	0.72	0.87	0.63
o_2	0.57	0.82	0.84	0.64	0.66	0.75	0.84	0.61
o_3	0.57	0.71	0.86	0.62	0.66	0.83	0.90	0.57
$F_{2,2}$	0.00	10.58	0.18	1.11	0.25	8.50	0.13	10.25
SE_m	0.007	0.017	0.041	0.027	0.010	0.021	0.086	0.010
n_1	0.54	0.75	0.85	0.59	0.64	0.78	0.88	0.57
n_2	0.58	0.77	0.90	0.63	0.67	0.79	0.91	0.62
n_3	0.59	0.79	0.90	0.66	0.68	0.81	0.89	0.64
$F_{2,27}$	5.10*	2.68	2.93	19.33**	2.67	0.97	0.35	20.21**
SE_m	0.012	0.014	0.018	0.008	0.014	0.019	0.030	0.008
CD(0.05)	0.035	–	–	0.022	–	–	–	0.024
k_1	0.59	0.79	0.88	0.63	0.69	0.82	0.92	0.62
k_2	0.56	0.76	0.89	0.64	0.65	0.80	0.89	0.62
k_3	0.56	0.76	0.88	0.62	0.65	0.77	0.88	0.59
$F_{2,27}$	1.37	1.19	0.17	1.49	2.38	2.25	0.48	3.57
SE_m	0.012	0.014	0.018	0.008	0.014	0.019	0.030	0.008
Controls								
$o_{1\ alone}$	0.58	0.60	0.65	0.51	0.62	0.52	0.59	0.47
$o_{2\ alone}$	0.56	0.59	0.65	0.55	0.62	0.45	0.65	0.57
$o_{3\ alone}$	0.55	0.60	0.65	0.54	0.58	0.53	0.69	0.51

** Significant at 1% level

* Significant at 5% level

Table 29b. Interaction effect of organic manures, nitrogen and potassium on chlorophyll b content

Interaction effects	Chlorophyll b content (mg g^{-1})							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1n_1	0.55	0.69	0.84	0.64	0.65	0.72	0.81	0.56
o_1n_2	0.59	0.74	0.94	0.58	0.67	0.73	0.97	0.69
o_1n_3	0.57	0.83	0.92	0.57	0.65	0.76	0.91	0.69
o_2n_1	0.52	0.85	0.84	0.57	0.63	0.71	0.85	0.55
o_2n_2	0.58	0.85	0.86	0.70	0.67	0.77	0.84	0.59
o_2n_3	0.62	0.82	0.89	0.70	0.69	0.85	0.89	0.71
o_3n_1	0.55	0.70	0.87	0.58	0.64	0.90	0.97	0.61
o_3n_2	0.56	0.72	0.91	0.62	0.68	0.88	0.92	0.57
o_3n_3	0.59	0.73	0.88	0.71	0.70	0.83	0.88	0.54
$F_{4,27}$	1.27	3.05*	0.77	24.79**	0.52	2.50	1.58	24.18**
S E_m	0.021	0.024	0.031	0.013	0.024	0.032	0.051	0.015
CD (0.05)	–	0.069	–	0.038	–	–	–	0.044
o_1k_1	0.61	0.77	0.89	0.62	0.71	0.78	0.96	0.66
o_1k_2	0.57	0.72	0.92	0.61	0.65	0.74	0.87	0.66
o_1k_3	0.53	0.77	0.90	0.57	0.61	0.70	0.86	0.61
o_2k_1	0.58	0.84	0.86	0.65	0.66	0.80	0.88	0.60
o_2k_2	0.57	0.85	0.88	0.67	0.64	0.77	0.89	0.62
o_2k_3	0.57	0.84	0.84	0.64	0.68	0.77	0.81	0.63
o_3k_1	0.56	0.75	0.89	0.61	0.69	0.89	0.91	0.60
o_3k_2	0.55	0.72	0.87	0.64	0.66	0.89	0.90	0.58
o_3k_3	0.59	0.69	0.90	0.65	0.66	0.84	0.96	0.54
$F_{4,27}$	2.06	1.12	0.39	2.74	1.63	0.28	0.80	2.78*
S E_m	0.021	0.024	0.031	0.013	0.024	0.032	0.051	0.015
CD (0.05)	–	–	–	–	–	–	–	0.044
n_1k_1	0.54	0.75	0.83	0.60	0.64	0.79	0.86	0.59
n_1k_2	0.52	0.75	0.87	0.60	0.65	0.80	0.88	0.58
n_1k_3	0.56	0.75	0.84	0.58	0.63	0.75	0.89	0.54
n_2k_1	0.59	0.79	0.90	0.62	0.70	0.81	0.91	0.61
n_2k_2	0.59	0.76	0.91	0.65	0.64	0.79	0.91	0.62
n_2k_3	0.54	0.76	0.89	0.64	0.68	0.78	0.91	0.62
n_3k_1	0.62	0.82	0.90	0.66	0.73	0.87	0.98	0.66
n_3k_2	0.58	0.78	0.89	0.67	0.67	0.80	0.87	0.66
n_3k_3	0.58	0.78	0.91	0.66	0.64	0.77	0.83	0.62
$F_{4,27}$	1.57	0.30	0.34	0.74	1.26	0.52	1.00	1.78
S E_m	0.021	0.024	0.031	0.013	0.024	0.032	0.051	0.015

** Significant at 1% level
* Significant at 5% level

4.3.2.9.3 Total chlorophyll

Perusal of the data in Table 30 a indicates that the variation in the total chlorophyll content due to different organic manures was not significant at various growth stages in both the years.

The effect of nitrogen levels was significant at all the stages in the first year and towards the final stages (6th month and 8th month) in the second year. Significantly higher content was obtained at higher levels of N (n_2 or n_3) at these stages. Different levels of potassium could not significantly affect the total chlorophyll content in either of the years.

Interaction effects are furnished in Table 30 b. The interaction effect, OxN was significant at 4th month in 99-00 and at final stages in both the years. In general, when combined with organic manures, even n_1 level recorded higher total chlorophyll content at most of the stages. However at the last phase in the second year, in o_1 and o_2 treated plots, significant response was noticed at n_2 and n_3 respectively. The interactions, OxK, and NxK were not significant in both the years..

4.3.2.10 Proline content

Organic manures, different levels of nitrogen and potassium, either independently or in combination, did not significantly influence the proline content at the active growth stage (5th month) in both the years. (Table 31). However, an increasing trend in proline content at higher rates of nitrogen or potassium was conspicuous in both the years.

4.3.3 Yield components and yield

4.3.3.1 Tuber weight

The effect of treatments on tuber weight for the two years of experimentation are presented in Tables 32a and 32b.

The various organic sources had similar effects in promoting tuber weight in both the years. Application of o_2 resulted in higher tuber weight. The effect of nitrogen was significant

Table 30a. Effect of organic manures, nitrogen and potassium on total chlorophyll content

Main effect of factors	Total chlorophyll (mg g^{-1})							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	2.35	2.62	2.94	1.85	2.27	2.61	2.98	1.89
o_2	2.37	2.74	2.97	1.96	2.33	2.69	3.02	1.92
o_3	2.34	2.58	2.82	1.94	2.27	2.77	3.03	1.85
$F_{2,2}$	0.90	17.31	1.15	8.13	0.06	0.79	0.05	19.33
SE_m	0.016	0.020	0.075	0.020	0.143	0.088	0.140	0.009
n_1	2.33	2.64	2.87	1.88	2.31	2.78	2.94	1.84
n_2	2.39	2.69	2.98	1.92	2.28	2.76	3.13	1.89
n_3	2.41	2.75	3.07	2.00	2.39	2.80	3.22	1.97
$F_{2,27}$	7.27**	9.02**	7.33**	6.42**	0.52	0.18	5.48*	6.81*
SE_m	0.017	0.019	0.038	0.025	0.079	0.054	0.060	0.024
CD(0.05)	0.049	0.054	0.110	0.073	–	–	0.174	0.069
k_1	2.37	2.71	2.96	1.95	2.44	2.81	3.11	1.94
k_2	2.37	2.68	2.97	1.93	2.29	2.79	3.10	1.89
k_3	2.39	2.68	2.99	1.92	2.23	2.73	3.08	1.87
$F_{2,27}$	0.20	0.65	0.25	0.40	1.84	0.56	0.04	2.12
SE_m	0.017	0.019	0.038	0.025	0.079	0.054	0.06	0.024
Controls								
o_1 alone	2.16	2.25	2.35	1.71	1.76	1.87	2.15	1.69
o_2 alone	2.11	2.23	2.35	1.85	2.06	1.81	2.26	1.82
o_3 alone	2.20	2.26	2.30	1.74	2.17	2.01	2.29	1.76

** Significant at 1% level
* Significant at 5% level

Table 30b. Interaction effect of organic manures, nitrogen and potassium on total chlorophyll contents

Interaction effects	Total chlorophyll content (mg g^{-1})							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1n_1	2.28	2.55	2.93	1.87	2.32	2.61	2.77	1.79
o_1n_2	2.42	2.67	3.04	1.87	2.31	2.72	3.13	1.97
o_1n_3	2.42	2.74	3.06	1.87	2.35	2.75	3.30	1.98
o_2n_1	2.35	2.74	2.87	1.84	2.37	2.67	3.02	1.86
o_2n_2	2.40	2.78	3.00	1.99	2.30	2.76	3.11	1.84
o_2n_3	2.45	2.88	3.23	2.10	2.41	2.94	3.18	2.10
o_3n_1	2.35	2.62	2.79	1.93	2.23	3.05	3.04	1.88
o_3n_2	2.35	2.62	2.91	1.90	2.22	2.80	3.13	1.86
o_3n_3	2.38	2.62	2.92	2.05	2.40	2.71	3.18	1.82
$F_{4,27}$	1.99	2.54	1.24	2.92*	0.11	3.19*	1.16	6.37**
SE_m	0.029	0.032	0.066	0.043	0.137	0.093	0.105	0.041
CD (0.05)	–	–	–	0.125	–	0.269	–	0.119
o_1k_1	2.40	2.67	3.00	1.91	2.59	2.73	3.02	1.97
o_1k_2	2.39	2.63	3.06	1.89	2.40	2.76	3.14	1.93
o_1k_3	2.34	2.67	2.97	1.81	1.99	2.59	3.04	1.84
o_2k_1	2.39	2.80	3.05	1.96	2.50	2.80	3.16	1.90
o_2k_2	2.41	2.81	2.97	1.96	2.18	2.75	3.18	1.92
o_2k_3	2.41	2.79	3.08	2.01	2.41	2.82	2.98	1.99
o_3k_1	2.33	2.66	2.82	1.99	2.24	2.90	3.14	1.94
o_3k_2	2.33	2.60	2.87	1.95	2.31	2.86	2.97	1.84
o_3k_3	2.41	2.60	2.93	1.94	2.30	2.79	3.24	1.79
$F_{4,27}$	1.99	0.48	0.87	1.10	2.38	0.46	1.67	2.62
SE_m	0.029	0.032	0.066	0.043	0.137	0.093	0.105	0.041
n_1k_1	2.31	2.65	2.90	1.90	2.30	2.74	3.03	1.89
n_1k_2	2.32	2.64	2.83	1.89	2.46	2.79	2.90	1.85
n_1k_3	2.35	2.62	2.87	1.85	2.17	2.80	2.90	1.79
n_2k_1	2.38	2.71	2.94	1.90	2.51	2.86	3.13	1.89
n_2k_2	2.40	2.68	3.00	1.95	2.14	2.72	3.07	1.93
n_2k_3	2.39	2.68	3.01	1.91	2.18	2.70	3.18	1.86
n_3k_1	2.42	2.77	3.03	2.05	2.52	2.85	3.17	2.03
n_3k_2	2.40	2.73	3.08	1.96	2.29	2.86	3.33	1.90
n_3k_3	2.42	2.75	3.11	2.00	2.35	2.70	3.17	1.97
$F_{4,27}$	0.35	0.12	0.40	0.67	1.13	0.64	0.75	1.26
SE_m	0.029	0.032	0.066	0.043	0.137	0.093	0.105	0.041

** Significant at 1% level

* Significant at 5% level

Table 31. Effect of organic manures , nitrogen and potassium . on proline content

Main effect of factors	Proline content ($\mu g g^{-1}$)	
	98-99	99-00
o_1	91.57	101.39
o_2	81.09	88.46
o_3	91.02	104.14
$F_{2,2}$	1.48	0.41
S E_m	4.847	13.074
n_1	89.42	89.87
n_2	90.14	93.21
n_3	87.98	118.78
$F_{2,27}$	0.22	2.91
S E_m	2.347	9.274
k_1	86.55	83.70
k_2	88.69	104.06
k_3	92.31	114.10
$F_{2,27}$	1.54	2.79
S E_m	2.347	9.274
Controls		
$o_{1\ alone}$	76.98	73.58
$o_{2\ alone}$	76.68	74.33
$o_{3\ alone}$	75.23	75.25

Table 32a. Effect of organic manures, nitrogen and potassium on yield components

Main effect of factors	Yield components					
	Mean tuber weight (kg)		Length of tuber(cm)		Girth of tuber(cm)	
	98-99	99-00	98-99	99-00	98-99	99-00
o_1	1.76	1.35	41.72	41.78	28.20	23.94
o_2	2.28	1.59	47.68	42.10	25.50	25.70
o_3	1.88	1.37	39.69	40.35	25.40	24.54
$F_{2,2}$	3.72	9.93	1.71	1.94	2.54	1.15
SE_m	0.142	0.042	3.172	0.669	1.000	0.837
n_1	1.93	1.34	44.22	42.29	25.92	24.19
n_2	2.37	1.52	44.32	41.98	27.22	25.18
n_3	1.96	1.65	42.85	42.32	27.00	25.19
$F_{2,27}$	13.94**	11.34**	0.21	0.03	1.56	2.36
SE_m	0.066	0.046	1.791	1.205	0.559	0.373
CD(0.05)	0.192	0.133	–	–	–	–
k_1	1.87	1.39	36.74	37.17	24.18	22.38
k_2	2.09	1.49	43.85	41.62	26.56	24.71
k_3	2.29	1.64	50.81	47.81	29.40	27.49
$F_{2,27}$	10.14**	6.99**	15.44**	19.64**	21.86**	47.05**
SE_m	0.066	0.046	1.791	1.205	0.559	0.373
CD(0.05)	0.192	0.133	5.197	3.497	1.622	1.082
Controls						
o_1 alone	0.85	0.82	33.92	35.38	23.25	23.63
o_2 alone	1.04	0.96	39.75	34.63	23.13	23.00
o_3 alone	0.89	0.70	34.63	32.88	23.13	24.00

** Significant at 1% level

in both the years. In 98-99, n_2 produced tubers with significantly higher weight (2.37kg). Further increase in nitrogen level to n_3 reduced tuber weight (1.96kg) considerably, which was on par with that of n_1. However, in the subsequent year, an increasing trend in tuber weight was observed with increase in nitrogen levels, though n_2 (1.52 kg) and n_3(1.65 kg) were on a par each other. Applied potassium at the highest level, k_3 produced tubers with significantly greatest weight in both the years (2.29 kg and 1.64 kg respectively). During 99-00, the lower doses (k_1 and k_2) showed similar effects (1.39 kg and 1.49 kg respectively).

As presented in Table 32 b, all the three interactions, OxN, OxK and NxK were significant in both the years. In 98-99, all the organic manures responded significantly upto n_2 level and a significant decline in tuber weight was noticed at n_3 in combination with o_2 or o_3. In 99-00, o_1 and o_3 responded upto n_3. Application of o_2 along with n_2 promoted tuber weight considerably in both the years (2.74 kg and 1.93 kg respectively). Significant increase in tuber weight was noticed upto k_3 in o_1 treated plots and upto k_2 in o_2 applied plots. In o_3 applied plots, k_1 resulted in significantly greatest tuber weight. Among OxK interactions, o_2k_2 registered greatest tuber weight in both the years (2.58 kg and 1.82 kg respectively). Similar trends were observed in both the years.

In 98-99, at n_1 and n_3, mean tuber weight increased with higher rates of K. In the case of n_2, this response was observed only upto k_2. In the next year also similar trends were observed for n_1 and n_2, though no conspicuous trend was observed at n_3. In general, n_2k_2 in 98-99 (2.42 kg) and n_3k_3 in 99-00 (1.78 kg) produced tubers with greatest mean weight.

4.3.3.2 Length of tuber

As shown in Table 32 a, organic manures had no significant effect on tuber length in either of the years. In both the years, o_2 produced longer tubers. The rates of applied nitrogen did not exert any influence on tuber length. Incremental doses of potassium significantly increased the tuber length in both the years, with k_3 producing longest tubers (50.81 cm and 47.81 cm respectively). None of the interaction effects could significantly influence the tuber length in the first or second year of experimentation (Table 32 b).

Table 32b. Interaction effect of organic manures,nitrogen and potassium on yield components

Interaction effects	Yield components					
	Mean tuber weight (kg)		Length of tuber (cm)		Girth of tuber (cm)	
	98-99	99-00	98-99	99-00	98-99	99-00
o_1n_1	1.56	1.33	44.08	42.08	28.54	23.46
o_1n_2	2.03	1.39	44.63	44.04	28.83	24.58
o_1n_3	1.98	1.51	39.04	41.33	28.88	23.88
o_2n_1	2.27	1.29	47.04	42.17	24.25	25.71
o_2n_2	2.74	1.93	49.21	41.15	27.00	25.21
o_2n_3	2.24	1.77	49.42	45.47	26.04	27.08
o_3n_1	1.95	1.41	41.54	42.63	24.96	23.42
o_3n_2	2.34	1.25	39.13	40.75	25.83	25.75
o_3n_3	1.66	1.67	40.08	40.17	26.10	24.63
$F_{4,27}$	3.03*	7.57**	0.55	0.99	0.46	1.97
$S\ E_m$	0.113	0.079	3.101	2.087	0.969	0.646
CD (0.05)	0.328	0.229	–	–	–	–
o_1k_1	1.23	1.09	35.79	38.33	26.83	22.63
o_1k_2	1.84	1.37	41.92	41.96	28.92	23.96
o_1k_3	2.50	1.78	50.04	47.17	30.50	25.33
o_2k_1	2.15	1.39	39.79	37.81	23.79	22.50
o_2k_2	2.58	1.82	50.13	42.19	25.88	25.33
o_2k_3	2.52	1.78	55.75	48.79	27.63	30.17
o_3k_1	2.24	1.71	34.63	35.38	21.92	22.00
o_3k_2	1.87	1.28	39.50	40.71	24.89	24.83
o_3k_3	1.84	1.35	46.63	47.46	30.08	26.96
$F_{4,27}$	14.78**	14.60**	0.24	0.16	1.94	4.08*
$S\ E_m$	0.113	0.079	3.101	2.087	0.969	0.646
CD (0.05)	0.328	0.229	–	–	–	1.875
n_1k_1	1.50	1.18	38.54	36.96	23.21	21.79
n_1k_2	1.90	1.22	45.33	41.13	25.38	24.08
n_1k_3	2.38	1.63	48.79	48.79	29.17	26.71
n_2k_1	2.32	1.37	36.50	35.83	24.71	22.21
n_2k_2	2.42	1.70	43.96	41.11	27.83	25.33
n_2k_3	2.36	1.50	52.50	49.00	29.13	28.00
n_3k_1	1.79	1.63	35.17	38.72	24.63	23.13
n_3k_2	1.97	1.55	42.25	42.63	26.47	24.71
n_3k_3	2.13	1.78	51.13	45.63	29.92	27.75
$F_{4,27}$	3.72*	4.67**	0.35	0.73	0.51	0.41
$S\ E_m$	0.113	0.079	3.101	2.087	0.969	0.646
CD(0.05)	0.328	0.229	–	–	–	–

** Significant at 1% level

* Significant at 5% level

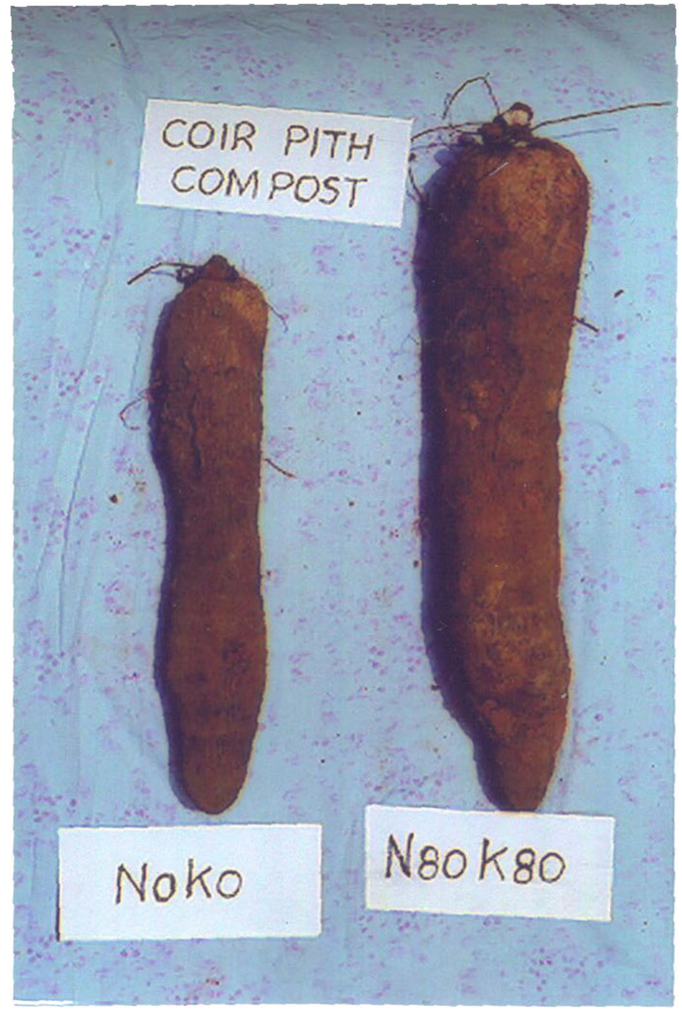


Plate 15. Tuber size influenced by nutrient management practices

4.3.3.3 Girth of tuber

It is clear from Table 32 a that tuber girth was significantly influenced by neither the organic manures nor the levels of nitrogen in both the years. Increased rates of potassium application significantly enhanced tuber girth in both the years. Maximum tuber girth was observed at k_3 level during both the years (29.40 cm and 27.49 cm respectively).

The OxN and NxK interaction effects were not significant during both the years, The interaction, OxK was significant only in the second year. At all levels of K, application of o_1 indicated similar tuber girth. However in o_2 and o_3 treated plots, increasing rates of K application was instrumental in enhancing tuber girth significantly (Table 32 b).

4.3.3.4 Tuber yield

It is evident from Table 33 a that organic manures had similar effects on tuber yield in both the years. However, application of coir pith compost (o_2) enhanced tuber yield considerably.

The influence of applied nitrogen on tuber yield was significant in both the years. In the first year, a significant response was obtained at n_2 (21.29 t ha^{-1}) and further increase to n_3 resulted in significant decline in tuber yield (17.64 t ha^{-1}). During the succeeding year, though yield due to n_3 (14.86 t ha^{-1}) was the highest, it was on par with n_2 (13.71 t ha^{-1}). Response to potassium was significant in both the years and tuber yield increased with higher rates of application. The highest level,k_3 proved significant superiority in both the years(20.59 t ha^{-1} in 98-99 and 14.72 t ha^{-1} in 99-00). However, in the second year the lower doses (k_1 and k_2) were at par.

Table 33 b depicts the significant OxN, OxK and NxK interaction effects on tuber yield in 98-99 and 99-00. In 98-99, the effect of organic manures was evident upto n_2 and o_2n_3 and o_3n_3 even resulted in a significant decline in tuber yield. On the other hand in 99-00, the effect of o_1 and o_3 in enhancing tuber yield was evident upto n_3. However in both the years

Table 33a. Effect of organic manures , nitrogen and potassium on tuber yield

Main effect of factors	Tuber yield ($t\ ha^{-1}$)	
	98-99	99-00
o_1	15.80	12.18
o_2	20.50	14.33
o_3	16.86	12.32
$F_{2,2}$	3.71	9.93
SE_m	1.279	0.382
CD(0.05)	-	-
n_1	17.33	12.09
n_2	21.29	13.71
n_3	17.64	14.86
$F_{2,27}$	13.93**	11.33**
SE_m	0.59	0.413
CD(0.05)	1.712	1.199
k_1	16.84	12.55
k_2	18.84	13.39
k_3	20.59	14.72
$F_{2,27}$	10.13**	7.00**
SE_m	0.590	0.413
CD(0.05)	1.712	1.199
Controls		
$o_{1\ alone}$	7.69	7.41
$o_{2\ alone}$	9.39	8.66
$o_{3\ alone}$	7.99	6.32

** Significant at 1% level

Table 33b. Interaction effect of organic manures ,nitrogen and potassium on tuber yield

Interaction effects	Tuber yield ($t\ ha^{-1}$)	
	98-99	99-00
o_1n_1	14.06	12.00
o_1n_2	18.23	12.53
o_1n_3	17.80	13.61
o_2n_1	20.39	11.59
o_2n_2	24.62	17.39
o_2n_3	20.19	15.90
o_3n_1	17.55	12.69
o_3n_2	21.03	11.21
o_3n_3	14.94	15.06
$F_{4,27}$	3.02*	7.55**
$S\ E_m$	1.022	0.715
CD (0.05)	2.966	2.075
o_1k_1	11.04	9.80
o_1k_2	16.53	12.34
o_1k_3	22.53	16.00
o_2k_1	19.33	12.50
o_2k_2	23.17	16.34
o_2k_3	22.69	16.05
o_3k_1	20.15	15.34
o_3k_2	16.82	11.51
o_3k_3	16.56	12.11
$F_{4,27}$	14.75**	14.58**
$S\ E_m$	1.022	0.715
CD (0.05)	2.966	2.075
n_1k_1	13.50	10.65
n_1k_2	17.06	10.96
n_1k_3	21.45	14.66
n_2k_1	20.91	12.34
n_2k_2	21.77	15.31
n_2k_3	21.19	13.49
n_3k_1	16.11	14.66
n_3k_2	17.69	13.91
n_3k_3	19.13	16.00
$F_{4,27}$	3.72*	4.66**
$S\ E_m$	1.022	0.715
CD(0.05)	2.966	2.075

** Significant at 1% level

* Significant at 5% level

Table 33 c. Influence of OxNxK interaction on tuber yield

N x K interaction	Tuber yield (t ha^{-1})					
	98-99			99-00		
	o_1	o_2	o_3	o_1	o_2	o_3
n_1k_1	10.28	15.82	14.40	9.31	10.17	12.47
n_1k_2	13.79	20.62	16.77	9.75	11.38	11.76
n_1k_3	18.13	24.72	21.50	16.94	13.22	13.84
n_2k_1	11.64	24.78	26.33	10.38	13.90	12.75
n_2k_2	17.06	26.78	21.48	12.86	22.44	10.63
n_2k_3	25.99	22.29	15.30	14.35	15.84	10.27
n_3k_1	11.21	17.40	19.72	9.73	13.44	20.82
n_3k_2	18.74	22.11	12.21	14.40	15.19	12.14
n_3k_3	23.46	21.05	12.89	16.71	19.08	12.22
$F_{8,27}$	4.04**			3.85**		
S E_m	1.770			1.239		
CD(0.05)	5.137			3.600		

**Significant at 1% level

Influence of fertility management practices on tuber yield

Plate 16. Coir pith compost+$n_{80}k_{80}$

Plate 17. Sunhemp + n_{120} k_{40}

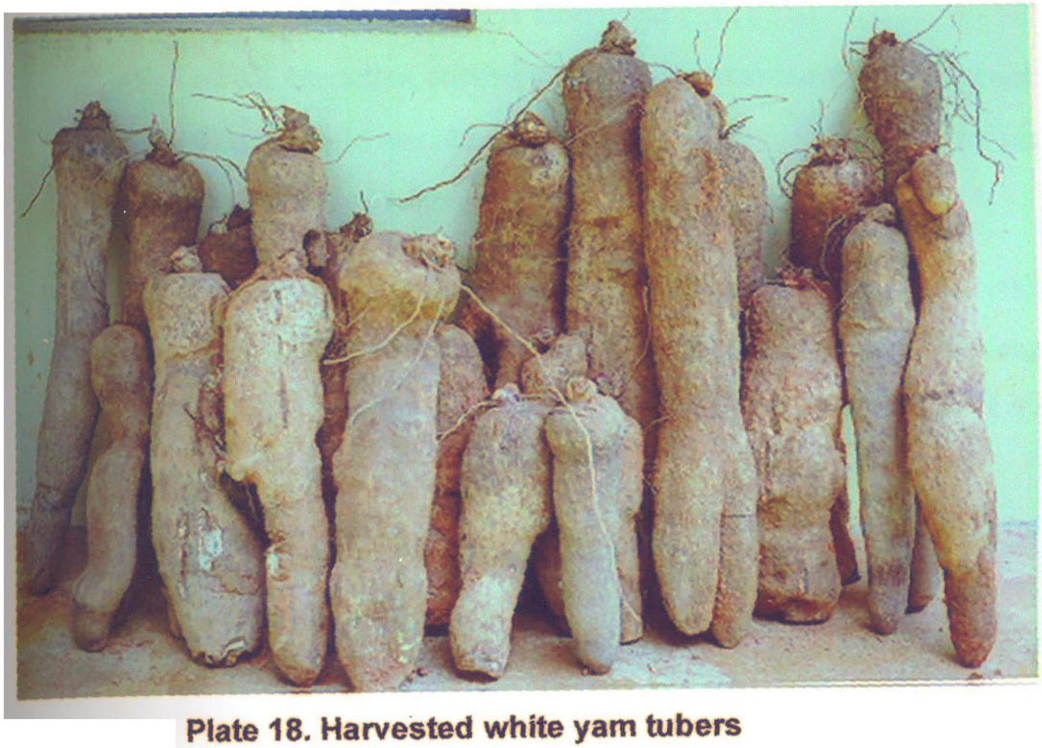


Plate 18. Harvested white yam tubers

application of coir pith compost along with 80 kg N ha^{-1}(o_2n_2) produced the highest tuber yield (24.62 t ha^{-1} and 17.39 t ha^{-1} respectively). The interaction ,OxK resulted in similar trends in tuber yield in both the years. The various organic manures interacted differently to different rates of K, o_1 responded upto k_3 level, o_2 upto k_2 level and o_3 only at k_1 in producing significantly higher tuber yields. In general, application of coir pith compost along with 80 kg K_2O ha^{-1} (o_2k_2) resulted in highest tuber yield (23.17 t ha^{-1} and 16.34 t ha^{-1} respectively). Effect of NxK interaction, on tuber yield was similar to that observed for mean tuber weight. Highest tuber yield was obtained in the interaction, n_2k_2(21.77 t ha^{-1}) in 98-99 and n_3k_3 (16.00 t ha^{-1}) in 99-00.

Considering the interaction of organic manures with nitrogen and potassium (OxNxK) which was significant in both the years (Table 33 c), application of coir pith compost along with 80 kg N and 80 kg K_2O per ha ($o_2n_2k_2$) resulted in the highest tuber yield in 98-99 (26.78 t ha^{-1}) and 99-00 (22.44 t ha^{-1}).

4.3.4 Quality attributes of tuber

4.3.4.1 Dry matter content

The main effects of organic manures, nitrogen and potassium on dry matter content of tuber in 98-99 and 99-00 are depicted in Tables 34a and 34b.

Dry matter content of tuber was significantly influenced by organic manures. The treatments, o_2 and o_3 were on a par each other but significantly superior to o_1 in accumulating dry matter in tuber. The main effects of both nitrogen and potassium was significant in both the years. Incremental doses of these nutrients significantly enhanced dry matter content in tuber in 98-99 as well as 99-00 (Table 34a).

A close scrutiny of data in Table 34b indicated that the interaction between organic manures and nitrogen had significant influence on dry matter content of tuber during 99-00. In combination with any of the organic manure, n_3 resulted in significantly higher values. The combination, o_3n_3 accumulated maximum dry matter in tuber in both the years. The interaction

Table 34a. Effect of organic manures, nitrogen and potassium on tuber quality

Main effect of factors	Dry matter(%)		Starch (%)		Crude protein(%)		Crude fibre (%)		Vitamin C (mg 100 mg^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1	27.79	30.15	24.50	24.77	1.46	1.49	0.59	0.57	5.67	5.72
o_2	28.93	30.61	24.76	25.12	1.54	1.55	0.66	0.67	5.77	5.93
o_3	28.84	30.59	24.19	24.86	1.48	1.55	0.64	0.67	6.34	5.92
$F_{2,2}$	48.75*	52.04*	87.81*	4.86	4.00	40.00*	59.00*	14.30	15.89	4.01
S E_m	0.091	0.036	0.030	0.084	0.019	0.005	0.005	0.016	0.090	0.059
CD(0.05)	0.554	0.219	0.183	–	–	0.030	0.030	–	–	–
n_1	27.68	29.81	24.55	25.15	1.38	1.46	0.63	0.63	5.61	5.78
n_2	28.98	30.71	25.18	25.58	1.62	1.58	0.66	0.66	6.13	5.96
n_3	29.58	31.79	24.33	24.75	1.57	1.62	0.58	0.61	6.30	6.07
$F_{2,27}$	80.81**	136.09**	10.13**	12.05**	47.86**	45.96**	32.23**	6.58**	7.27**	2.82
S E_m	0.108	0.085	0.127	0.120	0.018	0.012	0.007	0.011	0.133	0.086
CD(0.05)	0.313	0.247	0.369	0.348	0.052	0.035	0.020	0.032	0.386	–
k_1	28.07	29.78	23.27	24.06	1.83	1.83	0.58	0.59	6.07	5.96
k_2	28.73	30.93	24.62	25.18	1.47	1.51	0.68	0.68	6.24	6.19
k_3	29.44	31.60	26.11	26.24	1.27	1.34	0.62	0.62	5.73	5.67
$F_{2,27}$	40.29*	116.60**	123.94**	82.12**	231.22**	406.51**	39.79**	18.53**	3.89*	9.11**
S E_m	0.108	0.085	0.127	0.120	0.018	0.012	0.007	0.011	0.133	0.086
CD(0.05)	0.313	0.247	0.369	0.348	0.052	0.035	0.020	0.032	0.386	0.250
Controls										
o_1 alone	25.46	26.75	22.29	22.27	1.27	1.32	0.69	0.61	4.64	5.15
o_2 alone	26.86	28.00	23.12	23.12	1.26	1.27	0.69	0.69	5.67	5.15
o_3 alone	27.00	28.00	23.16	22.85	1.18	1.28	0.61	0.69	5.15	5.15

** Significant at 1% level

* Significant at 5% level

Table 34b. Interaction effect of organic manures, nitrogen and potassium on tuber quality

Interaction effects	Dry matter (%)		Starch (%)		Crude protein(%)		Crude fibre(%)		Vitamin C (mg 100 mg^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1n_1	26.71	29.58	24.22	24.70	1.36	1.44	0.63	0.56	5.15	5.15
o_1n_2	28.28	30.46	25.19	25.61	1.61	1.52	0.55	0.54	6.02	5.84
o_1n_3	29.15	31.54	24.84	24.83	1.49	1.58	0.55	0.58	6.19	6.36
o_2n_1	28.29	30.25	25.01	25.62	1.35	1.45	0.72	0.67	5.50	6.19
o_2n_2	29.27	30.46	25.35	25.47	1.69	1.61	0.78	0.77	5.84	5.50
o_2n_3	29.91	32.00	24.47	24.96	1.67	1.68	0.49	0.55	6.01	6.36
o_3n_1	28.05	29.58	24.41	25.12	1.43	1.50	0.56	0.64	6.18	6.01
o_3n_2	29.39	31.21	24.82	25.67	1.57	1.62	0.66	0.67	6.53	6.53
o_3n_3	29.67	31.83	23.69	24.47	1.55	1.62	0.70	0.69	6.70	5.49
$F_{4,27}$	1.94	5.93**	2.79**	2.37	4.18**	2.67	74.79**	16.22**	0.56	17.70**
S E_m	0.187	0.148	0.221	0.208	0.032	0.021	0.013	0.018	0.231	0.149
CD (0.05)	–	0.429	0.641	–	0.093	–	0.038	0.052	–	0.432
o_1k_1	27.47	29.46	23.34	24.13	1.82	1.83	0.61	0.58	5.33	4.98
o_1k_2	27.84	30.58	24.81	24.93	1.42	1.46	0.51	0.54	5.67	6.36
o_1k_3	28.83	31.54	26.11	26.07	1.22	1.25	0.61	0.56	6.36	6.02
o_2k_1	28.28	29.96	23.77	23.95	1.89	1.84	0.63	0.65	5.50	6.02
o_2k_2	29.24	31.17	24.94	25.49	1.56	1.58	0.71	0.73	6.36	6.53
o_2k_3	29.95	31.58	26.12	26.60	1.27	1.33	0.64	0.62	5.50	5.50
o_3k_1	28.46	29.92	22.71	24.11	1.78	1.81	0.51	0.56	7.39	6.87
o_3k_2	29.13	31.04	24.11	25.12	1.44	1.51	0.82	0.78	6.70	5.67
o_3k_3	29.53	31.67	26.10	26.03	1.34	1.42	0.60	0.67	5.32	5.49
$F_{4,27}$	1.26	1.02	1.66	1.29	3.43*	7.26**	72.52**	14.51**	13.38**	26.03**
S E_m	0.187	0.148	0.221	0.208	0.032	0.021	0.013	0.018	0.231	0.149
CD (0.05)	–	–	–	–	0.093	0.061	0.038	0.052	0.670	0.432
n_1k_1	26.97	28.71	23.61	24.25	1.57	1.62	0.73	0.70	5.32	5.84
n_1k_2	27.77	29.92	24.56	25.27	1.36	1.46	0.63	0.64	5.84	5.67
n_1k_3	28.32	30.79	25.49	25.92	1.22	1.32	0.54	0.54	5.67	5.84
n_2k_1	28.38	29.46	23.28	24.41	1.92	1.87	0.54	0.56	6.36	6.19
n_2k_2	29.03	31.00	25.09	25.57	1.57	1.50	0.75	0.74	6.53	6.01
n_2k_3	29.53	31.67	26.98	26.77	1.38	1.38	0.70	0.68	5.50	5.67
n_3k_1	28.86	31.17	22.94	23.53	1.98	1.98	0.49	0.52	6.53	5.84
n_3k_2	29.41	31.88	24.20	24.71	1.50	1.59	0.65	0.67	6.36	6.87
n_3k_3	30.47	32.83	25.86	26.02	1.23	1.31	0.61	0.63	6.01	5.50
$F_{4,27}$	0.78	4.15**	4.35**	1.25	10.13**	20.32**	66.22**	21.70**	2.23	8.88**
S E_m	0.187	0.148	0.221	0.208	0.032	0.021	0.013	0.018	0.231	0.149
CD(0.05)	–	0.429	0.641	–	0.093	0.061	0.038	0.052	–	0.432

** Significant at 1% level

* Significant at 5% level

between organic manures and potassium was not significant during both the years. The combined effect of nitrogen and potassium had significant effect on tuber dry matter content in the second year. At all levels of N, higher rates of K nutrition significantly enhanced tuber dry matter content and hence n_3k_3 registered the highest values.

4.3.4.2 Starch content

The data on starch content of tuber for the two years of experimentation are presented in Tables 34a and 34b.

During 1998-99, organic manures profoundly influenced starch content of tuber, with o_2 resulting in significantly higher content than o_1, which was superior to o_3. However in the next year, the difference in starch content between organic manures was not significant. The influence of nitrogen on starch content was significant in both the years. Nitrogen application at n_2 resulted in significantly higher starch content (25.18% in 98-99 and 25.58% in 99-00). Further increase had a significant negative effect on starch content. Effect of potassium on starch content was significant during both the years. There was significant increase in starch content with increased levels of potassium application, with the highest content recorded at k_3 (26.11% and 26.24% respectively) (Table 34a).

Starch content of tuber was significantly affected by the interaction, OxN in 98-99. When combined with any of the organic manure, medium level of nitrogen (n_2) tended to enhance starch content of tuber. The combined effect of organic manures and potassium was not significant in either 98-99 or 99-00. Significant NxK interaction occurred during 98-99. At all levels of nitrogen, increasing rates of potassium significantly promoted the starch content (Table 34b).

4.3.4.3 Crude protein content

Table 34a clearly depicts that organic manures had significant impact on crude protein content of tuber only in the second year. Application of o_2 and o_3 recorded almost the same crude protein content which was superior to o_1. Nitrogen application at n_2 in 98-99 (1.62%) and n_3 in 99-00 (1.62%) significantly enhanced the crude protein content. An increase in K levels was found to decrease significantly the crude protein content. Highest value was obtained at k_1 in both the years (1.83%).

As presented in Table 34b the interaction between organic manures and nitrogen significantly influenced crude protein content only in 98-99. In combination with o_1, o_2 or o_3 incremental rates of N upto n_2 significantly enhanced the crude protein content of tuber. The interaction, OxK was significant in both the years. Organic manures in combination with higher rates of potassium was found to depress significantly the crude protein content. Organic manures resulted in significantly higher values in combination with k_1. The interaction between nitrogen and potassium had significant influence on this attribute in both the years. Regardless of the levels of nitrogen, incremental rates of potassium significantly depressed the crude protein content. At all levels of nitrogen, significantly higher crude protein content was attained at k_1 level.

4.3.4.4 Crude fibre content

The data on crude fibre content for 98-99 and 99-00 are presented in Tables 34a and 34b.

Organic manures influenced the crude fibre content significantly during the first year. Application of o_2 resulted in the highest crude fibre content (0.66%) which was on a par with o_3. Plants that received o_1 recorded the lowest crude fibre content in tuber. During both the years, lower crude fibre contents were observed at the highest levels of N and K.

The interaction, NxK also significantly influenced the crude fibre content in 98-99 as well as in 99-00. Irrespective of the levels of N, highest rate of K depressed crude fibre content (Table 34b).

4.3.4.5 Vitamin C

The main effect of treatments on vitamin C content of tubers in 98-99 and 99-00 are furnished in Table 34a.

There was no appreciable difference in vitamin C content due to various organic manures in both the seasons. In 98-99, nitrogen application upto n_2 significantly increased the vitamin C content (6.13 mg 100 mg^{-1}). However in the subsequent year the difference in vitamin C content between N levels was not significant. The effect of potassium on vitamin C content was significant in both the years. The medium level of potassium indicated higher vitamin C content (6.24 mg 100 mg^{-1} and 6.19 mg 100 mg^{-1} respectively in 98-99 and 99-00) and further increase resulted in a decline.

As shown in Table 34b significant difference in vitamin C content due to OxN interaction was evident in the second year. Application of o_1 and o_3 registered significantly higher content of vitamin C at higher rates of N (n_3 and n_2 respectively). However, analysis of tubers from plants applied with o_2, revealed higher vitamin C content even at n_1 level. The OxK interaction was significant during both the years. Organic manures indicated varied response to different levels of potassium. Plants treated with o_1 responded upto k_3 in 98-99 but upto k_2 in 99-00. In the case of o_2, significant response was noticed upto k_2 and o_3 treated plants recorded higher vitamin C content at k_1 in both the years. The interaction, NxK affected the vitamin C content considerably only in 99-00. At n_1 and n_2 levels, higher vitamin C content was noticed at k_1 level, but at n_3, significantly higher value was obtained at k_2.

4.3.4.6 Organoleptic tests

Organoleptic test parameters viz., taste, texture, appearance, colour, doneness and flavour were not significantly influenced by the various treatments tested. In general, white yam variety Sree Priya was well accepted by the taste panel due to its appreciable white colour, good appearance and flavour, starchy taste and non fibrous texture. It was relished very much since it cooked well and was not slimy when cooked.

4.3.5 Uptake of major nutrients

4.3.5.1 Nitrogen

The data on uptake of nitrogen at the end of crop growth during each season are given in Tables 35a and 35b.

The effect of organic manures on the uptake of nitrogen was significant in the second year. Application of o_2 resulted in significantly higher uptake of nitrogen (70.88 kg ha^{-1}) than that of o_3, which was equally effective as o_1. The main effect of nitrogen and potassium on the uptake of nitrogen was significant during both the years. Application of these nutrients upto the medium level (n_2 or k_2) promoted uptake of nitrogen in the first year (76.50 kg ha^{-1} and 73.74 kg ha^{-1} respectively at n_2 and k_2). Medium and highest levels of these nutrients were found to be equally effective. However, in the second year, plant uptake of nitrogen increased significantly upto the highest levels of these nutrients (73.92 kg ha^{-1} and 72.77 kg ha^{-1} respectively at n_3 and k_3) (Table 35a).

It is evident from Table 35b that the interaction between organic manures and nitrogen was significant in both the years. In the first year, with increase in rates of nitrogen, plants treated with o_1 resulted in significantly higher uptake, with maximum value recorded at n_3. In the case of o_2 and o_3 response was obtained upto n_2. However in the second year, o_1 and o_2 promoted uptake upto n_2 and o_3 upto n_3. In both the years, highest uptake was attained at o_2n_3 (89.47 kg ha^{-1} and 83.73 kg ha^{-1} respectively).A significant OxK interaction occurred during both the years. Significantly higher uptake was registered upto k_3 in o_1 applied plots and upto k_2 in o_2 applied plots. In plots applied with o_3, uptake was promoted even at k_1. Among the OxK interactions, o_2k_3 registered highest uptake in 98-99 (84.73 kg ha^{-1}) and 99-00 (78.74 kg ha^{-1}). The interaction between nitrogen and potassium was significant only in the second year. At the lowest and highest levels of nitrogen, k_3 resulted in highest uptake which was significantly superior to k_1 and k_2. However, n_2 responded only upto k_2. Among the N x K interactions, n_3k_3 recorded the highest uptake (83.03 kg ha^{-1}).

Table 35a. Effect of organic manures, nitrogen and potassium on uptake of major nutrients

Main effect of factors	Nutrient uptake (kg ha $^{-1}$)					
	N uptake		P uptake		K uptake	
	98-99	99-00	98-99	99-00	98-99	99-00
o_1	61.66	57.94	6.87	7.01	61.62	60.38
o_2	76.53	70.88	8.44	7.65	79.05	70.93
o_3	64.80	60.50	6.87	7.12	65.96	61.98
$F_{2,2}$	8.54	37.32*	8.52	1.54	31.71*	9.38
SE_m	2.683	1.122	0.309	0.277	1.612	1.856
CD(0.05)	–	6.827	–	–	9.809	–
n_1	62.92	56.25	7.09	7.01	64.80	58.72
n_2	76.50	67.96	8.15	7.62	78.67	67.67
n_3	75.82	73.92	8.21	8.24	75.66	77.46
$F_{2,27}$	62.07*	63.84**	16.61**	9.44**	62.47**	57.59**
SE_m	0.971	1.125	0.155	0.200	0.923	1.235
CD(0.05)	2.818	3.264	0.500	0.580	2.679	3.584
k_1	65.30	61.08	7.01	6.58	64.80	59.56
k_2	73.74	64.27	8.09	7.46	75.22	68.04
k_3	76.20	72.77	8.35	8.83	79.12	76.25
$F_{2,27}$	34.68**	28.83**	20.99**	32.07**	64.35**	45.65**
SE_m	0.971	1.125	0.155	0.200	0.923	1.235
CD(0.05)	2.818	3.264	0.500	0.580	2.679	3.584
Controls						
$o_{1\ alone}$	31.96	32.91	3.53	3.49	30.39	26.53
$o_{2\ alone}$	29.99	36.96	3.68	4.15	32.77	33.16
$o_{3\ alone}$	30.78	39.95	3.47	4.32	30.93	38.49

** Significant at 1 % level
* Significant at 5% level

Table 35b. Interaction effect of organic manures, nitrogen and potassium on uptake of major nutrients

Interaction effects	Nutrient uptake (kg ha^{-1})					
	N uptake		P uptake		K uptake	
	98-99	99-00	98-99	99-00	98-99	99-00
o_1n_1	54.53	54.89	6.42	6.83	55.61	54.89
o_1n_2	67.34	61.33	7.22	6.94	66.74	60.48
o_1n_3	73.00	65.95	8.09	8.43	72.90	77.05
o_2n_1	69.46	58.00	7.81	6.74	73.79	62.49
o_2n_2	86.18	82.22	9.72	8.96	90.32	81.87
o_2n_3	89.47	83.73	9.36	8.41	88.47	81.03
o_3n_1	64.78	55.85	7.04	7.46	64.99	58.80
o_3n_2	75.98	60.33	7.52	6.95	78.95	60.68
o_3n_3	64.97	72.09	7.18	7.87	65.62	74.31
$F_{4,27}$	12.44**	8.83**	4.11**	5.09**	11.97**	6.67**
S E_m	1.682	1.949	0.268	0.346	1.599	2.139
CD (0.05)	4.881	5.656	0.778	1.004	4.640	6.207
o_1k_1	51.24	50.73	5.44	5.59	50.60	50.32
o_1k_2	68.74	58.41	7.55	6.94	68.28	62.43
o_1k_3	74.89	73.04	8.74	9.67	76.39	79.66
o_2k_1	75.92	68.82	8.34	6.67	75.71	64.15
o_2k_2	84.46	76.39	9.30	8.58	86.94	80.94
o_2k_3	84.73	78.74	9.26	8.88	89.94	80.29
o_3k_1	68.74	63.71	7.25	7.49	68.08	64.22
o_3k_2	68.03	58.02	7.44	6.87	70.46	60.77
o_3k_3	68.97	66.55	7.05	7.93	71.02	68.80
$F_{4,27}$	13.77**	8.51**	11.18**	9.20**	13.33**	12.59**
S E_m	1.682	1.949	0.268	0.346	1.599	2.139
CD (0.05)	4.881	5.656	0.778	1.004	4.640	6.207
n_1k_1	54.42	49.37	5.94	6.00	55.16	49.78
n_1k_2	64.40	53.08	7.41	6.97	65.85	56.44
n_1k_3	69.96	66.30	7.93	8.07	73.39	69.95
n_2k_1	71.37	63.17	7.67	6.48	71.88	59.05
n_2k_2	80.07	71.72	8.41	7.55	82.02	72.91
n_2k_3	78.06	68.99	8.39	8.82	82.11	71.05
n_3k_1	70.11	70.72	7.43	7.27	67.35	69.86
n_3k_2	76.76	68.02	8.47	7.86	77.80	74.78
n_3k_3	80.57	83.03	8.73	9.59	81.85	87.74
$F_{4,27}$	2.25	6.95**	1.43	0.27	1.96	4.24**
S E_m	1.682	1.949	0.268	0.346	1.599	2.139
CD(0.05)	–	5.656	–	–	–	6.207

** Significant at 1% level

4.3.5.2 Phosphorus

It is clear from Table 35a that the variation in phosphorus uptake between the organic manures was not significant in either of the years. Application of nitrogen upto n_2 significantly favoured the uptake of phosphorus in 98-99 (8.15 kg ha^{-1}). However, in the succeeding year, significant response was obtained upto n_3 (8.24 kg ha^{-1}). Significantly higher uptake of phosphorus was also obtained at k_2 level (8.09 kg ha^{-1}) in 98-99 and at k_3 level (8.83 kg ha^{-1}) in 99-00.

Interaction effects furnished in Table 35b, clearly indicate that plant uptake of phosphorus was significantly influenced by OxN interaction in both the years. Significantly higher uptake of phosphorus was noticed in o_1 applied plots at n_3 and in o_2 applied plots at n_2 during both the years. Application of o_3 in combination with n_1 favoured P uptake. The difference in P uptake due to OxK interaction was also significant in both the years. The treatment, o_1 responded upto k_3 and o_2 upto k_2 for attaining significantly higher exports. However, in o_3, considerable uptake was noticed at k_1. The interaction between nitrogen and potassium was not significant in either of the years.

4.3.5.3 Potassium

The data on uptake of potassium at the termination of crop growth in each year are presented in Tables 35a and 35b. Organic manures significantly influenced plant uptake of potassium only in 98-99. The treatment, o_2 resulted in the highest uptake (79.05 kg ha^{-1}) which was significantly superior to o_1 and o_3. However o_1 and o_3 were on par. Different levels of nitrogen profoundly influenced uptake of potassium in both the years with significantly higher uptake obtained at n_2 in 98-99 (78.67 kg ha^{-1}) and at n_3 (77.46 kg ha^{-1}) in 99-00. In both the years, incremental rates of potassium nutrition enhanced the uptake of potassium significantly with maximum uptake attained at k_3 (79.12 and 76.25 kg ha^{-1} respectively). (Table 35a).

As depicted in Table 35 b, the interaction OxN was significant during both the years. With increase in levels of N, there was significant increase in the uptake of potassium upto n_3 in o_1, upto n_2 in o_2 and o_3 in 98-99. In 99-00, similar trends were observed in the case of o_1 and o_2. But o_3 recorded significantly higher uptake at n_3. The interaction, OxK was also significant in 98-99 and 99-00. Incremental doses of potassium significantly enhanced plant uptake of potassium upto k_3 in o_1 and upto k_2 in o_2 in both the years. In the case of o_3, though all levels of K had similar effects on uptake of potassium in 98-99, k_3 attained significantly higher uptake than the other levels during 99-00. Considering NxK interaction which was significant in 99-00, at n_1 and n_3 higher uptake of potassium was noticed at k_3 but n_2 promoted uptake of K significantly at k_2.

4.3.6 Nutrient use efficiency

The data on use efficiency of nitrogen and potassium as influenced by organic manures, nitrogen and potassium during the two years of field experimentation are furnished in Tables 36a and 36b.

4.3.6.1 Nitrogen

4.3.6.1.1 Agronomic efficiency

Agronomic efficiency of applied N was not profoundly influenced by the various organic manures in the first year. However, the significant influence of organic manures on agronomic efficiency of N was evident in the subsequent year with o_3 plots registering the highest value (97.71 kg tuber / kg N). The other manures did not differ significantly. Different rates of applied N significantly affected the use efficiency of N in both the years, with n_1 indicating highest value (224.47 and 115.67 kg tuber/ kg N in 98-99 and 99-00 respectively). Further increase in N levels resulted in significant decrements in the efficiency. On the other hand, increasing levels of K tended to enhance the agronomic efficiency of N considerably during both the seasons with maximum efficiency computed from k_3 (192.55 and 108.81 kg tuber/kg N respectively). However k_1 and k_2 were on a par each other in the second year. (Table 36 a).

Table 36a. Effect of organic manures, nitrogen and potassium on nutrient use efficiency

Main effect of factors	Nutrient use efficiency							
	N use efficiency				K use efficiency			
	Agronomic efficiency kg tuber/kg N applied		Physiological efficiency kg tuber/kg N absorbed		Agronomic efficiency kg tuber/kg K applied		Physiological efficiency kg tuber/kg K absorbed	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1	125.19	76.77	251.51	211.42	106.02	64.32	252.03	208.56
o_2	185.06	80.90	271.91	202.94	177.19	84.51	261.21	204.40
o_3	153.34	97.71	257.32	202.12	161.89	112.87	253.66	197.84
$F_{2,2}$	2.86	20.21*	1.11	3.73	3.08	47.78*	0.16	0.68
SEm	17.720	2.468	9.998	2.665	21.341	3.529	12.267	6.559
CD(0.05)	–	15.019	–	–	–	21.475	–	–
n_1	224.47	115.67	272.21	215.41	115.48	61.10	264.67	207.32
n_2	161.72	78.10	274.74	200.21	196.21	90.05	268.67	202.07
n_3	77.39	61.62	230.12	200.83	133.42	110.56	230.02	190.99
F_{value}	92.63**	25.96**	14.37**	3.58*	14.68**	20.15**	9.19**	2.59
SEm	7.668	5.437	6.613	4.546	11.064	5.537	7.012	5.178
CD(0.05)	22.382	15.870	19.191	13.192	32.300	16.162	20.349	–
k_1	116.71	66.83	252.85	205.95	212.10	127.14	254.28	210.42
k_2	154.33	79.74	253.90	207.50	131.04	74.12	248.67	196.29
k_3	192.55	108.81	270.32	202.99	101.97	60.44	260.41	193.67
F_{value}	24.45**	15.64**	2.20	0.25	26.61**	40.48**	0.70	3.03
SEm	7.668	5.437	6.613	4.546	11.064	5.537	7.012	5.178
CD(0.05)	22.382	15.870	–	–	32.300	16.162	–	–
Controls								
01 alone	–	–	240.76	225.28	–	–	253.38	279.33
02 alone	–	–	313.10	234.15	–	–	286.99	261.03
03 alone	–	–	260.06	157.24	–	–	258.34	164.15

** Significant at 1% level
* Significant at 5% level

Table 36b. Interaction effect of organic manures, nitrogen and potassium on nutrient use efficiency

Interaction effects	Nutrient use efficiency							
	N use efficiency				K use efficiency			
	Agronomic efficiency		Physiological efficiency		Agronomic efficiency		Physiological efficiency	
	kg tuber/kg N applied		kg tuber/kg N absorbed		kg tuber/kg K applied		kg tuber/kg K absorbed	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1n_1	159.46	114.67	255.62	218.12	76.01	52.00	251.16	218.41
o_1n_2	131.80	63.96	264.34	203.97	122.83	66.68	266.58	207.83
o_1n_3	84.31	51.68	238.15	207.54	119.22	74.27	237.88	175.84
o_2n_1	274.88	73.17	291.49	200.18	142.92	36.53	274.10	186.65
o_2n_2	190.32	109.17	285.50	209.40	236.52	121.03	272.99	211.56
o_2n_3	89.97	60.36	225.03	188.83	152.14	95.99	227.96	196.11
o_3n_1	239.08	159.17	269.51	227.93	127.49	94.74	268.75	216.88
o_3n_2	163.05	61.17	274.39	187.27	229.29	82.45	266.45	186.84
o_3n_3	57.90	72.81	227.17	206.11	128.90	161.42	224.22	201.04
F value	5.53**	13.08**	1.22	2.84*	1.84	10.68**	0.59	4.15**
S E_m	13.282	9.417	11.454	7.874	19.163	9.591	12.145	8.969
CD (0.05)	38.770	27.488	–	22.850	–	27.996	–	26.028
o_1k_1	47.82	34.59	217.74	196.61	83.83	59.83	219.94	200.83
o_1k_2	120.61	61.61	241.53	211.73	110.54	61.57	242.61	199.58
o_1k_3	207.13	134.11	298.83	221.28	123.68	71.56	293.08	201.67
o_2k_1	139.92	47.65	253.57	182.83	248.54	96.04	252.43	194.37
o_2k_2	201.36	98.22	275.60	210.78	172.23	95.96	267.16	198.20
o_2k_3	213.89	96.82	272.84	204.80	110.81	61.54	255.46	201.75
o_3k_1	162.38	118.25	287.23	238.42	303.92	225.54	290.47	236.07
o_3k_2	141.04	79.40	244.55	199.99	110.34	64.84	236.25	191.09
o_3k_3	156.61	95.50	239.28	182.89	71.43	48.24	232.70	177.60
F value	10.59**	13.93**	8.71**	9.39**	14.85**	34.26**	8.16**	4.40**
S E_m	13.282	9.417	11.454	7.874	19.163	9.591	12.145	8.969
CD (0.05)	38.770	27.488	33.240	22.850	55.937	27.996	35.250	26.028
n_1k_1	128.54	79.54	247.75	217.86	128.54	79.54	243.98	214.64
n_1k_2	217.54	87.46	263.48	207.22	108.77	43.73	257.94	196.97
n_1k_3	327.33	180.01	305.39	221.15	109.11	60.00	292.10	210.33
n_2k_1	156.98	60.96	284.34	196.58	313.96	121.92	283.52	210.42
n_2k_2	167.69	98.07	269.53	207.58	167.69	98.07	263.84	205.89
n_2k_3	160.48	75.28	270.35	196.47	106.99	50.18	258.66	189.92
n_3k_1	64.60	59.99	226.45	203.42	193.79	179.96	235.33	206.21
n_3k_2	77.77	53.71	228.67	207.71	116.65	80.57	224.24	186.00
n_3k_3	89.82	71.15	235.22	191.36	89.82	71.15	230.48	180.78
F value	16.41**	12.18**	2.63	1.21	6.25**	8.52**	2.41	0.86
S E_m	13.282	9.417	11.454	7.874	19.163	9.591	12.145	8.969
CD(0.05)	38.770	27.488	–	–	55.937	27.996	–	–

** Significant at 1% level * Significant at 5% level

All the interactions were significant in both the years. In general, all the organic manures resulted in maximum efficiency in combination with the lowest level of N. However, higher efficiency in o_2 plots was obtained at n_2. Considering OxK interaction, higher levels of K (k_2 or k_3) enhanced the efficiency in the case of o_1 and o_2. In the case of o_3, the efficiency was higher at k_1 itself. At the lowest and highest levels of N, k_3 tended to enhance the efficiency of applied N for tuber production. Medium level of N indicated higher efficiency at k_2 (Table 36b).

4.3.6.1.2 Physiological efficiency

The physiological efficiency of applied N was significantly influenced by different levels of nitrogen in both the years. Higher use efficiencies were computed from n_2 (274.74 kg tuber/ kg N absorbed) in 98-99 and from n_1 (215.41 kg tuber/kg N absorbed) in 99-00. The main effects of organic manures or potassium was not significant in either of the years. (Table 36a).

The interaction between organic manures and nitrogen was significant in 99-00. The efficiency of applied N for tuber production per unit of N absorbed was maximum at n_1 in the case of o_1 and o_3 and at n_2 in o_2 treated plots. The interaction, OxK was significant in both the years. In the case of o_1 and o_2, higher rates of K improved the efficiency of N. However in o_3, higher efficiency was attained even at k_1. The interaction between the inorganic nutrients was not significant during both the seasons. (Table 36b).

4.3.6.2 Potassium

4.3.6.2.1 Agronomic efficiency

The effect of organic manures on the efficiency of applied K for tuber production was significant only during the second year. Application of o_3 resulted in significantly higher efficiency (112.87 kg tuber / kg K) and o_1 and o_2 proved equally effective. The main effects of nitrogen and potassium was significant in both the years. Increasing rates of N upto n_2 in 98-99 (196.21 kg tuber/kg K) or n_3 in 99-00 (110.56 kg tuber/ kg K) showed a tendency to enhance the efficiency significantly, whereas the lowest dose of K resulted in significantly higher efficiency in both the years (212.10 kg tuber/ kg K and 127.14 kg tuber/ kg K respectively) (Table 36a).

The significant effect of the interaction, OxN was evident in 99-00. In the case of o_1 and o_3, highest rate of N (n_3) tended to enhance the efficiency of applied K, whereas n_2 enhanced the efficiency with o_2. The interaction between organic manures and potassium was significant in both the years. Though all levels of K had similar effects, an increasing trend in the efficiency was observed with increasing levels of K in plots applied with o_1. In o_2 and o_3 treated plots lowest dose of K indicated higher efficiency. The interaction between nitrogen and potassium was significant in both the years. Regardless of the levels of N, lowest dose of K tended to increase the use efficiency of K in both the years (Table 36b).

4.3.6.2.2 Physiological efficiency

Organic manures did not significantly affect the physiological efficiency of potassium in either of the years. Different doses of N, significantly affected the quantity of tuber produced per kg of K absorbed in the first year, with n_2 attaining higher efficiency (268.67) though on par with n_1. All the levels of potassium resulted in almost similar rates of tuber production per unit kg of K absorbed (Table 36a).

The interaction, OxN was significant in 99-00. In the case of o_1 and o_3, lowest dose of N favoured tuber production per unit kg of K absorbed. However in o_2, this attribute was favoured by n_2. The interaction between organic manures and potassium was significant in both the years. In the case of o_1 though all levels of K imparted similar effects on this attribute, an increasing trend was observed at higher levels of K. The other manures interacted differently with K. Higher efficiency was registered in o_2 applied plots at k_2 and in o_3 at k_1. The interaction between nitrogen and potassium was not significant during both the seasons (Table 36b).

4.3.7 Soil moisture content

Significant differences were not found in soil moisture content due to the independent or combined effects of organic manures, levels of nitrogen and potassium at various growth stages during the period of experimentation.(Table 37).

4.3.8 Soil physical properties

The variation in the physical properties of the soil viz., bulk density, particle density, water holding capacity, porosity and aggregate stability due to the effects of organic manures, rates of nitrogen and potassium was not significant in either of the years. None of the interactions also could significantly influence these attributes during the two years of experimentation. However, towards the termination of the experiment there was a slight decrease in the bulk density and particle density of soil. The water holding capacity, porosity and aggregate stability showed a marginal improvement (Tables 1 and 38).

4.3.9 Soil chemical properties

4.3.9.1 Total nutrient status of the soil

4.3.9.1.1 Total nitrogen

The data on total nitrogen content of the soil after each year are provided in Table 39. The influence of organic manures, levels of nitrogen and potassium on total nitrogen content of the soil was not significant either in 98-99 or 99-00. None of the interaction effects were significant in either of the years.

4.3.9.1.2 Total phosphrous

Neither the independent nor the combined effects of organic manures, levels of nitrogen and potassium had significant influence on total phosphorus content of the soil in 98-99 and 99-00 (Table 39).

4.3.9.1.3 Total potassium

The variation in the total potassium content of the soil due to the effects of organic manures, nitrogen levels or rates of potassium was not significant in both the years (Table 39). The interactions also had no significant effect on total K content of the soil in 98-99 as well as 99-00.

Table 37 Effect of organic manures, nitrogen and potassium on soil moisture content

Main effect of factors	Soil moisture content(%)							
	98-99				99-00			
	2 MAP	4 MAP	6 MAP	8 MAP	2 MAP	4 MAP	6 MAP	8 MAP
o_1	2.62	5.29	15.43	8.01	8.37	5.56	15.71	3.47
o_2	2.55	5.37	15.30	7.80	7.99	5.70	15.21	3.53
o_3	3.73	6.00	15.39	7.62	8.26	5.62	15.22	3.56
$F_{2,2}$	3.34	0.25	0.15	1.14	0.23	0.69	3.94	0.37
SE_m	0.361	0.778	0.171	0.182	0.413	0.084	0.143	0.078
n_1	2.58	6.29	15.41	7.68	8.39	5.51	15.39	3.40
n_2	2.99	5.64	15.41	7.87	8.20	5.66	15.45	3.55
n_3	3.13	4.85	15.34	7.92	8.08	5.79	15.42	3.61
$F_{2,27}$	1.16	2.22	0.12	1.26	1.36	1.25	0.05	3.20
SE_m	0.263	0.483	0.107	0.113	0.135	0.128	0.112	0.060
k_1	2.99	5.62	15.38	7.91	8.35	5.57	15.40	3.56
k_2	2.91	5.73	15.41	7.79	7.98	5.56	15.52	3.44
k_3	2.80	5.44	15.38	7.76	8.34	5.83	15.33	3.55
$F_{2,27}$	0.13	0.09	0.03	0.50	2.37	1.40	0.65	1.22
SE_m	0.263	0.483	0.107	0.113	0.135	0.128	0.117	0.060
Controls								
$o_{1\ alone}$	3.34	5.91	15.86	7.98	9.23	5.63	15.36	3.30
$o_{2\ alone}$	3.25	4.93	15.17	7.65	7.22	5.05	14.71	3.59
$o_{3\ alone}$	4.10	4.63	14.75	7.44	7.79	5.57	15.11	3.75

Table 38. Effect of organic manures, nitrogen and potassium on physical properties of soil

Main effect of factors	Bulk density (g cc^{-1})		Particle density (g cc^{-1})		Water holding capacity(%)		Porosity (%)		Aggregate stability (%)	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1	1.58	1.54	2.38	2.29	24.33	25.38	35.93	36.90	42.04	43.35
o_2	1.58	1.55	2.42	2.36	24.31	25.57	35.28	36.64	42.38	43.79
o_3	1.60	1.54	2.40	2.32	24.70	25.53	34.50	36.27	42.54	44.10
$F_{2,2}$	1.00	0.33	0.45	1.30	0.08	0.02	8.01	1.71	0.41	0.53
SE_m	0.005	0.009	0.031	0..030	0.795	0.685	0.254	0.245	0.427	0.519
n_1	1.57	1.55	2.38	2.32	23.77	24.86	35.77	36.83	42.43	43.82
n_2	1.58	1.54	2.42	2.34	24.87	26.06	35.17	36.51	42.26	43.88
n_3	1.60	1.55	2.40	2.32	24.66	25.50	34.78	36.54	42.26	43.36
$F_{2,27}$	3.14	0.39	1.39	0.58	1.81	1.86	1.40	0.12	0.49	1.70
SE_m	0.007	0.009	0.018	0.018	0.436	0.440	0.425	0.515	0.140	0.218
k_1	1.58	1.55	2.40	2.32	24.18	25.61	34.99	36.63	42.41	43.52
k_2	1.59	1.55	2.38	2.32	24.85	25.57	35.69	36.89	42.22	43.90
k_3	1.58	1.54	2.41	2.34	24.27	25.25	35.05	36.37	42.32	43.65
$F_{2,27}$	0.63	0.77	0.52	0.17	0.71	0.20	0.83	0.26	0.46	0.78
SE_m	0.007	0.009	0.018	0.018	0.436	0.440	0.425	0.515	0.140	0.218
Controls										
$o_{1\,alone}$	1.60	1.50	2.43	2.32	24.94	25.37	37.87	36.63	42.72	43.77
$o_{2\,alone}$	1.55	1.50	2.45	2.35	23.70	26.34	33.98	37.05	41.90	43.90
$o_{3\,alone}$	1.55	1.49	2.36	2.33	25.08	25.29	33.74	35.47	42.01	45.24

Table 39. Effect of organic manures, nitrogen and potassium on total nutrient status

Main effect of factors	Nutrient contents (%)					
	Total nitrogen		Total phosphorus		Total potassium	
	98-99	99-00	98-99	99-00	98-99	99-00
o_1	0.076	0.083	0.056	0.056	0.026	0.031
o_2	0.078	0.081	0.054	0.056	0.026	0.028
o_3	0.079	0.092	0.053	0.057	0.026	0.034
$F_{2,2}$	0.000	0.000	0.000	0.000	0.000	0.000
SE_m	0.000	0.000	0.000	0.000	0.005	0.005
n_1	0.075	0.084	0.053	0.056	0.026	0.031
n_2	0.077	0.087	0.055	0.056	0.027	0.031
n_3	0.081	0.088	0.057	0.057	0.026	0.031
$F_{2,27}$	0.000	0.000	0.000	0.000	0.000	0.000
SE_m	0.003	0.003	0.002	0.000	0.000	0.000
k_1	0.077	0.083	0.055	0.056	0.025	0.030
k_2	0.078	0.089	0.056	0.057	0.029	0.031
k_3	0.079	0.087	0.055	0.057	0.025	0.032
$F_{2,27}$	0.000	0.000	0.000	0.000	0.000	0.000
SE_m	0.003	0.003	0.002	0.000	0.000	0.000
Controls						
$o_{1\ alone}$	0.071	0.071	0.051	0.056	0.022	0.031
$o_{2\ alone}$	0.078	0.075	0.047	0.055	0.024	0.028
$o_{3\ alone}$	0.076	0.087	0.044	0.056	0.023	0.031

4.3.9.2 Available nutrients in the soil

4.3.9.2.1 Available nitrogen

The data on available nitrogen content of the soil after the harvest of the crop in each year are furnished in Tables 40a and 40b.

Available nitrogen content of the soil varied significantly due to the application of different organic manures in 98-99. Application of o_3 resulted in highest values (206.54 kg ha^{-1}) which was on a par with o_2 (201.90 kg ha^{-1}). Plots that received o_1 or o_2 recorded almost similar content. However, significant difference between organic manures was not evident in the subsequent year. In both the years, available N increased with increase in applied N. This effect was significant upto n_2 (214.34 kg ha^{-1} in 98-99 and 206.60 kg ha^{-1} in 99-00). The increase in the quantity of available N at n_3 over n_2 was not significant in either of the years. In both the years, increased rates of K fertilization significantly enhanced the available N status of the soil. Higher available N content was registered at k_3 (221.36 kg ha^{-1} and 214.34 kg ha^{-1} respectively) (Table 40a).

It is evident from Table 40b that the combined effect of organic manures and nitrogen was significant during 98-99, with o_1 and o_2 registering significantly higher content upto n_2 and o_3 upto n_3. Available N status of the soil did not vary significantly due to the interaction effect OxK either in 98-99 or 99-00. Significant variation in available N content was observed due to NxK interaction effect in the first year. At the lowest and highest levels of N, increased rates of K application significantly enhanced available N content. However at medium levels of N significant response was noticed upto k_2, which registered the same content as that of k_3.

4.3.9.2.2 Available phosphorus

The data on available phosphorus status of the soil at the end of each season are presented in Tables 40a and 40b.

Table 40a Effect of organic manures, nitrogen and potassium on the status of available nutrients and organic carbon content of soil

Main effect of factors	Nutrient status (kg ha^{-1})						Organic carbon content(%)	
	Available nitrogen		Available phosphorus		Available potassium			
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1	196.04	190.88	56.12	57.85	162.51	158.97	0.53	0.54
o_2	201.90	201.32	54.20	61.06	163.61	165.51	0.64	0.55
o_3	206.54	201.61	66.65	67.75	182.83	168.13	0.63	0.55
$F_{2,2}$	20.07*	3.11	44.74*	6.60	33.21*	0.97	18.25	0.50
SE_m	1.175	3.464	1.002	1.970	1.983	4.796	0.014	0.012
CD(0.05)	7.150	–	6.097	–	12.067	–	–	–
n_1	187.84	190.17	56.94	64.25	171.70	158.42	0.60	0.55
n_2	214.34	206.60	60.44	63.08	181.43	168.33	0.63	0.56
n_3	215.30	210.79	60.72	61.94	169.09	179.67	0.61	0.55
$F_{2,27}$	57.89*	18.36**	2.03	0.42	1.72	14.71**	1.57	0.94
SE_m	2.048	2.543	1.478	1.780	4.956	2.771	0.013	0.009
CD(0.05)	5.943	7.380	–	–	–	8.041	–	
k_1	190.16	187.91	55.49	61.26	128.72	139.76	0.59	0.54
k_2	205.96	205.32	60.32	62.05	188.94	177.92	0.62	0.56
k_3	221.36	214.34	62.30	65.97	204.55	188.75	0.63	0.57
$F_{2,27}$	57.99**	27.91**	5.614**	2.01	65.27**	86.24**	2.20	1.57
SE_m	2.048	2.543	1.478	1.78	4.956	2.771	0.013	0.009
CD(0.05)	5.943	7.380	4.289	–	14.382	8.041	–	
Controls								
o_1 alone	150.84	156.65	55.28	53.58	127.28	117.36	0.40	0.50
o_2 alone	159.55	162.44	55.25	54.34	130.76	124.76	0.49	0.45
o_3 alone	176.95	150.84	56.17	55.25	131.44	126.12	0.56	0.47

** Significant at 1% level
* Significant at 5% level

Table 40b Interaction effect of organic manures, nitrogen and potassium on the status of available nutrients and organic carbon content of soil

Main effect of factors	Nutrient status (kg ha^{-1})						Organic carbon content(%)	
	Available nitrogen		Available phosphorus		Available potassium			
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
o_1n_1	179.65	185.68	53.04	57.34	165.77	143.92	0.52	0.53
o_1n_2	216.59	193.39	53.56	58.52	171.92	172.97	0.59	0.56
o_1n_3	206.92	204.99	62.04	59.11	161.57	173.89	0.53	0.54
o_2n_1	187.58	197.25	51.34	67.21	159.60	176.96	0.66	0.55
o_2n_2	216.59	210.79	54.10	59.48	181.71	159.55	0.65	0.55
o_2n_3	215.63	208.86	56.80	58.75	160.47	173.60	0.66	0.58
o_3n_1	196.29	187.59	66.45	68.21	189.73	154.39	0.62	0.56
o_3n_2	209.83	215.63	73.66	71.23	190.67	172.48	0.66	0.59
o_3n_3	223.36	218.53	63.32	67.97	185.23	191.52	0.65	0.54
$F_{4,27}$	3.70*	2.16	3.65*	1.16	0.44	8.28**	1.18	1.57
S E_m	3.548	4.405	2.560	3.080	8.584	4.799	0.023	0.016
CD (0.05)	10.296	–	–	–	–	13.927	–	–
o_1k_1	189.52	174.05	49.01	52.07	136.64	131.51	0.52	0.53
o_1k_2	199.19	199.22	60.61	59.94	178.51	174.88	0.54	0.56
o_1k_3	214.46	210.79	59.02	62.98	184.11	184.40	0.57	0.54
o_2k_1	187.58	191.45	53.13	61.93	128.71	143.31	0.65	0.55
o_2k_2	210.79	207.89	51.41	59.67	171.60	175.84	0.66	0.55
o_2k_3	221.43	217.56	57.71	63.84	201.47	190.96	0.66	0.57
o_3k_1	193.39	198.22	64.33	69.78	120.83	144.47	0.61	0.55
o_3k_2	207.89	208.86	68.94	66.53	216.72	183.03	0.66	0.56
o_3k_3	228.19	214.66	70.16	71.10	228.08	190.89	0.66	0.58
$F_{4,27}$	1.33	1.42	1.74	1.18	4.56**	0.40	0.47	0.47
S E_m	3.548	4.405	2.560	3.080	8.584	4.799	0.023	0.016
CD (0.05)	–	–	–	–	24.911	–	–	–
n_1k_1	169.21	179.85	50.39	60.60	123.65	125.99	0.57	0.52
n_1k_2	188.55	196.32	58.94	64.02	192.77	177.43	0.63	0.55
n_1k_3	205.76	194.35	61.50	68.14	198.67	171.85	0.61	0.57
n_2k_1	204.03	188.55	58.55	61.22	128.19	153.85	0.62	0.56
n_2k_2	219.49	207.89	61.80	62.99	194.48	167.17	0.63	0.57
n_2k_3	219.49	223.36	60.97	65.02	221.63	183.97	0.65	0.57
n_3k_1	197.25	195.32	57.53	61.96	134.33	139.44	0.59	0.55
n_3k_2	209.83	211.76	60.22	59.13	179.57	189.15	0.61	0.55
n_3k_3	238.83	225.30	64.42	64.74	193.36	210.43	0.63	0.56
$F_{4,27}$	5.51**	1.78	0.91	0.35	1.32	7.92**	0.32	0.63
S E_m	3.548	4.405	2.560	3.080	8.584	4.799	0.023	0.016
CD(0.05)	10.296	–	–	–	–	13.927	–	–

** Significant at 1% level

* Significant at 5% level

The effect of organic manures on the available phosphorus content of the soil was significant only during 98-99. Plots treated with o_3 resulted in highest content (66.65 kg ha^{-1}) that was significantly superior to o_1 and o_2, which were on a par each other. Levels of nitrogen did not differ significantly in either of the years. Increasing levels of potassium resulted in higher content of available phosphorus during both the years. In 98-99, the effect was significant upto k_2, which was on par with k_3. However, K levels did not differ significantly in the subsequent year. None of the interaction effects were significant in 98-99 as well as 99-00.

4.3.9.2.3 Available potassium

The data on available potassium content of the soil at the end of each season are presented in Tables 40a and 40b.

Organic manures significantly influenced the available potassium content in 98-99, with o_3 resulting in significantly higher content (182.83 kg ha^{-1}). The other manures proved equally effective. However in the subsequent year, organic manures did not influence significantly the available potassium content. Increasing levels of N significantly enhanced available K content of the soil in 99-00. In both the years, available K content of the soil was also enhanced significantly at higher rates of K nutrition, with maximum content being recorded at k_3 (204.55 kg ha^{-1} and 188.75 kg ha^{-1} respectively) (Table 40a).

Table 40b depicts that OxN interaction was significant in 99-00. At higher rates of N nutrition, (n_2 or n_3), o_1 and o_3 resulted in significantly higher available K content in soil. However, o_2 maintained higher content at n_1. The interaction between organic manures and potassium was significant in 98-99. All the organic manures resulted in significantly higher available K content, at higher rates of K (k_2 or k_3). A significant NxK interaction was present during 99-00, n_1 responded upto k_2, n_2 and n_3 upto k_3 in attaining significantly higher available K content.

4.3.9.2.4 Organic carbon

Organic carbon content did not vary significantly due to different organic manures or levels of nitrogen or potassium in either of the years. None of the combined effects of these treatments were significant in 98-99 or 99-00 (Tables 40a and 40b).

4.3.9.3 Nutrient balance sheet

4.3.9.3.1 Balance sheet for available nitrogen

The results revealed that there was considerable loss of nitrogen during the first year (Table 41a) in all the treatments, whereas during the second year the loss was comparatively lower (Table 41b). During both the years, comparatively lower net loss was observed in sunhemp incorporated (o_2) plots. Increasing levels of nitrogen showed a tendency to enhance the N loss. On the other hand, incremental doses of potassium reduced the loss considerably. Similar trends were observed due to the effect of the interaction between nitrogen and potassium. In general, at all levels of N, higher rates of potassium nutrition reduced the net loss of N. It is also obvious that the highest dose of nitrogen indicated greatest loss, irrespective of the levels of potassium.

4.3.9.3.2 Balance sheet for available phosphorus

Available P content of soil showed deficit balance in 98-99 as well as 99-00 (Tables 42a and 42b). However, considerable decrement in the magnitude of net loss was observed in the second year in all the treatments. In both the years, incorporation of sunhemp resulted in comparatively lesser loss. In 98-99, a declining trend in the net loss of phosphorus was observed with increasing levels of N or K. However in the subsequent year, higher rates of N (n_2 and n_3) slightly enhanced the loss of P. Considering the NxK interaction, irrespective of the levels of N, higher rates of K reduced the net deficit in both the years.

Table 41a. Nutrient balance sheet for nitrogen (98-99)

Treatments	Initial status (kg ha^{-1})	N addition (kg ha^{-1})	N uptake (kg ha^{-1})	Expected balance (kg ha^{-1})	Available N status (kg ha^{-1})	Net loss\gain (kg ha^{-1})
o_1	264.68	122.00	61.66	325.02	196.04	-128.98
o_2	264.58	140.00	76.54	328.05	201.90	-126.15
o_3	264.48	91.19	64.80	290.87	206.54	-79.84
n_1	264.63	88.22	62.93	289.92	187.84	-97.41
n_2	263.75	125.15	76.50	312.40	214.34	-98.06
n_3	265.54	164.94	75.82	354.66	215.30	-139.35
k_1	263.49	134.15	65.30	332.34	190.16	-132.40
k_2	265.22	124.48	73.75	315.95	205.96	-110.00
k_3	265.20	124.78	76.20	313.79	221.36	-92.43
n_1k_1	263.34	99.00	54.42	307.91	169.21	-121.10
n_1k_2	261.86	84.04	64.40	281.50	188.55	-92.95
n_1k_3	268.68	85.21	69.96	283.93	205.76	-78.17
n_2k_1	263.46	125.26	71.37	317.36	204.03	-113.33
n_2k_2	266.59	124.96	80.08	311.47	219.49	-91.98
n_2k_3	261.20	125.24	78.06	308.38	219.49	-88.89
n_3k_1	263.67	166.47	70.11	360.03	197.25	-162.77
n_3k_2	267.21	164.45	76.77	354.89	209.83	-145.06
n_3k_3	265.73	163.90	80.58	349.05	238.83	-110.22
n_0k_0	264.07	41.38	30.91	274.54	162.45	-112.09

Table 41b. Nutrient balance sheet for nitrogen (99-00)

Treatments	Initial status (kg ha^{-1})	N addition (kg ha^{-1})	N uptake (kg ha^{-1})	Expected balance (kg ha^{-1})	Available N status (kg ha^{-1})	Net loss\gain (kg ha^{-1})
o_1	196.04	122.00	57.95	260.09	190.88	-69.21
o_2	201.90	140.00	70.88	271.01	201.32	-69.70
o_3	206.54	110.35	60.48	256.41	201.61	-54.80
n_1	187.84	94.75	56.25	226.34	190.18	-36.17
n_2	214.34	132.20	67.96	278.57	206.60	-71.97
n_3	215.30	170.58	73.92	311.96	210.79	-101.16
k_1	190.16	131.73	61.09	260.81	187.91	-72.90
k_2	205.96	134.86	64.28	276.54	205.33	-71.22
k_3	221.36	130.93	72.78	279.52	214.34	-65.18
n_1k_1	169.21	91.62	49.37	211.46	179.85	-31.61
n_1k_2	188.55	98.91	53.08	234.38	196.32	-38.06
n_1k_3	205.76	93.73	66.30	233.19	194.36	-38.83
n_2k_1	204.03	131.58	63.17	272.43	188.55	-83.88
n_2k_2	219.49	134.89	71.73	282.65	207.89	-74.76
n_2k_3	219.49	130.13	68.99	280.63	223.37	-57.26
n_3k_1	197.25	171.99	70.72	298.53	195.32	-103.21
n_3k_2	209.83	170.79	68.02	312.60	211.76	-100.84
n_3k_3	238.83	168.94	83.03	324.74	225.30	-99.45
n_0k_0	162.45	48.59	36.61	174.43	156.64	-17.79

Table 42a. Nutrient balance sheet for phosphorus (98-99)

Treatments	Initial status (kg ha^{-1})	P addition (kg ha^{-1})	P uptake (kg ha^{-1})	Expected balance (kg ha^{-1})	Available P status (kg ha^{-1})	Net loss\gain (kg ha^{-1})
o_1	63.37	80.00	6.88	136.50	56.12	-80.38
o_2	62.44	63.00	8.44	117.01	54.20	-62.81
o_3	62.33	61.40	6.87	116.86	66.65	-50.21
n_1	64.37	68.07	7.09	125.34	56.94	-68.40
n_2	61.18	68.22	8.16	121.24	60.44	-60.80
n_3	61.78	68.20	8.21	121.77	60.72	-61.05
k_1	61.80	68.15	7.02	122.93	55.49	-67.44
k_2	62.86	68.16	8.10	122.92	60.32	-62.60
k_3	62.67	68.19	8.35	122.51	62.30	-60.21
n_1k_1	63.03	67.86	5.94	124.96	50.39	-74.57
n_1k_2	63.98	68.11	7.41	124.68	58.94	-65.75
n_1k_3	66.09	68.23	7.93	126.39	61.50	-64.89
n_2k_1	61.57	68.23	7.68	122.13	58.55	-63.58
n_2k_2	62.47	68.20	8.41	122.26	61.81	-60.45
n_2k_3	59.50	68.23	8.39	119.34	60.97	-58.37
n_3k_1	60.79	68.35	7.43	121.70	57.53	-64.18
n_3k_2	62.13	68.15	8.47	121.81	60.22	-61.59
n_3k_3	62.42	68.10	8.73	121.79	64.42	-57.37
n_0k_0	65.14	67.86	3.56	129.45	55.57	-73.88

Table 42b. Nutrient balance sheet for phosphorus (99-00)

Treatments	Initial status (kg ha^{-1})	P addition (kg ha^{-1})	P uptake (kg ha^{-1})	Expected balance (kg ha^{-1})	Available P status (kg ha^{-1})	Net loss\gain (kg ha^{-1})
o_1	56.12	80.00	7.01	129.11	57.85	-71.26
o_2	66.56	63.00	7.65	121.90	61.07	-60.84
o_3	54.24	63.65	7.12	110.77	67.75	-43.02
n_1	56.94	69.13	7.01	119.06	64.25	-54.81
n_2	60.44	68.89	7.62	121.71	63.08	-58.63
n_3	60.72	68.74	8.24	121.22	61.94	-59.27
k_1	55.49	68.85	6.58	117.75	61.26	-56.49
k_2	60.32	69.14	7.46	122.00	62.05	-59.95
k_3	62.30	68.77	8.83	122.24	65.97	-56.27
n_1k_1	50.39	68.84	6.00	113.23	60.60	-52.63
n_1k_2	58.94	69.53	6.97	121.50	64.02	-57.48
n_1k_3	61.50	69.04	8.07	122.47	68.14	-54.33
n_2k_1	58.55	68.83	6.48	120.90	61.22	-59.68
n_2k_2	61.81	69.15	7.56	123.40	62.99	-60.40
n_2k_3	60.97	68.69	8.82	120.84	65.03	-55.82
n_3k_1	57.53	68.87	7.27	119.13	61.96	-57.17
n_3k_2	60.22	68.76	7.86	121.11	59.13	-61.98
n_3k_3	64.42	68.58	9.59	123.41	64.74	-58.66
n_0k_0	55.40	68.55	3.99	119.96	54.39	-65.57

4.3.9.3.3 Balance sheet for available potassium

As presented in Table 43a, the balance sheet of available K was positive for certain treatments in 98-99. In the succeeding year (Table 43b) negative balance for K was observed for most of the treatments. However, the magnitude of loss was comparatively lesser than that for N and P.

In 98-99, a distinct gain in the quantity of available K was observed in plots that received sunhemp incorporation (30.80 kg ha^{-1}). Medium levels of N or K (n_2 or k_2) also resulted in net gains in K. Regarding NxK interaction, at all levels of N, medium dose of K registered net gains. It is also noteworthy that medium dose of N maintained net gains at higher rates of K (n_2k_2 and n_2k_3) and the net gain was maximum with n_2k_2 (28.81kg ha^{-1}).

In the next year, incorporation of green manure sunhemp (o_3) resulted in reducing the net loss of K. Incremental doses of N also tended to reduce the loss, with the least values at n_3, whereas higher potassium nutrition favoured greater loss. Interaction between nitrogen and potassium also followed similar trend, at all rates of applied N higher doses of K promoted greater loss. Among NxK interactions,n_2k_1 registered a positive balance during this year.

4.3.10 Economic analysis of nutrient management practices

4.3.10.1 Net return

The treatment, $o_2n_2k_2$ fetched maximum net return (Rs. 36,187. 00 ha^{-1}), closely followed by $o_3n_3k_1$ (Rs. 35,657.00 ha^{-1}) and $o_1n_2k_3$ (Rs. 34,720.00 ha^{-1}). Omission of nitrogenous and potassic fertilizers (n_0 k_0) resulted in negative net returns irrespective of the sources of organic manures (Table 44).

4.3.10.2 Benefit - Cost Ratio (BCR)

Highest BCR was realized from $o_3n_3k_1$ (1.54) followed by $o_1n_2k_3$ (1.53) and $o_1n_3k_3$ (1.51). High BCR ratios were also computed from $o_3n_2k_1$ (1.50) and $o_2n_2k_2$ (1.42), providing alternative feasible options for the small holder farmers. Application of organic manures alone without N and K fertilizers (n_0 k_0) resulted in lowest BCR (Table 44).

Table 43a. Nutrient balance sheet for potassium (98-99)

Treatments	Initial status (kg ha^{-1})	K addition (kg ha^{-1})	K uptake (kg ha^{-1})	Expected balance (kg ha^{-1})	Available K status (kg ha^{-1})	Net loss\gain (kg ha^{-1})
o_1	134.45	112.00	61.62	184.83	162.51	-22.32
o_2	133.17	127.00	79.05	181.12	163.61	-17.51
o_3	134.71	83.29	65.97	152.03	182.83	30.80
n_1	135.10	114.91	64.80	185.20	171.70	-13.50
n_2	132.21	116.14	78.67	169.68	181.43	11.75
n_3	134.23	115.97	75.67	174.53	169.09	-5.44
k_1	134.19	75.54	64.80	144.93	128.72	-16.20
k_2	133.26	115.62	75.23	173.65	188.94	15.29
k_3	134.10	155.85	79.12	210.83	204.55	-6.28
n_1k_1	135.65	73.26	55.16	153.75	123.65	-30.09
n_1k_2	135.41	115.28	65.86	184.84	192.77	7.94
n_1k_3	134.24	156.18	73.39	217.03	198.67	-18.35
n_2k_1	131.76	76.22	71.88	136.10	128.19	-7.91
n_2k_2	131.71	115.99	82.03	165.67	194.48	28.81
n_2k_3	133.17	156.21	82.11	207.27	221.63	14.36
n_3k_1	135.15	77.15	67.36	144.94	134.33	-10.60
n_3k_2	132.65	115.59	77.80	170.45	179.57	9.12
n_3k_3	134.88	155.18	81.85	208.21	193.36	-14.85
n_0k_0	136.48	33.24	31.36	138.36	129.83	-8.53

Table 43b. Nutrient balance sheet for potassium (99-00)

Treatments	Initial status	K addition	K uptake	Expected balance	Available K status	Net loss\gain
	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})
o_1	162.51	112.00	60.38	214.13	158.97	-55.16
o_2	163.61	127.00	70.93	219.68	165.51	-54.17
o_3	182.83	63.65	61.99	184.49	168.13	-16.37
n_1	171.70	106.47	58.73	219.44	158.42	-61.02
n_2	181.43	106.22	67.68	219.98	168.33	-51.65
n_3	169.09	106.07	77.46	197.69	179.67	-18.02
k_1	128.72	79.51	59.57	148.67	139.76	-8.91
k_2	188.94	106.48	68.05	227.37	177.92	-49.46
k_3	204.55	132.77	76.25	261.07	188.75	-72.32
n_1k_1	123.65	79.50	49.78	153.38	125.99	-27.39
n_1k_2	192.77	106.86	56.45	243.19	177.43	-65.76
n_1k_3	198.67	133.04	69.96	261.75	171.85	-89.90
n_2k_1	128.19	79.50	59.05	148.63	153.85	5.22
n_2k_2	194.48	106.48	72.92	228.04	167.17	-60.87
n_2k_3	221.63	132.69	71.06	283.26	183.97	-99.29
n_3k_1	134.33	79.54	69.86	144.01	139.44	-4.57
n_3k_2	179.57	106.09	74.78	210.88	189.15	-21.74
n_3k_3	193.36	132.58	87.75	238.19	210.43	-27.77
n_0k_0	129.83	52.55	32.73	149.65	122.75	-26.90

Table 44. Economics of cultivation as influenced by nutrient management practices

Treatments	Tuber yield ($t\ ha^{-1}$)	Yield gap	Gross returns ($Rs\ ha^{-1}$)	Added returns ($Rs\ ha^{-1}$)	Total cost ($Rs\ ha^{-1}$)	Added cost ($Rs\ ha^{-1}$)	Net returns ($Rs\ ha^{-1}$)	Added profit ($Rs\ ha^{-1}$)	BCR	Marginal BCR
$o_1n_1k_1$	9.80	2.25	48975.00	11225.00	65247.70	1852.70	-16272.70	9372.30	0.75	6.06
$o_1n_1k_2$	11.77	4.22	58850.00	21100.00	65515.30	2120.30	-6665.30	18979.70	0.90	9.95
$o_1n_1k_3$	17.54	9.99	87675.00	49925.00	65782.90	2387.90	21892.10	47537.10	1.33	20.91
$o_1n_2k_1$	11.01	3.46	55050.00	17300.00	65595.30	2200.30	-10545.30	15099.70	0.84	7.86
$o_1n_2k_2$	14.96	7.41	74800.00	37050.00	65862.90	2467.90	8937.10	34582.10	1.14	15.01
$o_1n_2k_3$	20.17	12.62	100850.00	63100.00	66130.50	2735.50	34719.50	60364.50	1.53	23.07
$o_1n_3k_1$	10.47	2.92	52350.00	14600.00	65942.90	2547.90	-13592.90	12052.10	0.79	5.73
$o_1n_3k_2$	16.57	9.02	82850.00	45100.00	66210.50	2815.50	16639.50	42284.50	1.25	16.02
$o_1n_3k_3$	20.09	12.54	100425.00	62675.00	66478.10	3083.10	33946.90	59591.90	1.51	20.33
$o_1n_0k_0$	7.55		37750.00		63395.00		-25645.00		0.60	
$o_2n_1k_1$	13.00	3.97	64975.00	19850.00	86247.70	1852.70	-21272.70	17997.30	0.75	10.71
$o_2n_1k_2$	16.00	6.98	80000.00	34875.00	86515.30	2120.30	-6515.30	32754.70	0.92	16.45
$o_2n_1k_3$	18.97	9.95	94850.00	49725.00	86782.90	2387.90	8067.10	47337.10	1.09	20.82
$o_2n_2k_1$	19.34	10.32	96700.00	51575.00	86595.30	2200.30	10104.70	49374.70	1.12	23.44
$o_2n_2k_2$	24.61	15.59	123050.00	77925.00	86862.90	2467.90	36187.10	75457.10	1.42	31.58
$o_2n_2k_3$	19.07	10.04	95325.00	50200.00	87130.50	2735.50	8194.50	47464.50	1.09	18.35
$o_2n_3k_1$	15.42	6.40	77100.00	31975.00	86942.90	2547.90	-9842.90	29427.10	0.89	12.55
$o_2n_3k_2$	18.65	9.63	93250.00	48125.00	87210.50	2815.50	6039.50	45309.50	1.07	17.09
$o_2n_3k_3$	20.07	11.04	100325.00	55200.00	87478.10	3083.10	12846.90	52116.90	1.15	17.90
$o_2n_0k_0$	9.03		45125.00		84395.00		-39270.00		0.53	
$o_3n_1k_1$	13.44	6.28	67175.00	31400.00	64997.40	1853.20	2177.60	29546.80	1.03	16.94
$o_3n_1K_2$	14.27	7.11	71325.00	35550.00	65265.00	2120.80	6060.00	33429.20	1.09	16.76
$o_3n_1k_3$	17.67	10.52	88350.00	52575.00	65532.60	2388.40	22817.40	50186.60	1.35	22.01
$o_3n_2k_1$	19.54	12.39	97700.00	61925.00	65345.00	2200.80	32355.00	59724.20	1.50	28.14
$o_3n_2k_2$	16.06	8.90	80275.00	44500.00	65612.60	2468.40	14662.40	42031.60	1.22	18.03
$o_3n_2k_3$	12.79	5.63	63925.00	28150.00	65880.20	2736.00	-1955.20	25414.00	0.97	10.29
$o_3n_3k_1$	20.27	13.12	101350.00	65575.00	65692.60	2548.40	35657.40	63026.60	1.54	25.73
$o_3n_3k_2$	12.18	5.02	60875.00	25100.00	65960.20	2816.00	-5085.20	22284.00	0.92	8.91
$o_3n_3k_3$	12.56	5.40	62775.00	27000.00	66227.20	3083.00	-3452.20	23917.00	0.95	8.76
$o_3n_0k_0$	7.16		35775.00		63144.20		-27369.20		0.57	

On the whole, it is obvious that application of coir pith compost @ 5 t ha^{-1} along with 80 kg N and 80 kg K_2O ha^{-1} ($o_2n_2k_2$) maintained high yields (24.61 t ha^{-1}), besides generating higher net income (Rs. 36187.00 ha^{-1}) and benefit cost ratio (1.42).

4.3.10.3 Added profit and marginal BCR

Computation of added profit and marginal BCR of inputting N and K fertilizers indicated that $o_2n_2k_2$ resulted in highest added profit (Rs.75,457.10) and marginal BCR(31.58). The treatments,$o_3n_3k_1$ (Rs.63,026.60) , $o_1n_2k_3$ (Rs.60,364.50) and $o_3n_2k_1$(Rs.59,724.20) also resulted in higher added profits.Higher marginal BCR were also realized from $o_3n_2k_1$(28.14) $o_3n_3k_1$(25.73) and $o_1n_2k_3$ (23.07) (Table 44).

4.3.11 Economic evaluation of coconut - white yam system

Perusal of the data in Table 45 indicates that coconut-white yam intercropping system is an economical proposition as it generates a profit of Rs. 31,525 and BCR of 1.33.

Table 45. Economic evaluation of coconut - white yam system

Cropping situation	Gross return (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net return (Rs. ha^{-1})	BCR
Coconut sole crop	28875.00	21875.00	7000.00	1.32
Coconut + white yam	126295.00	94770.00	31525.00	1.33

DISCUSSION

DISCUSSION

The results of the investigations conducted to assess the production potential of white yam as an intercrop and to standardize agrotechniques for intercropping white yam in coconut garden are discussed in this chapter.

5.1 Experiment I

Effect of growth promoting substances on sprouting of white yam setts

5.1.1 Days taken for sprouting

Sett treatment using thiourea 2% favoured early sprouting during both the years (Table 3) (Fig.5). In the present study, tuber pieces of considerably smaller size (100g) referred to as "setts" derived from the nondormant tubers were used for treatment with various growth promoting substances. When the corm has been detached from the tuber, the remaining tuber piece commences meristematic activity leading to the formation of new buds, a process designated as *de novo* bud formation (Onwueme, 1982). Thiourea through its cell division promoting effect (Audus,1972) might have induced substantial bud development in lesser number of days (47 days) in the treated setts. The pronounced effect of thiourea in inducing early sprouting in dormant white yam tubers has been reported earlier (Samarawira, 1983; Bala Nambisan and Indira, 1993).

5.1.2 Sprouting per cent

Thiourea treatment proved consistently better in achieving higher sprouting per cent (Fig 6a and 6b). The mean data for the two years of study indicate 23% sprouting by 30 days and 40% sprouting by 45 days in this treatment (Table 4). The corresponding figures recorded by Bala Nambisan and Indira (1993) with 100 ppm thiourea treatment in minisetts of *D. rotundata* (viz., 15% and 77% respectively in 30 and 45 days) substantiates the result obtained in the present study. Moreover the poor sprouting percentage observed in the farmer's practice

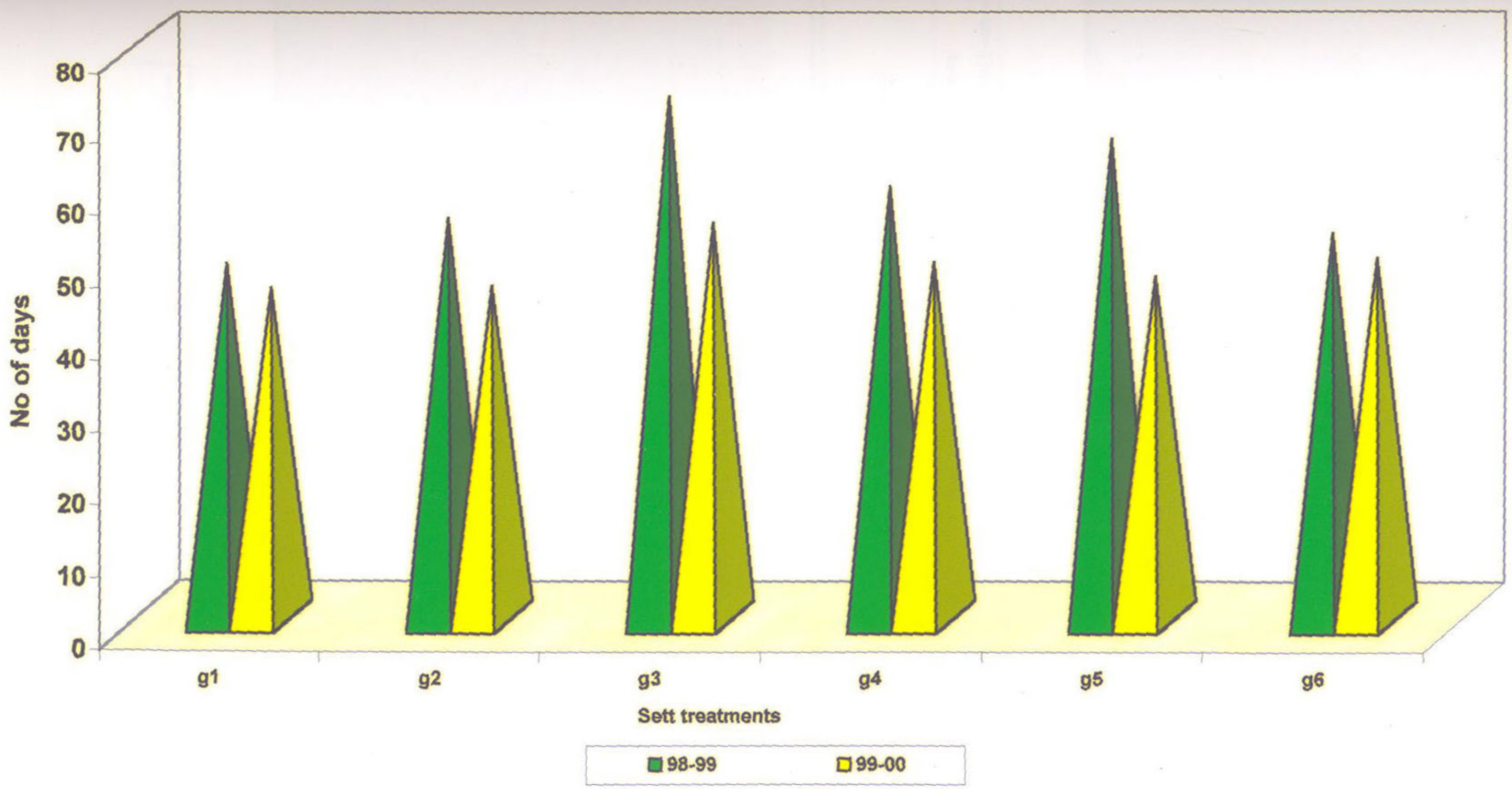


Fig .5 Effect of sett treatments on number of days taken for 50 per cent sprouting

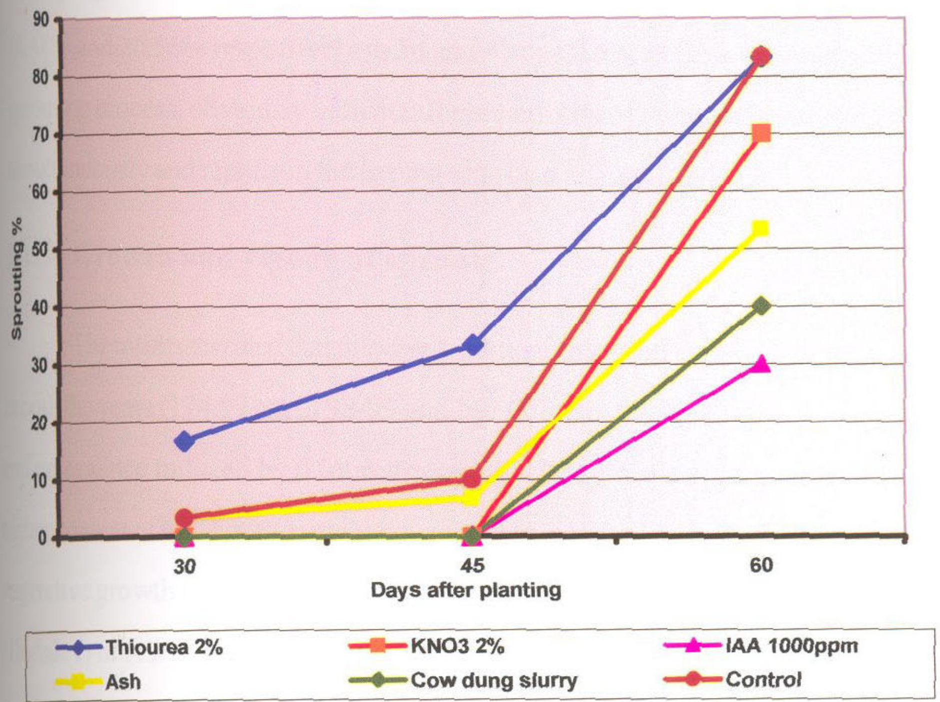


Fig.6a Effect of sett treatments on sprouting (1998-1999)

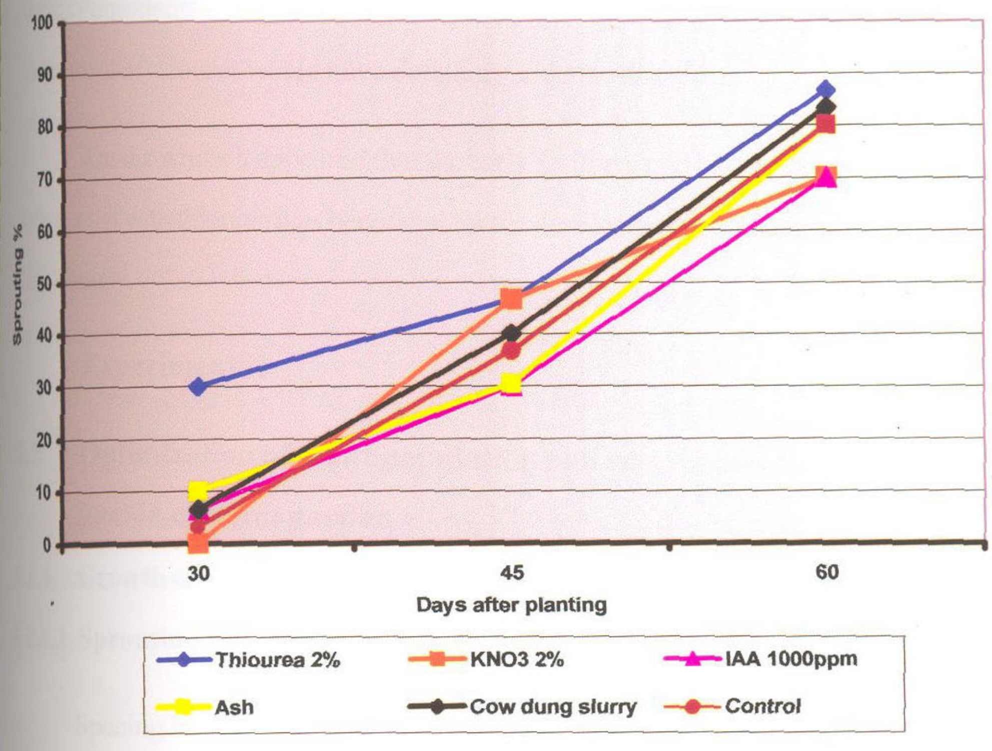


Fig. 6b Effect of sett treatments on sprouting (1999-2000)

of dipping the setts in cowdung slurry or treating with ash as well as with untreated setts (4.44% and 20.56% respectively in 30 and 45 days) due to slow and staggered nature of the sprouting process, obviously indicates the superiority of thiourea in inducing sprouts almost simultaneously and rapidly in the treated setts by active cell division.

5.1.3 Growth and vigour of sprouts

The results revealed that thiourea treatment enhanced the length of sprouts considerably in both the years (174.99 cm in 98-99 and 169.00 cm in 99-00) (Table 5). The early sprouting and emergence induced by thiourea coupled with its growth promoting effect due to the higher content of N (36.80%) might have resulted in longer vines. Influence of N in promoting vegetative growth through its effect on rapid meristematic activity is a well established fact (Tisdale *et al.*, 1995).

Vigour of sprouts was expressed as vigour index, a parameter computed using values of sprouting per cent, vine length and root length. It is probable that thiourea promoted all these components of vigour index and produced vigorous sprouts (Table 5). The nitrogen constituent of thiourea would have definitely added to this effect.

On the whole it appeared that the early, uniform and better sprouting obtained in the setts treated with thiourea was beneficial for the development and establishment of a vigorous crop canopy.

Experiment II

5.2 Optimization of plant population and sett size for intercropping white yam in coconut garden

5.2.1 Growth characters

5.2.1.1 Sprouting per cent

Spacing had no significant influence on the sprouting per cent in both the years. Apparently the yam tuber, with its high moisture content and food reserves requires no further hydration or nutrition for sprouting (Onwueme and Charles, 1994). Hence spacing was not influential on the sprouting process in yams in this study (Table 6).

On the other hand, sett size significantly influenced the sprouting per cent. Significantly highest sprouting per cent was observed with the largest sett size (300 g) at all stages of observation in both the years (Table 6) (Fig. 7). The sprouting per cent observed with 300 g setts at 60 DAP was 97.49 in 98-99 and 90.73 in 99-00. This is in accordance with the previous observation of Nair (1985) in *D. esculenta.* Onwueme and Charles (1994) attributed the rapid and better sprouting of large setts to the presence of greater amount of tuber skin (periderm) and high skin: cut surface ratio. In addition to these, large setts produced more sprouting loci for differentiating sprouts and more sprouts per sett (Onwueme, 1973).

5.2.1.2 Vine length

Lower vine lengths were observed in the closest spacing (60x60 cm) at most stages during the period of experimentation (Table 8). Competition from the dense population for resources viz., nutrient, moisture and light might have suppressed the vine length at the closer spacing in both the years. Decline in height of cassava plants consequent to closer planting in coconut gardens has been reported earlier (CTCRI, 1979; Nayar, 1986).

In the case of sett size, heaviest setts (300 g) resulted in significantly longest vines during 98-99 as well as 99-00 (Table 8). It seems likely that the greater amount of food material initially available in the large sett plants enables it to put forth elaborate, longer and vigorous shoot structures (Onwueme, 1972; Nwoke *et al.*, 1973; Onwueme and Charles, 1994). Experimental evidences also provide considerable insight to this fact. Nair (1985) observed significant increase in vine length in 130 g seed size, in his experimentation with *D. esculenta.* Furthermore, Toyohara *et al.* (1998) stated that larger seed tuber fragments resulted in larger initial growth in *D. alata.*

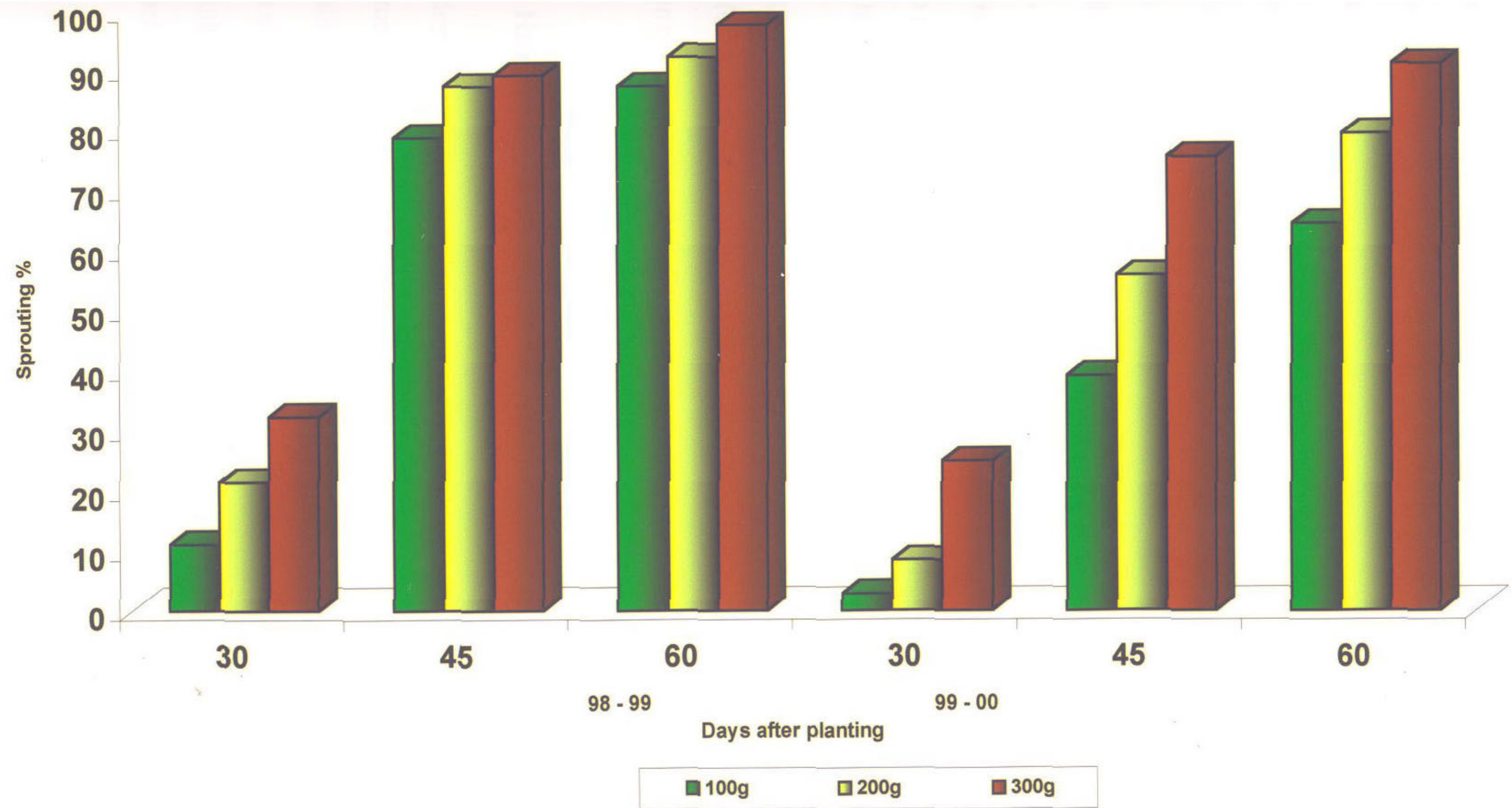


Fig.7 Effect of sett size on sprouting

5.2.2 Pattern of dry matter distribution

5.2.2.1 Dry matter production

Maximum tuber dry matter as well as total dry matter per hectare were computed from the closest spacing (60x60 cm) (Table 10) (Fig.8). This is solely due to the effect of high plant population.

Largest sett size (300 g) produced plants with greatest total dry matter and also accumulated maximum dry matter in tubers which resulted in greater dry matter yields per hectare (Fig.8). It seems that vigorous initial growth of root, vine and leaves produced by a large sett gives the plant an advantage that lasts throughout the growing season (Onwueme, 1972; Nwoke *et al.*, 1973; Nwoke *et al.*, 1984). Moreover, the greater leaf area produced, results in greater carbon assimilation in the plant as well as assimilate translocation to the tubers. Thus in plants established from large setts, mean tuber bulking rates were higher contributing to higher dry matter yield.

Amongst the interaction between spacing and sett size, largest sett size planted at the closest spacing (60x60 cm and 300 g) resulted in significantly higher total dry matter yield due to the integration of the growth and yield promoting effects of the large sett size on the dense stand.

5.2.2.2 Harvest index

The widest spacing (90x90 cm) registered significantly the highest harvest index in both the years (mean value of 0.57) (Table 10). The greater plant space facilitated the plants to capture and utilize the resources available in the coconut garden effectively and give rise to a more vigorous shoot system. It also appears that the synthesized photosynthates were also allocated efficiently to the tuber, resulting in increased size of tubers and highest harvest index in the widest spacing.

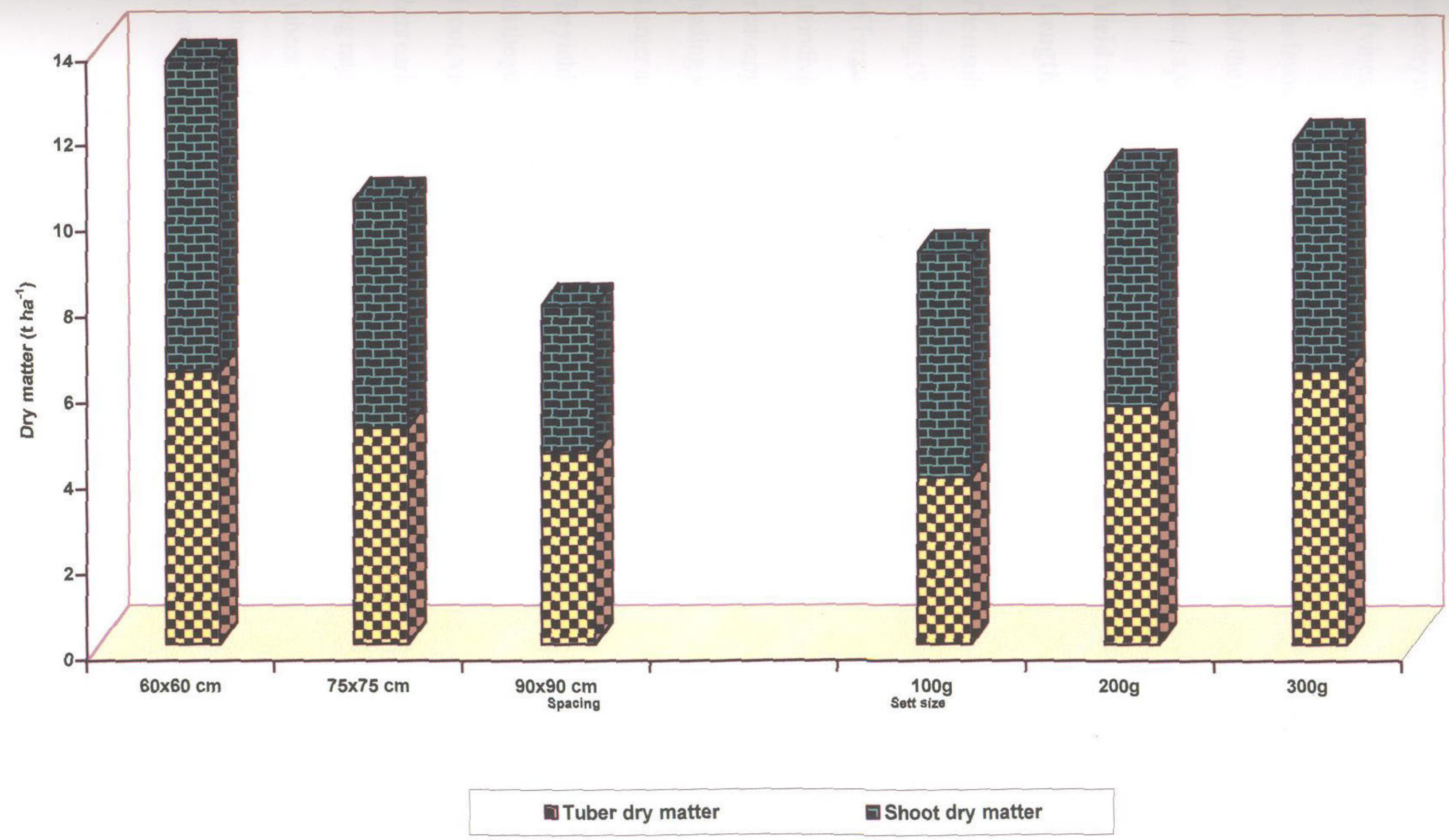


Fig.8 Dry matter distribution as influenced by spacing and sett size

During both the years, the largest sett (300 g) resulted in highest harvest index with mean value of 0.56. The vigorous plant structures formed by the large sett size contributed to higher tuber dry matter partitioning ratio. This heavy investment by the plant in the tuber at the expense of vines, leaves and roots resulted in higher harvest index.

The favourable effects of widest spacing and largest sett size when considered jointly accounts for the highest harvest index (mean H.I. of 0.64) worked out from the treatment combination, s_3w_3 (300 g setts planted at 90 x 90 cm) in both the years (Table 10).

5.2.3 Yield components and yield

5.2.3.1 Length, girth and weight of tuber

The results on length, girth and weight of tubers clearly indicate the positive effects of widest spacing (90x90 cm) on these attributes (Table 11). This result is in agreement with the findings of Ferguson *et al.* (1984) and Singh *et al.* (1994) in *D. alata.* Larger growing space provided to individual plants enabled the use of a greater fraction of the resources and resulted in greater canopy coverage. The larger source size favoured greater and prolonged tuber bulking leading to greater dry matter accumulation in tubers. Thus widely spaced plants produced larger and heavier tubers that out yielded others.

The yield attributes were also appreciably favoured by the largest sett size (300 g) during both the years (Table 11). Large setts tend to emerge earlier, produce vigorous initial growth of root, vine and leaves, particularly greater leaf area and greater plant dry weight, initiate tubers earlier and thus culminate in rapid and longer tuber bulking. The higher mean tuber bulking rates observed with larger setts would have definitely promoted the size and weight of tubers. Moreover, the large sett has more food material which can be translocated directly to the new tuber (Nwoke *et al.*, 1973; Onwueme, 1975). Toyohara *et al.* (1998) could even work out a positive correlation of the length and weight of the new tuber with seed tuber size.

5.2.3.2 Tuber yield

Planting at the closest spacing, 60x60 cm resulted in significantly highest tuber yield in both the years with mean yield of 23.46 t ha^{-1} on account of higher plant population (20,000 plants ha^{-1}) (Table 12 (Fig.9) . It is a well established fact that yield in yams tend to increase with increasing plant density (Ferguson *et al.*, 1984; King and Risimeri, 1992; Singh *et al.*, 1994). This has been confirmed in the present intercropping experiment also. Based on field experimentation at CTCRI, Nayar and Suja (1999) also found that yields were considerably reduced when *D. rotundata* was intercropped at wider spacing (120 x 120 cm) in coconut gardens.

Significantly highest tuber yield was realized from the largest sett weight (300 g) (mean yield of 22.16 t ha^{-1}) in *D. rotundata* intercropped with coconut (Table 12) (Fig.9). Citing a couple of reports to corroborate the present result, sett size of 200-250 g gave optimum sett multiplication ratio for *D. rotundata* under monocrop system at Ibadan, Nigeria (Akoroda, 1985) and for commercial yam production, setts weighing 150-300 g proved to be optimum (Onwueme and Charles, 1994). In general, yield tends to increase with increasing sett size. As discussed earlier, large sett resulted in more rapid emergence (Onwueme, 1972; Onwueme, 1973). The greater potential of direct transfer of food material to the new tubers and the vigorous plant growth set forth by the large setts effecting early, longer and greater tuber bulking and larger storage size might have eventually resulted in higher tuber yield (Onwueme and Charles, 1994).

Considering the interaction between spacing and sett size, the largest sett (300 g) planted at the closest spacing (60x60 cm) resulted in the highest tuber yield in both the years with mean value of 28.07 t ha^{-1} (Table 12). This is obviously due to the combined effect of spacing and sett size. Maintenance of a more dense crop stand with vigorous growth and superior yield attributes was influential in producing higher net yield per hectare. Oriuwa and Onwueme (1980) and Ferguson *et al.* (1984) also reported similar results.

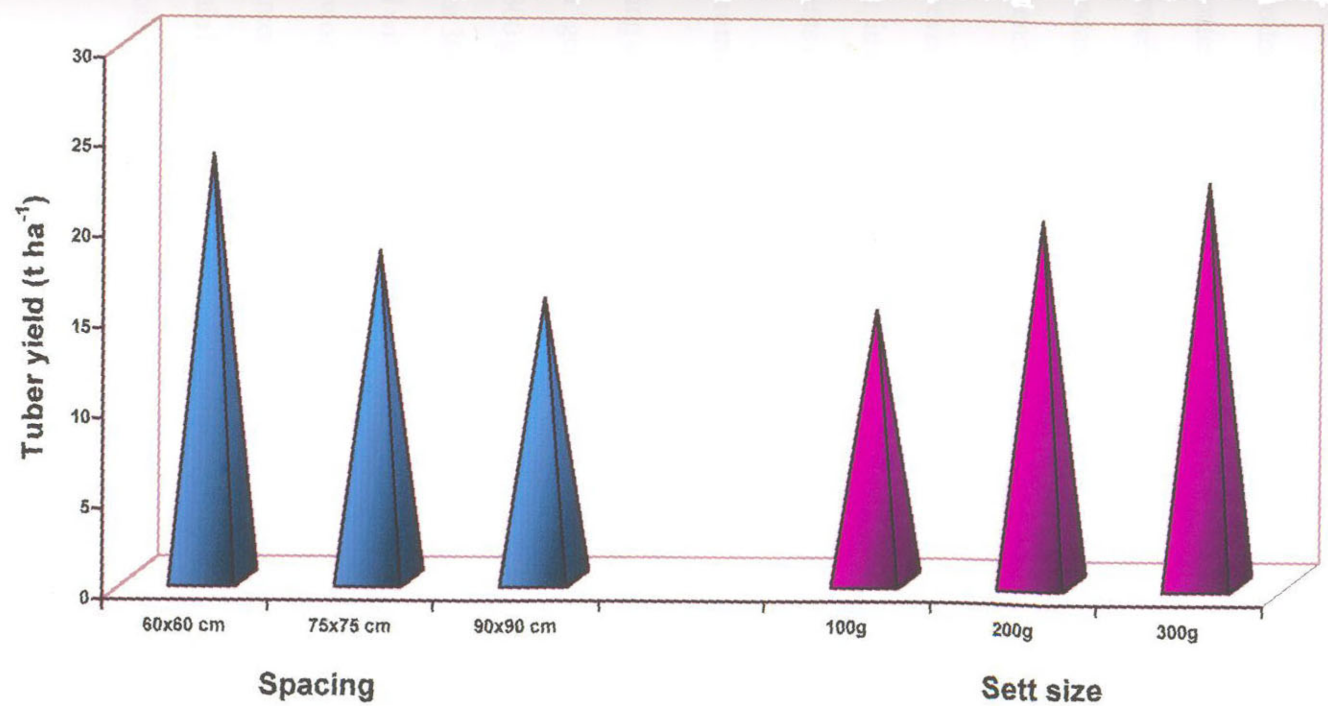


Fig. 9 Effect of spacing and sett size on tuber yield

5.2.4 Quality attributes

Significantly highest starch content (23.70%) was observed at the widest spacing (90x90 cm) (Table 13). Carbohydrates are the major dry matter component of yams that account for approximately one quarter of the tuber fresh weight. Most of the carbohydrate is starch and exists in cells in the form of starch grains. Sufficient filling of these storage cells as a result of greater production and translocation of assimilates to the tubers might have enhanced the starch content of tubers in widely spaced plants. Similar trends were observed by earlier workers in sweet potato (Sharfuddin and Voican, 1984) and in intercrops of cassava (Nayar and Sadanandan, 1991) and arrow root (Maheswarappa *et al.*,1997) in coconut gardens at lower plant density.

However, as stated by Nair (1985) in *D. esculenta* and Maheswarappa *et al.* (1997) in arrow root, in the present investigation also, sett size had no impact on starch or crude protein contents in *D. rotundata.*

5.2.5 Economic analysis

Planting setts of size 200 g or 300g at a spacing of 90x90 cm so as to accommodate 9000 plants ha^{-1} generated higher net returns (Table 14) (Rs 19,363 and Rs. 21,613 respectively for 200 g and 300 g at 90x90 cm). The lesser planting material requirement (1.8 t ha^{-1} for 200 g and 2.7 t ha^{-1} for 300 g) for the above spacing reduced the production cost considerably. This aspect coupled with the better size and quality of tubers fetched higher profit. Nayar and Suja (1999) also worked out higher net return to the tune of Rs. 20,000 ha^{-1} from *D. rotundata* intercropped at a density of 9000 plants ha^{-1} in coconut gardens. It was also possible to obtain higher return per rupee invested for intercropping white yam, by following the above package (BCR 1.31 and 1.32 respectively) due to the same reasons.

Experiment III

5.3. Nutrient management for intercropping white yam in coconut garden

5.3.1 Growth response

During both the years, application of coir pith compost favoured crop growth by producing longer plants (885.88cm) and retaining more number of leaves (610.35) (Tables 15a and 16a).The substantial contribution of N (68 kg ha^{-1}) as well as the gradual and controlled release of essential plant nutrients (viz., N,P,K, Ca, Mg, Fe, Mn, Zn and Cu) particularly nitrogen from coir pith compost might have resulted in favourable crop growth conditions.

Application of nitrogen at the highest level of 120 kg ha^{-1} significantly enhanced vine length (900.22cm) and leaf retention (624.22) (Tables 15a and 16a). It is a proven fact that an adequate supply of nitrogen promotes vegetative growth especially leaf production and keep leaves green for a longer time (Russell, 1973; Tisdale *et al.,* 1995). Stimulation of vegetative growth at higher rates of applied nitrogen has been reported earlier in *D. esculenta* (Enyi, 1972) and in intercrops of *D. alata* (Pushpakumari, 1989), cassava (Nayar, 1986) and arrow root (Veena, 2000) in coconut gardens.

The impact of medium rates of potassium (80 kg ha^{-1}) in increasing vine length at all stages in both the years, and highest dose of K (120 kg ha^{-1}) in retaining greater number of leaves upto 6^{th} month in both the seasons is indicative of the significant role of potassium in promoting vigorous healthy crop growth. However, the reduced canopy size at the highest rate of K especially towards harvest could have resulted from the diversion of photosynthates more to the tubers than to the shoots. Nayar (1986) also observed similar growth reponse of potassium in cassava intercropped in coconut garden.

5.3.2. Physiological parameters

5.3.2.1 Dry matter accumulation and partitioning

Application of coir pith compost resulted in significantly higher dry matter accumulation in leaves, vines and tubers and eventually in the whole plant. (Tables 18a, 19a, 20a and17a) (Figs.10a and 10b). Plants treated with coir pith compost put forth vigorous vegetative structures, maintained higher LAI during critical phases of tuber development and produced tubers with greater size and dry matter content. Citing, Evans (1975) roots and tubers continue cell division and growth during storage.He further explained that photosynthesis prior to storage phase determines storage capacity and generates reserves that may be mobilized during the storage phase. The demand for assimilates for storage in turn has a pronounced stimulant effect on the rate of photosynthesis. In this study a balance was seen maintained between these two interrelated processes in plants supplied with coir pith compost. This favoured higher dry matter accumulation in both the vegetative and storage structures and ultimately resulted in higher biomass production.

Higher rates of N application significantly enhanced the leaf and vine dry matter production at almost all stages of growth during both the years (Tables18a and 19a). Maximum values were obtained at 120 kg N ha^{-1}. At higher rates of N, the number of sinks for accumulating photosynthates in the vegetative structures usually increases. Effects on the vegetative sinks results in more axilliary structures, such as branches,more number of leaves and enhances the leaf area available for photosynthesis (Squire, 1990). Higher LAI noticed at higher rates of N in this study led to greater interception of PAR (Tables 21a and 27a) and greater photosynthetic rates and carbohydrate accumulation in leaves and vines. Similar results were reported earlier in yams (Enyi, 1970, 1972, 1973) and in cassava under artificial shade (Kasale *et al.*, 1983) as well as in intercropping situation (Nayar, 1986). Tuber dry matter production was the highest at 80 kg N ha^{-1} (n_2) at most stages in 98 - 99. Further increase in the level of N decreased the tuber dry matter production significantly since the photosynthates produced by increased N nutrition was diverted for shoot growth rather than for tuber

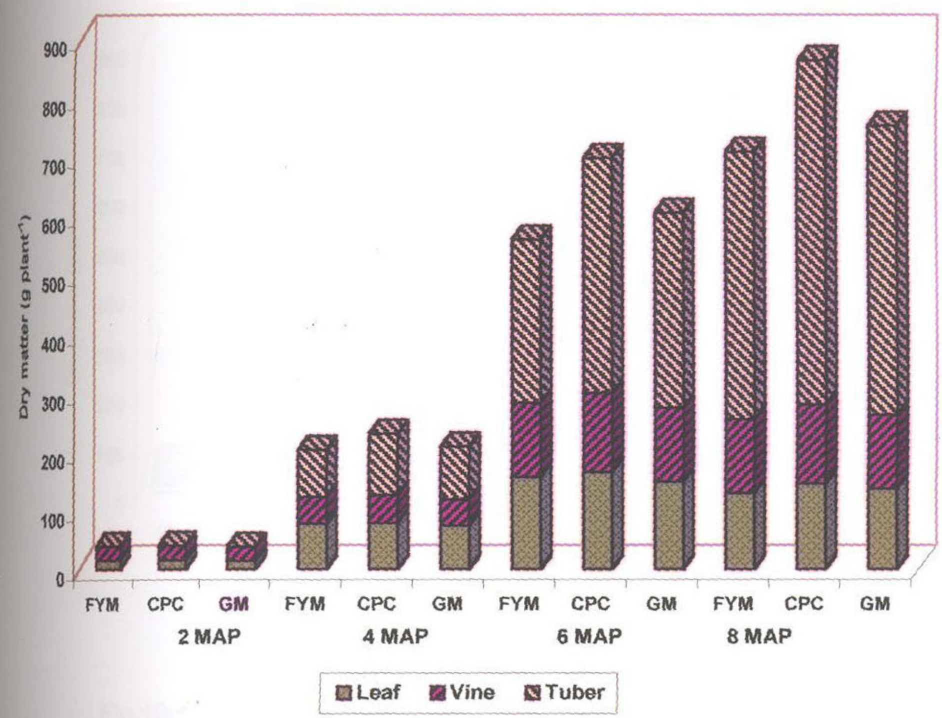


Fig.10a Dry matter distribution as influenced by organic manures *(98-99)*

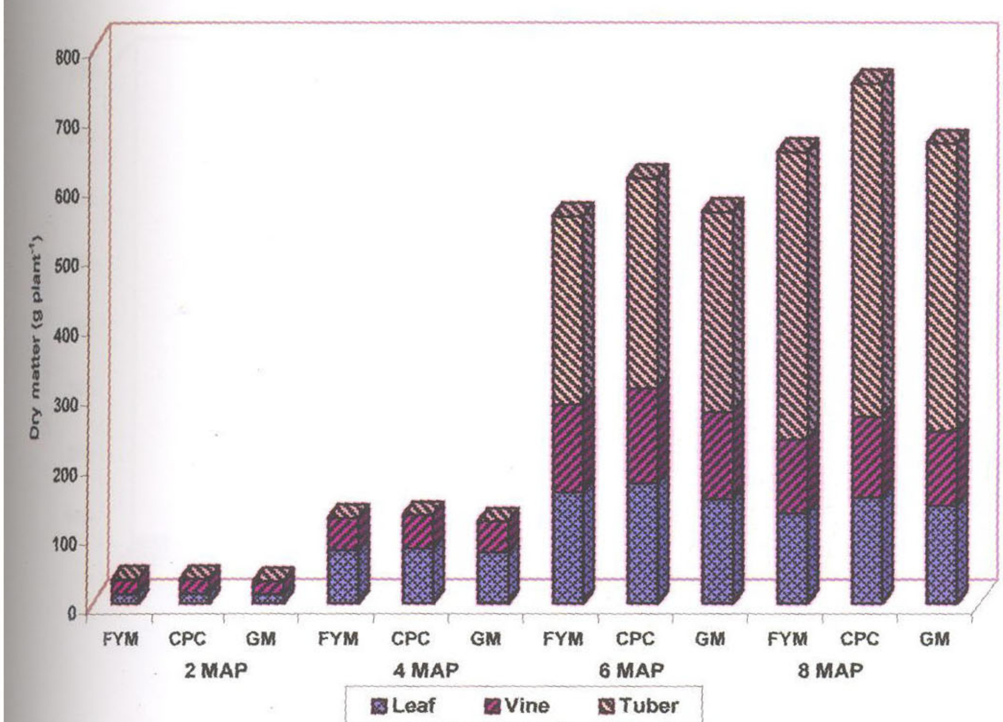


Fig.10b Dry matter distribution as influenced by organic manures (99-00)

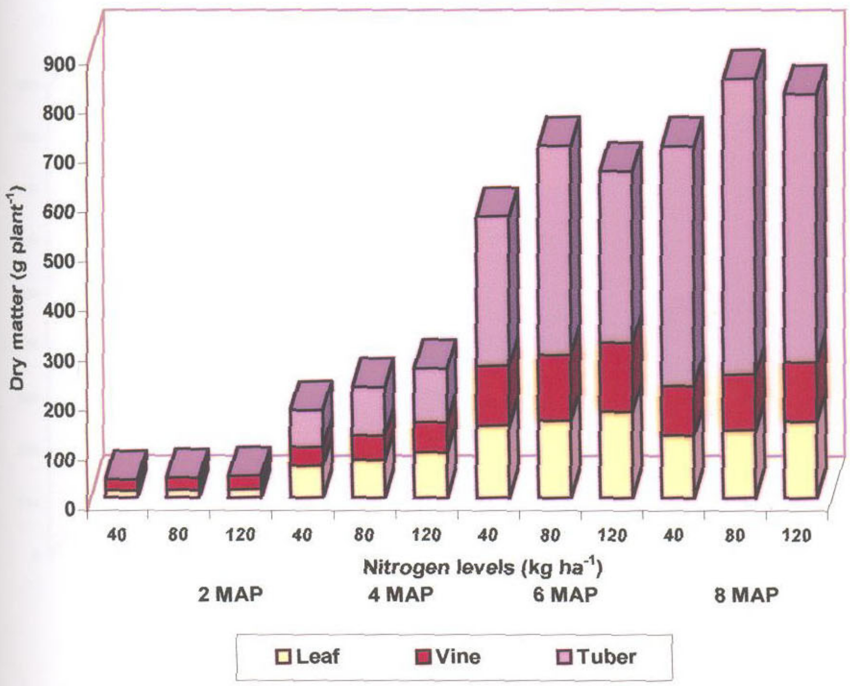


Fig.10c Dry matter distribution as influenced by nitrogen (98-99)

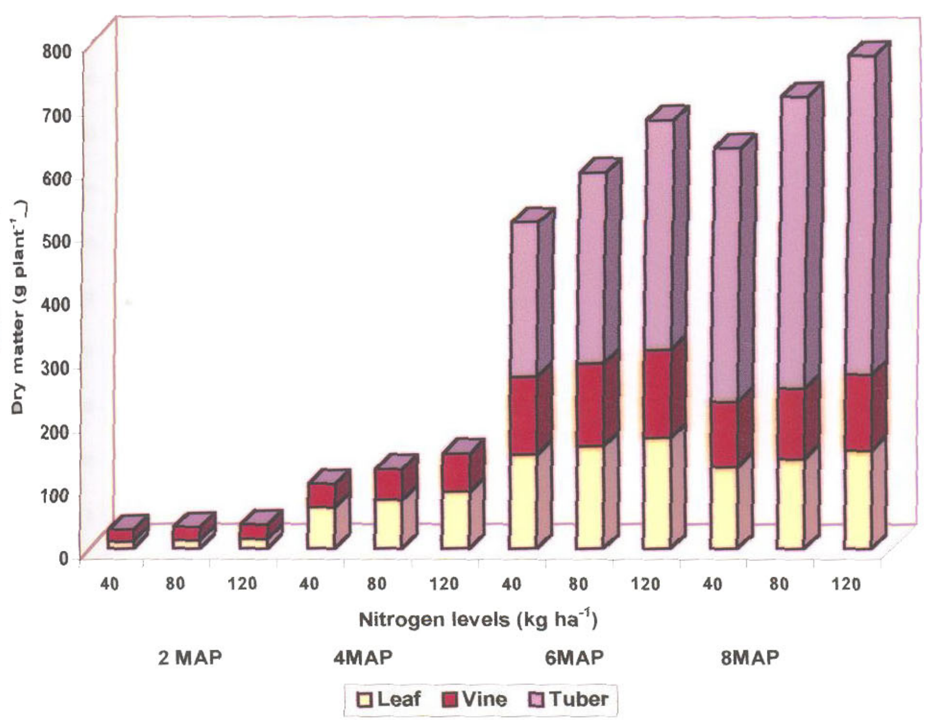


Fig.10d Dry matter distribution as influenced by nitrogen (99-00)

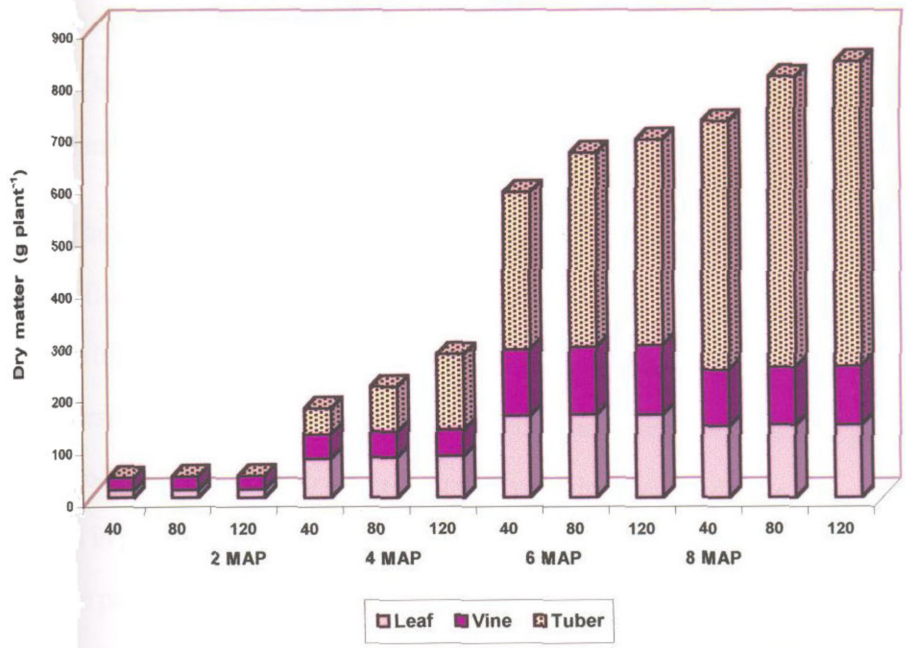


Fig.10e Distribution of dry matter as influenced by potassium (98-99)

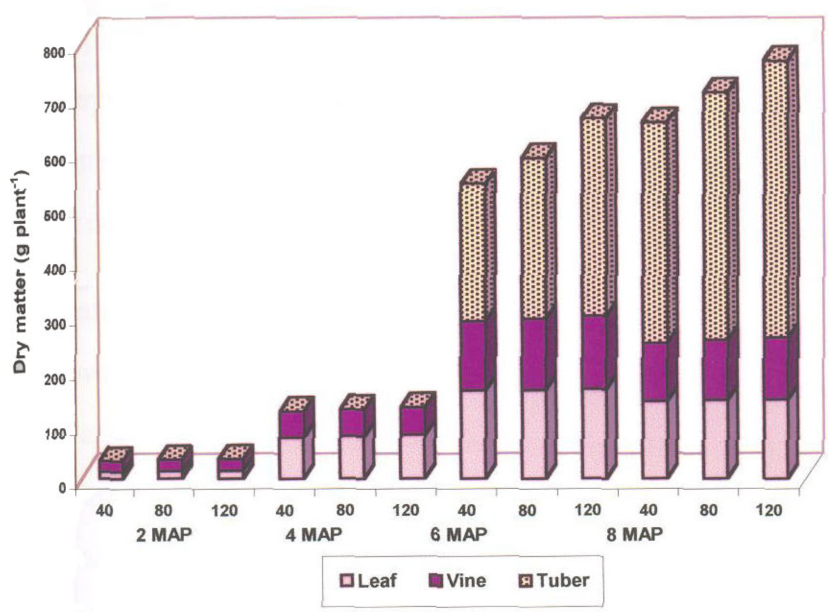


Fig. 10f Dry matter distribution as influenced by potassium (99-00)

development. However in the subsequent year, highest tuber dry matter accumulation was observed at 120 kg N ha^{-1} (Table20a) . This response may be attributed to the reduction in the native soil fertility on account of significant nutrient uptake by the first crop. The cumulative effects of higher leaf, vine and tuber dry matter production at higher rates of N resulted in higher plant dry matter yield (Table17a) (Figs.10c and 10d).

The influence of potassium in promoting leaf, vine and tuber dry matter production was significant upto 120 kg K_2O ha^{-1} in both the seasons (Tables18a,19a,20a). It may be recalled in this context that K exerted profound influence in enhancing leaf area and leaf area duration resulting in higher photosynthetic rates and diversion of greater proportion of dry matter into tubers and thereby increasing dry matter accumulation in tubers. The role of potassium in photosynthesis and translocation of assimilates is well known (Tisdale *et al.*, 1995). The present result is in agreement with the findings of Enyi (1972) in *D. esculenta,* Kasele *et al.* (1983) and Nayar (1986) in cassava grown in shade. It may be noted that the favourable effects of higher rates of potassium on growth and yield resulted in greater plant dry weights in both the seasons(Table 17a) (Figs.10e and 10f).

5.3.2.2 Leaf area index

Coir pith compost application resulted in significantly highest LAI at almost all stages during the period of experimentation (Table 21a). The substantial contribution of a number of essential plant nutrients especially N coupled with higher uptake of N from coir pith compost increased the number of functional leaves and leaf size which in turn led to higher LAI.

Increasing rates of N application was beneficial in maintaining significantly higher LAI at various growth stages in both the years(Fig.11). Maximum values were obtained at 120 kg N ha^{-1} (4.58 and 4.52 in 98-99 and 99-00 respectively) (Table 21a). As the level of N supply increases, the extra protein produced allows the leaves to grow larger and the amount of leaf area available for photosynthesis is roughly proportional to the amount of N supplied (Russell, 1973). Larger leaf size coupled with more number of functional leaves retained per plant at higher levels of N as indicated in Table 16a could have resulted in higher

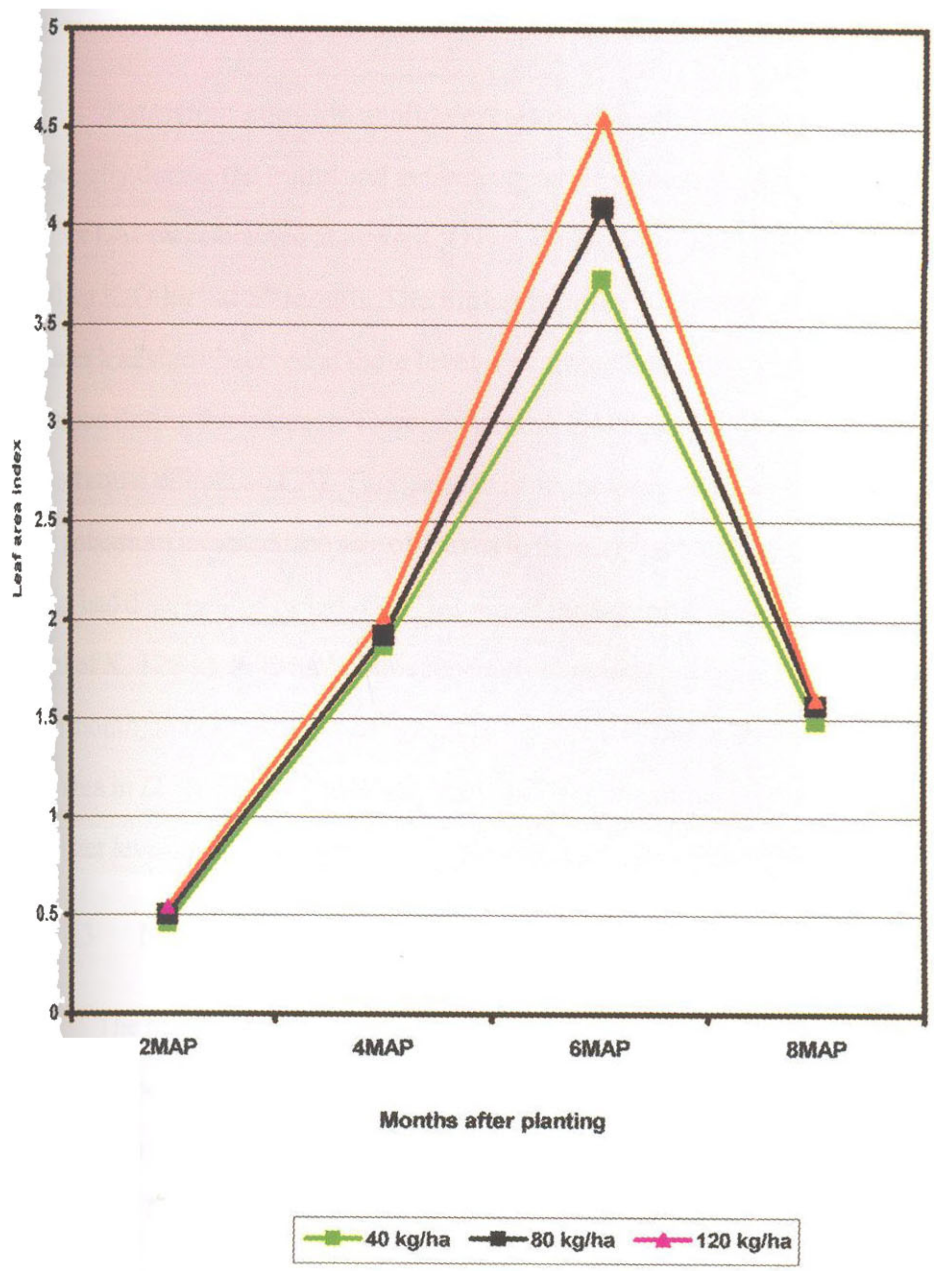


Fig.11 Influence of nitrogen on leaf area index

LAI in this study. Previous studies in *D. esculenta* (Enyi, 1972) and in intercrop of cassava in coconut (Nayar, 1986) also indicated that N application favoured higher LAI.

Potassium nutrition at higher rates profoundly influenced LAI in both the years especially during the initial and active vegetative growth stages (Table 21a). Significantly higher LAI was obtained at 80 kg K_2O ha^{-1} during the initial stages (2nd and 4th month) and 120 kg K_2O ha^{-1} at 6th month. The higher number of functional leaves (Table 16a) and greater leaf size observed at these levels promoted LAI considerably at higher levels of K nutrition during these stages. Towards harvest, LAI decreased considerably and all levels of K had equal effects on LAI. This trend is in accordance with the finding of Watson (1947) that potassium increased the size of leaves in the early part of the growing season, though this effect had disappeared by harvest. This report further justifies the requirement of the highest level of K, 120 kg K_2O ha^{-1} in this research to maintain higher LAI at peak growth stage (6th month) in both the seasons. Enyi (1972) reported that K application resulted in greater leaf area in *D. esculenta.* Pushpakumari (1989) also noticed maximum LAI at the highest fertilizer level in *D. alata* and *D. esculenta* intercropped in coconut garden.

5.3.2.3 Net assimilation rate, crop growth rate and relative growth rate

The rate of dry matter production per unit leaf area (NAR) and the rate of dry matter production per land area (CGR) were higher for plants treated with coir pith compost (Tables 22a and 23a). This was obviously due to the contribution of a number of plant nutrients particularly N and K for crop nourishment by coir pith compost.

The greater uptake of N and K from coir pith compost applied plots favoured crop growth, maintained higher LAI and accumulated maximum dry matter per unit time per unit leaf area resulting in higher NAR values, especially during active growth stages (Table 22a). Due to maintenance of higher LAI during the initial and active growth stages in both the years, higher CGR values were also computed due to coir pith compost application (Table 23a). However all the organic manures resulted in almost same RGR values (Table 24a).

Increasing levels of nitrogen were influential in significantly enhancing NAR, CGR and RGR in both the years. Highest values of all these growth indices were computed from 120 kg N ha^{-1} during the initial phase (2-4 MAP). The higher LAI attained at this level of nitrogen resulted in greater rate of dry matter production per unit ground area, greater rate of drymatter production per unit photosynthesising area as well as higher rate of dry matter accumulation per unit original plant material with respective increases in the values of CGR, NAR and RGR. (Tables 22a, 23a and 24a). Earlier experiments with *D. esculenta* by Enyi (1970) and Enyi (1973) also proved that applied N tended to increase RGR and CGR. However during the active growth phase (4-6 MAP) all these growth parameters were promoted mostly by medium level of N (80 kg ha^{-1}). Towards harvest, a decline in NAR and RGR values were observed at higher rates of N nutrition. This trend is in accordance to the postulation of Watson (1958) that as leaf area ratio falls with advancing age the rate of respiration per unit leaf area tends to increase and hence NAR decreases, independently of any change in the rate of photosynthesis or respiration per unit dry weight.

Enhanced levels of potassium resulted in significantly higher NAR, CGR and RGR values during the initial and active growth phases in both the years. This suggests that potassium exerted a favourable role in enhancing the photosynthetic efficiency in white yam.

5.3.2.4. Tuber bulking rate

Similar tuber bulking rates observed due to the application of various organic manures may be attributed to their similar effects on physical parameters of the soil (Table 25a).

Though N nutrition was beneficial in promoting bulking rate, the effect due to higher levels was not significant. Enyi (1970,1973) and Nayar (1986) also experienced negative effects of higher rates of applied N on tuber bulking rates in *D. esculenta* and intercrop of cassava in coconut respectively. However, the combined effect of organic manures and nitrogen levels significantly promoted bulking rates in the first season (Table 25b).

There was a slight increase in bulking rates with increasing levels of K upto 120 kg ha^{-1} in 98-99 and upto 80 kg ha^{-1} in 99-00. It is evident from Table 25a that there was appreciable increase in bulking rate, even at 40 kg ha^{-1} over zero K plots. This indicates that 40 kg K_2O ha^{-1} promoted synthesis and translocation of starch to the storage organs. A significant interaction between organic manures and potassium occurred especially at 40 kg K_2O ha^{-1} in FYM and sunhemp treated plots and at 80 kg K_2O ha^{-1} in plots that received coir pith compost. Tuber bulking rates had significant NxK interaction in the second year. Highest bulking rates were computed from 80 kg N and 80 kg K_2O (Table 25b). The beneficial effect of a positive interaction between N and K in 1:1 ratio is well known in tuber crops. Pushpakumari (1989) also noticed highest bulking rates in the highest fertilizer level (80:60:80 kg NPK ha^{-1}) in *D. alata*.

5.3.2.5 Harvest index

The variation in HI due to different sources of organic manures was not significant during both the years (Table 26a). As discussed earlier, the effect of organic manures on the weight, size and potential growth rate of storage organs (tuber) were not significantly different. Thus the almost similar sink strength, an important determinant of translocation pattern, resulted in similar rates and efficiency of assimilate translocation which culminated in almost same HI due to the various organic manures in both the years.

Medium level of N resulted in significantly higher HI in the first year (0.70) (Table 26a). It is presumed that 80 kg N ha^{-1} resulted in optimum canopy structure. This aspect coupled with the favourable translocation pattern might have established higher storage capacity and thus higher HI. Excessive shoot growth at the expense of tuber enlargement obtained at the highest rate of N could have reduced HI at 120 kg N ha^{-1} (0.66). CIAT (1977) reported decrease in HI due to application of N at higher levels in cassava. Nayar (1986) also obtained lower root: shoot ratio (utilization index) at the highest rate of N nutrition in cassava- coconut intercropping system. On the other hand, in the second year, all the levels of N influenced the partitioning and storage of assimilates to the same extent resulting in almost the same harvest indices.

Application of potassium at higher rates increased the HI significantly during both the years (Table 26a). As explained by Tisdale *et al.* (1995) the plant's transportation system uses energy in the form of ATP which requires potassium for its synthesis. Thus higher rates of potassium might have enabled translocation of carbohydrates for storage as starch or sugar in tubers, increasing the tuber: biomass ratio and thereby HI.

The trend observed in the main effect of nitrogen was also reflected in its interaction with organic manures. In combination with organic manures, the lowest or medium levels of nitrogen resulted in higher HI. Considering the OxK interaction which was present in both the years, plots treated with FYM or coir pith compost, manifested positive effect when combined with higher rates of K. However, plants that received green manure incorporation attained higher HI values in combination with 40 kg K_2O ha^{-1}. It is to be recalled in this context that green manure sunhemp with its soil mining ability was capable of bringing in more K in soil solution from the rather inaccessible pool and hence led to good response even at 40 kg of applied potassium (Gu and Wen, 1981). Positive NxK interaction was evident in the second year. Higher levels of K resulted in higher HI values irrespective of N levels. The results of the present study greatly emphasizes the significant role of potassium in any fertilizer programme in white yam under intercropping situation.

5.3.2.6 Light interception

Of the different factors studied in this experiment, only nitrogen levels imparted significant influence on the interception of PAR. However, this was evident only at 4th month in 99-00. Incremental doses of nitrogen resulted in significant increase in the interception of PAR with maximum values at 120 kg N ha^{-1} (501.28 $\mu E\ m^{-2}s^{-1}$) (Table 27a)(Figs.12a and 12b). During rapid leaf expansion, light interception is linearly related to LAI, which is favoured at higher N nutrition (Monteith and Elston, 1983). The observed increase in LAI at higher rates of N (Table 21a) significantly promoted interception of PAR in this research also. Infact, the combined effect of N from organic manures as well as fertilizers expanded the leaf area considerably for significant interception of PAR. This accounts for the OXN interaction that

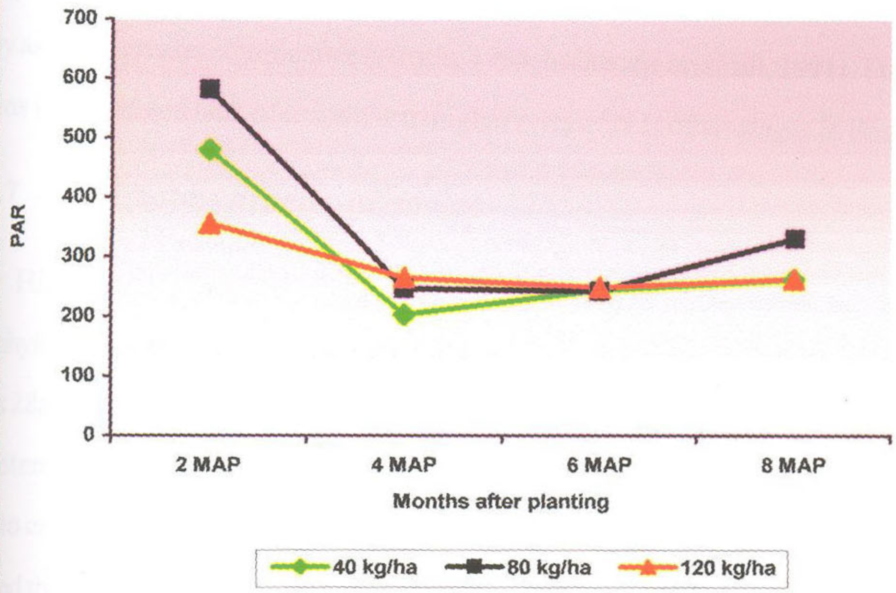


Fig.12a Interception of PAR as influenced by nitrogen (98-99)

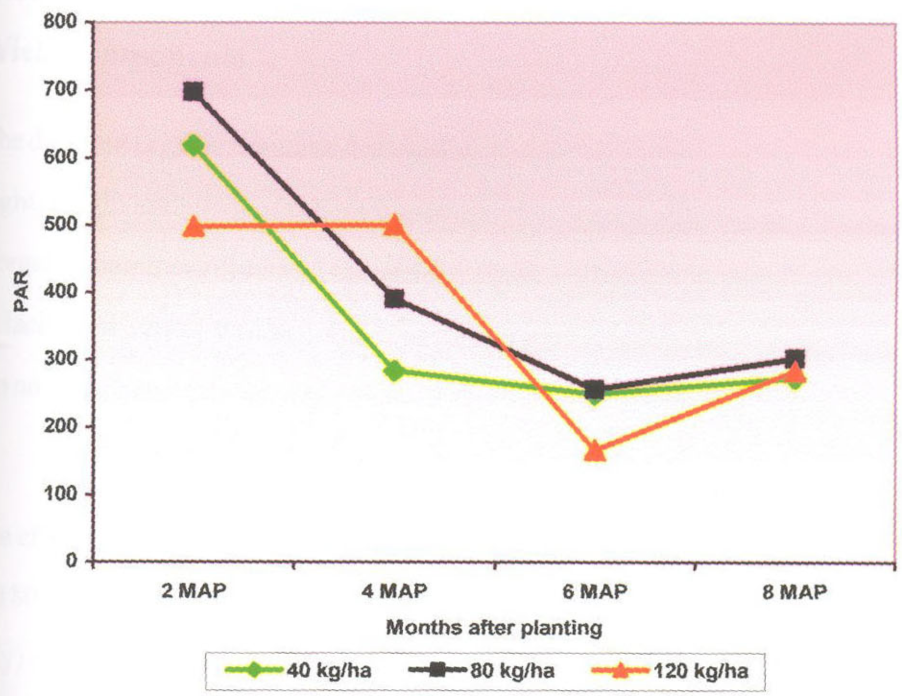


Fig.12b Interception of PAR as influenced by nitrogen (99-00)

also occurred at the 4th month in 99-00. After canopy closure, the relation between light interception and leaf area is no longer linear and the distribution of radiation throughout the canopy assumes greater significance (Austin, 1994; Mckenzie and Hill, 1991). This probably explains the observed lack of response to higher rates of N at other stages in this study.

5.3.2.7 Photosynthetic pigments

Higher rates of applied nitrogen was found to enhance chlorophyll 'a', 'b' and total chlorophyll contents particularly at the active growth stages during the period of experimentation. (Tables 28a,29a and 30a) (Fig.13).It is a known fact that N is an integral part of the porphyrin ring system, the basic unit of chlorophyll structure (Tisdale *et al.,* 1995). Hence N supply tended to enhance the chlorophyll content. As expected, the OxN interaction also profoundly increased the content of the components of the green pigment as well as its total content at the above stage due to the manifestation of the integrated effects of N from the organic and inorganic sources(Tables 28b,29b and 30b).

5.3.3 Yield components and yield

5.3.3.1 Yield components

The different organic manures did not significantly affect the yield components viz., tuber weight, length and girth of tubers in either of the years (Table 32a). As indicated in Table 38, organic manures influenced the various physical parameters of the soil to the same extent and facilitated almost similar conditions for elongation and bulking of tuber ultimately resulting in no difference in yield contributing factors namely tuber weight, tuber length and tuber girth.

The effect of N on mean tuber weight was significant in 98-99 as well as 99-00 and applied N at 80 kg N ha^{-1} produced tubers with significantly higher weights (2.37 kg and 1.52 kg respectively) (Table 32a). Further increase in N level to 120 kg ha^{-1} reduced tuber weight considerably in the first year (1.96 kg). In the subsequent year, though an increasing trend was observed upto 120 kg N ha^{-1} (1.65 kg), 80 and 120 kg N ha^{-1} did not differ significantly. This

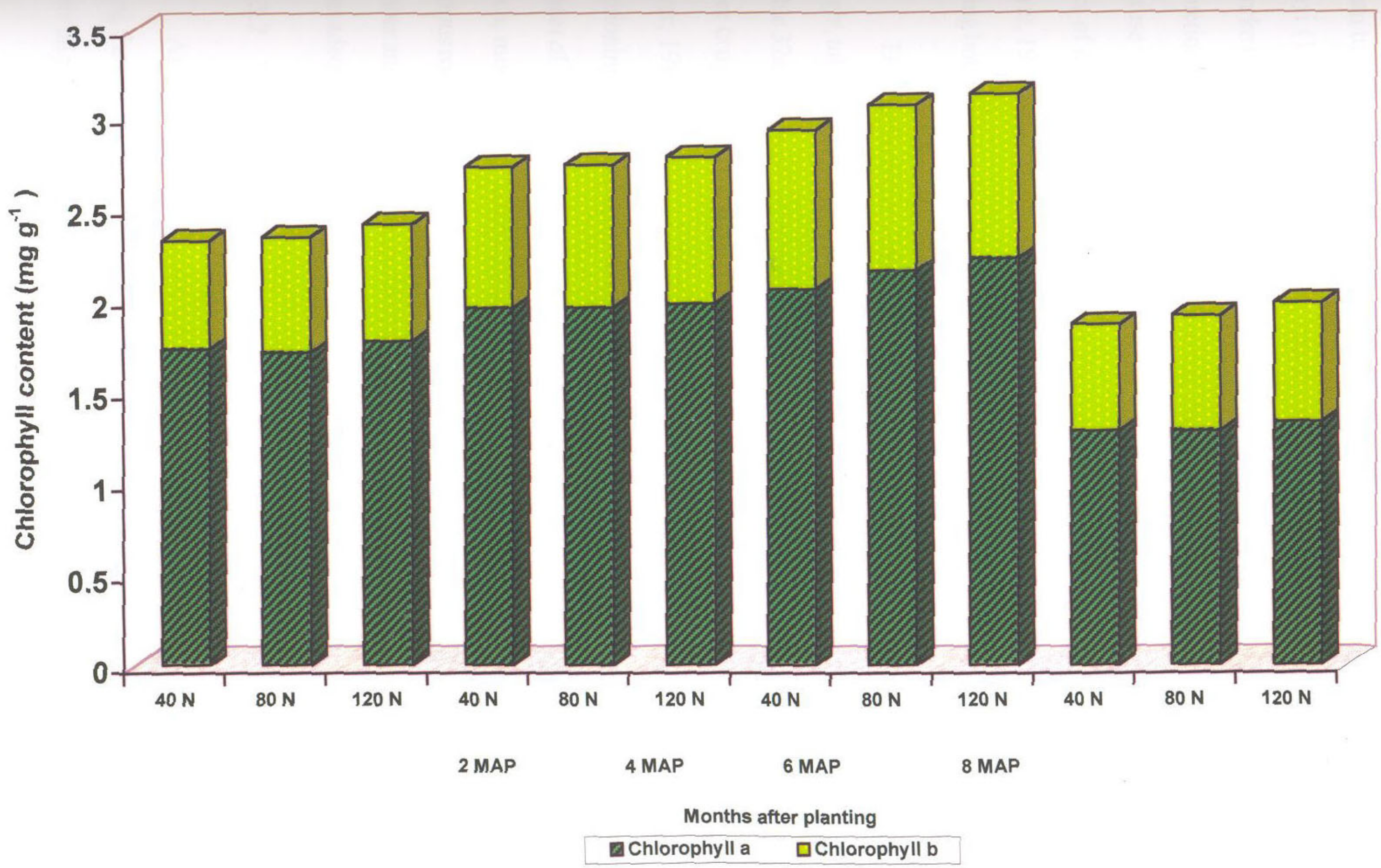


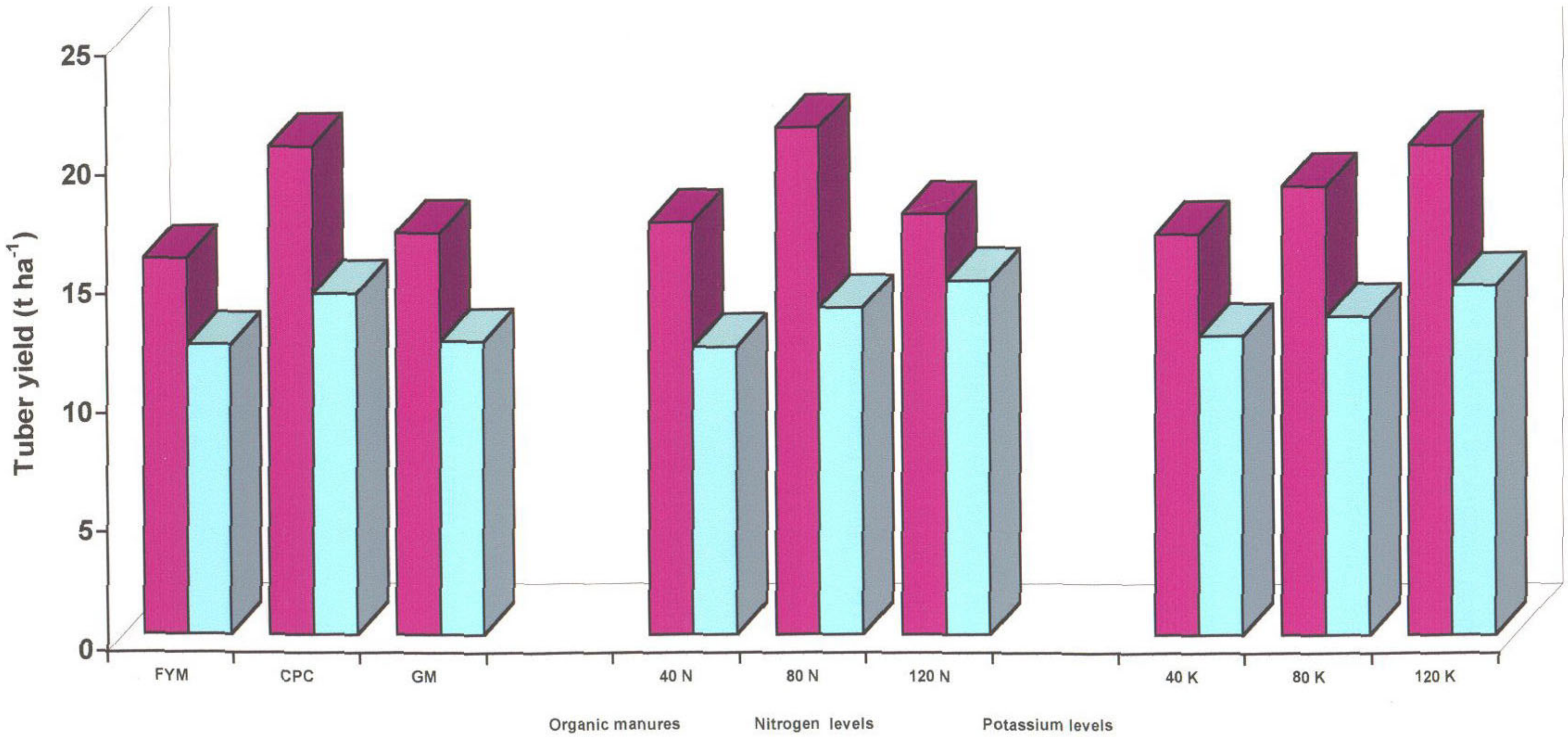
Fig. 13 Influence of nitrogen on chlorophyll content

suggests that adequate N nutrition encouraged vine growth, produced greater leaf area which was maintained for a considerably longer period during the tuber bulking phase (Table 21a). The greatly extended leaf area duration favoured higher canopy photosynthetic rates and enhanced the proportion of dry matter allocation to the tubers which in turn led to greater mean tuber weights. Similar results were reported by Singh *et al.* (1973a) in *D. alata,* Enyi (1972) and Singh *et al.* (1973b) in *D. esculenta,* Igwilo (1989) in *D. rotundata*, Bourke (1985) in sweet potato and Nayar (1986) in cassava intercropped in coconut. The reduction in tuber weight at the highest dose of nitrogen in this study is probably due to the profuse vegetative growth at the expense of tuber development.Negative effects of higher rates of applied N has been noted elsewhere (Singh *et al.*, 1973 b; Kasele *et al.*, 1983; Nayar, 1986). On the other hand, length and girth of tubers remained unaffected by N levels during both the years of experimentation.

During both the years, higher rates of potassium significantly promoted mean tuber weight, tuber length and tuber girth with maximum values at the highest level of 120 kg K_2O ha^{-1} (Table 32a). Increase in mean tuber weight consequent to potassium nutrition is common in tuber crops. (Enyi, 1972; Singh *et al.*, 1973a; Bourke ,1985; Kasele *et al.* ,1983; Nayar, 1986). Increase in tuber weight observed at higher rates of K was due to high partitioning and translocation of dry matter to tubers. Another potential reason proposed by Hunt *et al.* (1977) is that tuber enlargement occurs through synthesis and accumulation of starch, mediated by adequate supply of K. The observation of Kasele *et al.* (1983) that tuberous root initiation was sufficiently earlier, root diameter and weight, storage cell size and number and dry matter allocation to roots were significantly greater in shade grown cassava plants adequately fertilized with potassium, further strengthens the present finding.

5.3.3.2 Tuber yield

As explained in section 5.3.3.1, lack of significant yield difference (Table 33a) (Fig.14) among the various organic manures in this investigation was attributed to their almost similar effects on yield components particularly tuber weight and size, consequent to the same extent



FYM -Farm yard manure ; CPC - Coir pith compost
GM - Green manure sunhemp

Fig.14 Effect of organic manures,nitrogen and potassium on tuber yield of improvements in the physical conditions of the soil brought out by their addition in both the years (Table 38). This result implies the suitability of coir pith compost or green manure as alternatives to FYM, the common organic source currently used by farmers, in yam production and hence suggest feasible alternative options for organic manuring in white yam. Field experiments undertaken at CTCRI (CTCRI, 1998b) also indicated that there was no conspicuous yield variation among the organic manures viz., press mud, coir pith compost and FYM in cassava.

Influence of nitrogen on tuber yield was significant during both the years. N application at 80 kg ha^{-1} enhanced tuber yield considerably (60.73% in 98-99 and 45.56% in 99-00) over zero N probably by maintaining a higher leaf area index for a longer duration, enabling greater photosynthetic rates and assimilate translocation to storage organs (Table 33a) (Fig.14). Results to date indicate positive yield response of yams to N application (Enyi, 1972; Singh *et al.*, 1973a; Singh *et al.*, 1973b; Rao *et al.*, 1975; Koli, 1973; Umanah, 1977; Aduayi and Okpon, 1980; Kpeglo *et al.*, 1980; Behura and Swain, 1997). In the present research, further increase in N levels resulted in significant decrease in tuber yield in 98 - 99 (20.69%) or in slight increase (7.74%) as in 99-00. This could be due to the excessive vegetative growth, significant increase in leaf and vine dry matter production at the expense of tuber dry matter production at higher levels of nitrogen which is evident form Tables 15a, 16a, 18a, 19a and 20a. Thus shoots acted as intermediary sinks at higher levels of nitrogen, restricting tuber enlargement. Lack of yield response to higher levels of N has been noted previously in cassava intercropped in coconut garden (Gunasena *et al.*, 1980 and Nayar, 1986) as well as in cassava under artificial shade (Kasele *et al.*, 1983).

On the other hand, tuber yield increased significantly with incremental doses of potassium and maximum yield was obtained at the highest level (120 kg ha^{-1})in 98-99 (20.59 t ha^{-1}) as well as 99-00 (14.72 t ha^{-1}) (Table 33a) (Fig.14). Data on number of functional leaves per plant, LAI, NAR and CGR (Table 16a, 21a, 22a, 23a) indicate that potassium exerted positive influence on these parameters especially during active growth stages in both the years which led to more efficient photosynthetic activity and more assimilate production.

Furthermore, at higher levels of potash nutrition, there was higher bulking rate and increase in tuber dry matter that eventually resulted in greater tuber weight and size. Enhanced uptake of nitrogen and potassium at higher rates of potassium application could have resulted in vigorous canopy growth and tuber development. Combined effect of all these factors favoured early tuberisation, tuber enlargement and tuber yield at higher levels of K. Positive yield response to higher levels of K in yams has been reported earlier (Enyi, 1972; Singh *et al.,* 1973b; Obigbesan, 1973; Obigbesan *et al.,* 1977; Behura and Swain, 1997).

All the interaction effects were significant in both the years (Table 33b). Though organic manures exerted similar influence on tuber yield, they interacted significantly with 80 kg N ha^{-1} and resulted in higher yields due to the favourable main effect of nitrogen. Further increase in N level to 120 kg ha^{-1} resulted in serious decline in yield especially in combination with coir pith compost and green manuring in the first year due to excess vegetative growth. However, in the next year, response was obtained upto 120 kg N ha^{-1} with FYM and green manuring. The decrease in indigenous soil N supply after the first crop might have imparted greater response at 120 kg N in combination with these manures. It is also probable that N contribution through the green matter addition was not sufficient to fulfil the entire N requirement of yam at the previous level of 80 kg N ha^{-1}. Hence response was obtained at the highest level of N in the subsequent year. Another potential reason could be the difference in the cropping system. In the present study, in both the years, green manure sunhemp was sown in between yam mounds simultaneously with white yam while earlier workers (Prabhakar and Nair, 1987; Nayar *et al.,* 1993) incorporated green matter before planting tuber crops in their experiments. Moreover, white yam did not receive any basal application of organic manure. Hence N application at 120 kg ha^{-1} was imperative to maintain yields in the second year. However, application of coir pith compost at 80 kg N ha^{-1} resulted in higher yields in both the seasons due to the substantial contribution of several macro and micro essential nutrients in addition to N, viz., P, K, Ca, Mg, Fe, Mn, Zn, Cu from coir pith compost for crop removal.

The various organic manures responded differently to different rates of K. The relative contents of K in the organic manures indicated in Table 2 may provide explanations for the observed result. FYM responded upto 120 kg K_2O ha^{-1} due to its low content of K (0.40%) while coir pith compost responded only upto 80 kg K_2O ha^{-1} as it contained relatively higher per cent of K (1.10%). Green manuring exhibited significant response at 40 kg K_2O ha^{-1}. Leguminous green manure plants because of their typical root characteristics possess a strong ability to absorb the rather inaccessible K in the soil (Gu and Wen, 1981).Increased availability of K in soils due to green manuring is an established fact (Katyal, 1977; Tiwari *et al.*, 1980; Nagarajah *et al.*, 1989; Swarup, 1987). Higher content of available K noticed in plots that received green manure incorporation in the present study also corroborates the known fact (Table 40a). As detected by Singh *et al.* (1992) the K contained in the green manure (2.02%) was also eventually released on its decomposition for crop removal. Owing to these reasons, response was not obtained when green manuring was combined with higher levels of fertilizer K.

A strong NxK interaction existed in this study. Highest tuber yields were obtained in the interaction 80 kg N and 80 kg K_2O (21.77 t ha^{-1}) in 98-99 and 120 kg N and 120 kg K_2O (16.00 t ha^{-1}) in 99-00 indicating that N:K ratio of 1:1 is ideal to realize maximum tuber yield in white yam under intercropping situation. Positive interaction between N and K is common in tuber crops. Kabeerathumma *et al.* (1987) also worked out an almost similar N:K uptake ratio (1:1.05) for *D. rotundata* in sole crop situation at CTCRI.

A significant OxNxK interaction was present in both the years. Application of 5 t ha^{-1} of coir pith compost along with 80 kg N and 80 kg K_2O ha^{-1} ($o_2n_2k_2$) resulted in the highest tuber yield in both the seasons (26.78 t ha^{-1} and 22.44 t ha^{-1} respectively) (Table 33c). The trends observed in the effects of independent or two way interactions of factors explained in the preceding text was reflected in the OxNxK interaction also.

5.3.4 Quality attributes of tuber

5.3.4.1 Dry matter content

Application of coir pith compost or *in situ* green manuring accumulated higher dry matter content in tuber during 99-00 on account of greater uptake of N and K, mobilized from these manures during the current as well as previous seasons and the resultant higher biomass accumulation and diversion to tubers. (Table 34a).

Incremental doses of nitrogen or potassium significantly enhanced dry matter content in tuber in both the seasons with maximum values at 120 kg ha^{-1}(Table34a) (Fig.15).The results of the present study support the findings of other researchers that an increasing trend in dry matter content of tuber occurs at higher rates of N nutrition in *D. alata* (Singh *et al.*, 1973a) and K supply in *D. rotundata* (Obigbesan, 1973).The trends noticed in the main effects of organic manures, nitrogen and potassium were also manifested in their two way interactions, OxN, OxK and NxK (Table 34b).

5.3.4.2 Starch content

Of the organic manures tested, coir pith compost favoured starch content of tuber in the first year due to greater K nourishment from coir pith compost (Table 34a).This resulted in greater production and allocation of carbohydrates for utilization in the tubers for the synthesis and storage of starch.

In both the years, nitrogen application at 80 kg ha^{-1} significantly increased the starch content, while further increase in N levels reduced the starch content significantly (Table 34 a Fig.15). Carbohydrate utilization is related to N supply. As the supply of N increases, protein is formed from the synthesized carbohydrate with the consequent increase in vegetative growth and decrease in starch content. These results are similar to those reported earlier by Nayar (1986) and Vijayan and Aiyer (1969) in cassava, Nair (1994) in sweet potato and Geetha and Nair (1993) in coleus.

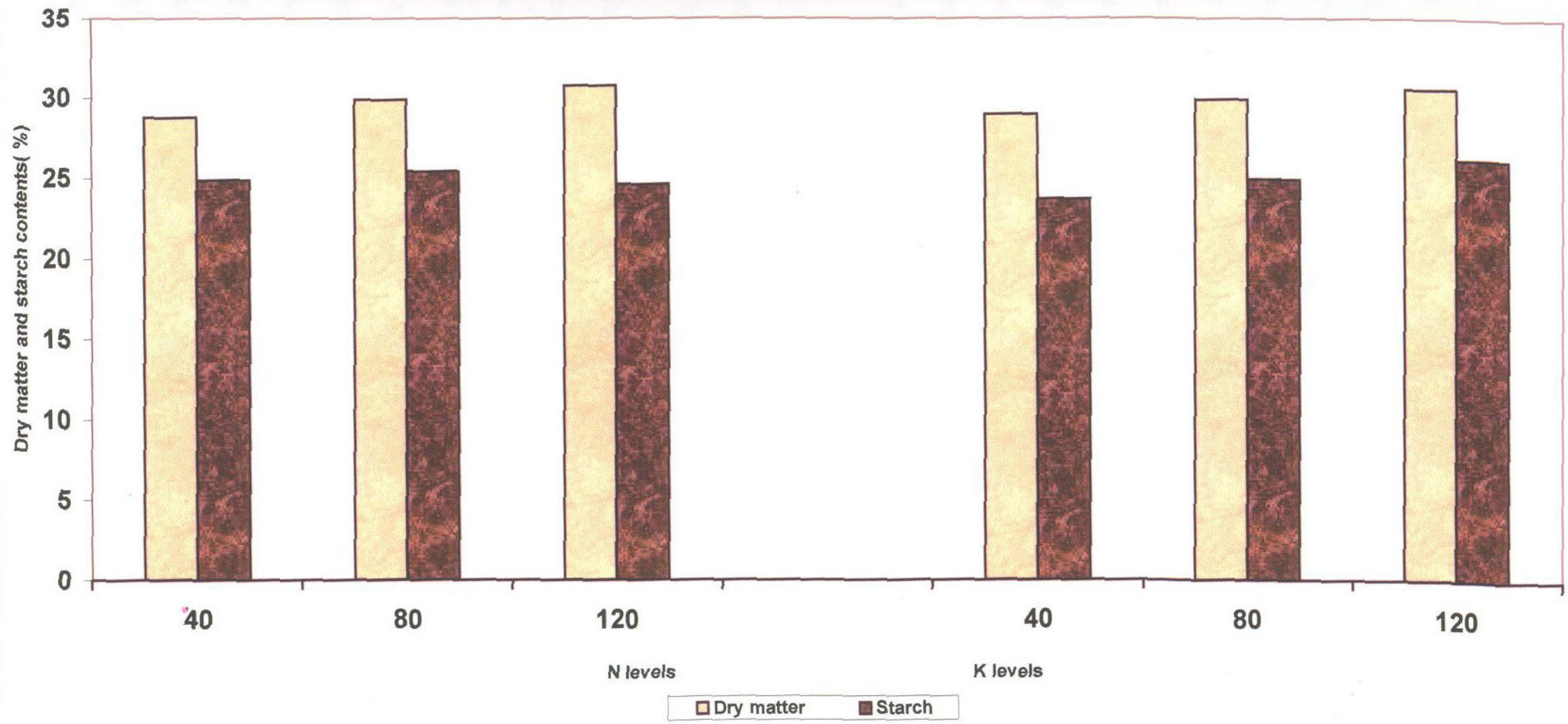


Fig.15 Effect of nitrogen and potassium on tuber quality

Starch content of tuber increased significantly with higher rates of potassium and maximum content was observed at 120 kg K_2O ha^{-1} (Tables 34a,Fig.15). Previous studies also indicated similar results in cassava (Nayar, 1986), sweet potato (Nair, 1994), colocasia (Premraj, 1980), taro (Mohandas and Sethumadavan, 1980), arrow root (Ramesan *et al.*, 1996; Veena, 2000), *D. esculenta* (Singh *et al.*, 1973b)and *D. rotundata* (Obigbesan, 1973). The indispensable role of potassium in the synthesis and translocation of starch is well known. Akatsu and Nelson (1966) indicated that potassium stimulated the activity of the enzyme starch synthetase and protected it from thermal inactivation. Moreover the effect of K level on photosynthesis also affects the amount of sugar available for starch production. Under high K levels, sugar is used more effectively because of its transfer from the stem to storage organs. The pronounced main effect of potassium on starch content also resulted in a strong NxK interaction. At all levels of N, increasing rates of K significantly promoted starch content (Table 34b).

5.3.4.3 Crude protein content

Coir pith compost or green manuring enhanced crude protein content significantly in 99-00 (Table 34a) due to considerable contribution of N and K for crop uptake.

Nitrogen application at higher rates significantly favoured crude protein content in both the years (Table 34a). It is a well established fact that adequate N supply enhances the crude protein content in plants (Tisdale *et al.*, 1995). Observed results were consistent with those previously reported in various tuber crops viz., *D. alata* (Singh *et al.*, 1973a) *D. esculenta* (Singh et al., 1973b; CTCRI, 1976) cassava (Vijayan and Aiyer, 1969; Prema *et al.*, 1975), sweet potato (Nambiar *et al.*, 1976) and arrow root (Ramesan, 1991 and Veena, 2000). Potassium nutrition at 40 kg K_2O ha^{-1} resulted in higher protein synthesis (Table 34a). Ashokan and Sreedharan (1977) and Shyu and Chang (1978) observed gradual reduction in crude protein content in cassava and *D. alata* respectively with increased K levels. The two way interactions, OxN, OxK and NxK also followed the same trends of main effects (Table 34b).

5.3.4.4 Crude fibre content

Highest level of N or K depressed the content of crude fibre (Table 34a). Lowering of crude fibre content at higher rates of K has been reported earlier in other tuber crops (Nair and Aiyer, 1985; Ramesan *et al.,* 1996; Veena, 2000). Similar trends were noticed when these factors were combined (Table 34b).

5.3.4.5 Vitamin C content

Vitamin C content varied significantly due to different levels of N in 98-99 with higher content noticed at medium level of N. Similarly moderate K nutrition (80 Kg ha^{-1}) significantly promoted vitamin C content in both the seasons (Table 34a). The result indicates that potassium and nitrogen hold key roles in vitamin C synthesis.

5.3.5 Uptake of major nutrients

5.3.5.1 Nitrogen

The effect of organic manures on the uptake of nitrogen was significant in the second year. This trend could be associated with a decrease in the indigenous soil N supply due to considerable nutrient exports by 1999 harvest, indicating a strong response to various organic manures in terms of nutrient removal in the second season. Moreover, greater N release from these manures as a result of substantial N mobilization at the end of first season might have added to this effect. Since nutrient uptake is a function of dry matter production, of the organic manures tested, coir pith compost treated plants registered significantly higher uptake due to greater total dry matter production (Table 35a).

Applied N had significant impact on plant uptake of nitrogen in the present study during both the seasons. Due to native soil fertility the effect was significant upto medium level of nitrogen in the first year. In the subsequent year, response was obtained upto 120 kg N ha^{-1} (Table 35a). Increase in the uptake of N due to higher rates of application of N is a proven fact. The present result is consistent with those previsously reported in *D. rotundata* (Aduayi and Okpon, 1980) and intercrop of cassava in coconut (Nayar, 1986).

Similarly plant uptake of nitrogen was significantly favoured upto 80 kg K_2O ha^{-1} in 98-99 and upto 120 kg K_2O ha^{-1} in 99-00 (Table 35a). Better N uptake is commonly associated with adequate K fertilization. Nitrogen uptake occurs at the expense of energy from ATP, which requires potassium for its synthesis (Tisdale *et al.,* 1995). Past experiments in yams and cassava also provided insight to this fact (Nair, 1982; Nayar, 1986; Aduayi and Okpon, 1980).

The trends observed in the main effects of organic manures, nitrogen and potassium were also reflected in their two way interactions, OxN and OxK (Table 35b). Thus $o_2 n_3$ and o_2k_3 registered highest uptake of nitrogen. Among NxK interactions, n_3k_3 recorded the highest uptake. Several researchers noticed maximum uptake of N at the highest level of inorganic fertilization in *Dioscorea* spp. (Kang and Wilson, 1981 and Irizarry and Rivera, 1985 in *D. rotundata;* Nair, 1985 in *D. esculenta;* Pushpakumari, 1989 in *D. alata*).

5.3.5.2 Phosphorus

Application of nitrogen at 80 kg N ha^{-1} significantly enhanced P uptake in 98-99, while in the subsequent year, P uptake was maximum at 120 kg N ha^{-1}. Similar trends were noticed for the effects of applied K (Table 35a). Higher rates of N increases protein biosynthesis leading to new tissue formation. Protein biosynthesis involves ADP and ATP which are high energy phosphorus compounds. Hence for the operation of the pathway, phosphorus is utilized in greater amounts at higher rates of N (Tisdale *et al.,* 1995). Vijayan and Aiyer (1969) and Nayar (1986) have also documented similar results in cassava. As explained by Tisdale *et al.* (1995) potassium promotes N uptake and protein synthesis, a highly energy dependent pathway that requires sufficient amount of P. Thus higher rates of K also favoured P uptake in this study.

5.3.5.3 Potassium

Different organic manures, levels of nitrogen and potassium profoundly influenced K uptake. Among organic sources, application of coir pith compost resulted in higher K uptake,

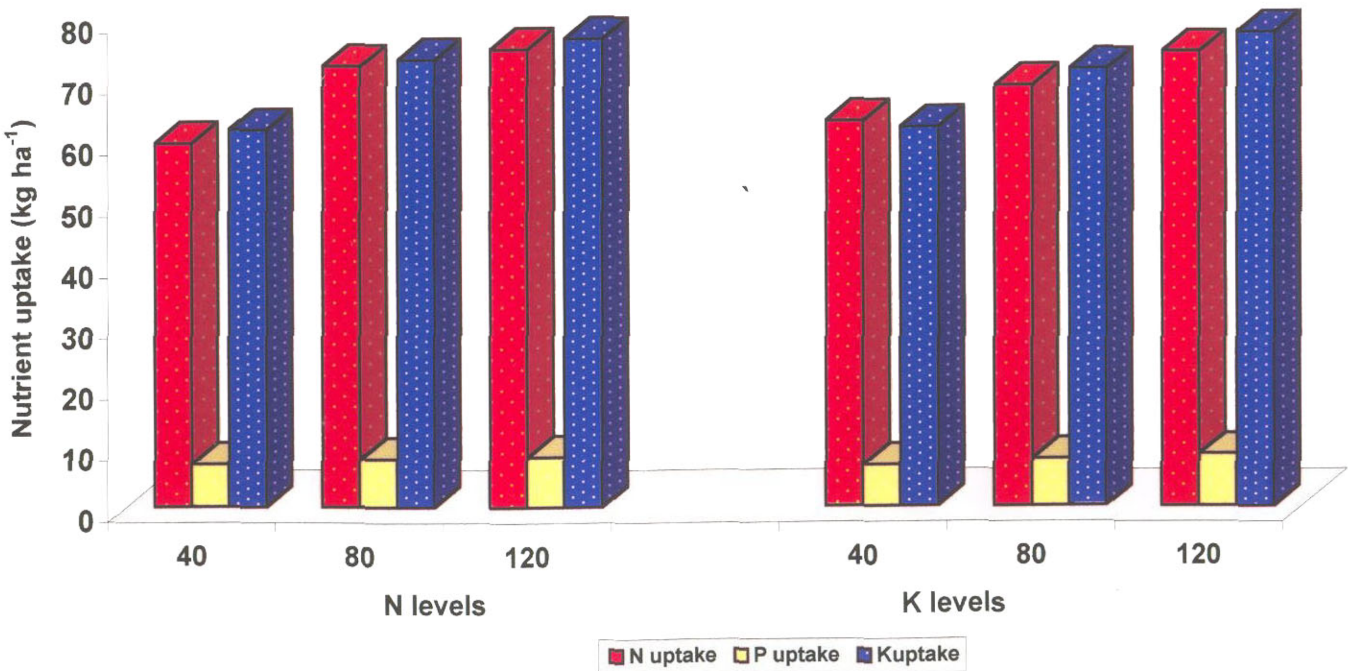


Fig.16 Effect of nitrogen and potassium on nutrient uptake

which is ascribed to greater dry matter yield. Applied N and K followed similar trends. In 98-99 medium levels of these nutrients favoured K uptake. However, in the next year, K uptake was promoted significantly at the highest levels of N or K (Table 35a). It has been established earlier that increasing rates of N, enhanced K uptake in cassava (Rajendran *et al.*, 1976; Nayar 1986). The indispensable involvement of K in the synthesis of ATP needed for protein synthesis as well as for N uptake has been stated earlier (Tisdale *et al.*, 1995).

The enhanced K uptake at higher levels of K is attributable to the greater tuber size, tuber yield and dry matter production observed at these levels of K nutrition. This result corroborates with that of Nair (1982) and Nayar (1986) in cassava.

Potassium uptake was promoted by OxN and OxK interactions in both the years due to the combined favourable effects of organic manures, levels of nitrogen and potassium on K uptake described in the preceding paragraphs (Table 35b). Application of moderate or higher levels of N or K conjointly with organic manures recorded higher uptake of K. NxK interaction was discernible in 99-00. Regardless of rates of applied N, higher uptake of K was noticed at higher levels of applied K. Highest uptake of K at the highest level of fertilization has been previously documented in *D. rotundata* (Kang and Wilson, 1981; Irizarry and Rivera, 1985) *D. alata* (Pushpakumari, 1989) and *D. esculenta* (Nair, 1985).(Fig.16 indicates the effect of applied N and K on the mean uptake of N,P and K).

5.3.6 Nutrient use efficiency of nitrogen and potassium

The impact of different organic manures on the agronomic efficiency of applied N or K was not visible in the first year. However, agronomic efficeincy of N as well as K varied significantly in the subsequent year and plots that received green manure incorporation registered highest values (Table 36a) (97.71kg tuber/kg N applied) (112.87 kg tuber/kg K applied).

Data on tuber yield given in Table 33a indicates that plots that received sunhemp incorporation alone without N and K fertilizers produced lower yields compared to that of FYM alone or coir pith compost alone during the second year. Green manure in combination with NK fertilizers resulted in higher yield,which obviously indicates higher efficiency of N and K fertilizers when combined with green manure.Hence higher nutrient use efficiencies were computed from green manured plots.

On the other hand, since tuber production from different organic sources did not differ significantly,the efficiency of applied N or K for tuber production per unit of N or K absorbed designated as "physiological efficiency" was same for the different organic manures in 98-99 as well as 99-00.

As seen in other experiments with cereal crops (Pearman *et al.*, 1977, Makunga *et al.*, 1978; Thomas *et al.*, 1978; Eagle *et al.*, 2000) this research also revealed that an enhanced N supply diminished the agronomic and physiological efficiency of N. This was due to stimulation in the use of photosynthates for shoot growth or due to increased respiration (Pearman *et al.*, 1977) Negligible effect of N on carbon distribution, despite the large increase in growth and yield (Makunga *et al.*, 1978) or reduction in translocation efficiency (Mc Neal *et al.*, 1971) at high N supply might have reduced the nitrogen use efficiency. Furthermore, Thomas *et al.* (1978) proposed that extra carbon did not appear in the shoot or storage weights. Similarly potassium supply also reduced the agronomic efficiency of K. However all levels of K resulted in almost similar rates of tuber production per unit of K absorbed. Hence physiological efficiency of K did not vary widely among K levels in this study.

Increasing levels of K tended to enhance the agronomic efficiency of N considerably during both the seasons with maximum efficiency computed from 120 kg K_2O ha^{-1}. This can be explained by considering the interaction between nitrogen and potassium. At all levels of N, higher rates of K nutrition led to greater synthesis and allocation of photoassimilates for storage in the tuber and eventually translated into greater tuber yields and higher agronomic efficiency. But physiological efficiency of N remained unaffected by different K levels. It is generally considered to be the result of higher N uptake at higher levels of K . Apart from this, almost similar tuber production per unit N absorbed upto 80 kg K_2O ha^{-1} and slight decrements in tuber production per unit N absorbed at the highest level (120 kg K_2O ha^{-1}), might have resulted in almost similar physiological efficiencies for different K levels.

Increasing rates of nitrogen upto 80 kg or 120 kg N ha^{-1} tended to enhance significantly the agronomic efficiency of potassium in both the years. This is because per unit of K applied, higher rates of N enhanced tuber yield considerably in comparison to zero N and zero K plots. Whilst the physiological efficiency of K was promoted upto 80 kg N ha^{-1} since sufficient K uptake at this level of N resulted in higher tuber production.

5.3.7 Soil physical properties

The physical parameters of the soil did not differ significantly due to the influence of various organic manures, levels of nitrogen and potassium or their interactions (Table 38). However at the termination of the experiment, slight decrease in the bulk density and particle density of soil and marginal improvements in the water holding capacity, porosity and aggregate stability were apparent in all the plots. As explained by Brady (1996), organic matter stimulates the formation and stabilization of granular and crumb type aggregates, facilitates greater pore space and lowers the specific gravity of soils. It is important to note that the extent of physical improvements in the soil brought about by the various organic manures evaluated in this study was almost the same.

5.3.8 Soil chemical properties

5.3.8.1 Total nutrient status

The total contents of nitrogen, phosphorus and potassium in the soil did not vary significantly under the influence of different organic manures, levels of N or K or their interactions (Table 39). Drastic changes in the total nutrient status of the soil under the impact of organic manures and inorganic fertilizers after two years of cropping cannot normally be expected. The changes that occur are small, the total nutrient pool of the soil is large and significant differences become apparent only over time.The nutrient exhausting nature of white yam further reinforces the observed results.

5.3.8.2 Available nutrients in the soil

5.3.8.2.1 Available nitrogen

As indicated in Table 40a, available nitrogen content was significantly higher in plots that received green manure incorporation or coir pith compost during 98-99. This result is in conformity with the general finding that green manuring enhances available N content of soils (Russell, 1973; Singh *et al.,* 1991; Singh *et al.,* 1992). Prabhakar and Nair (1987) and Nayar *et al.* (1993) also noted similar effects of *in situ* green manuring using cowpea in cassava. By the end of second season, the available N status of the soil did not vary greatly due to the various organic manures in this study. The release of mineral N from green manure is initially rapid, but slows down markedly within a fairly short time (Khind *et al.,* 1985; Singh *et al.,* 1988), which can be attributed largely to plant uptake, losses from the soil-plant system by way of leaching and volatilization or due to incorporation of legume N into microbial biomass. Hence the peaks observed in N release from green manure declined and paralleled to that of FYM and coir pith compost, since substantial amount of N present in these manures would have mineralized by the end of crop season.

Nitrogen supplementation at higher rates enhanced the available N content of the soil significantly (Table 40a) as shown in other studies (CTCRI, 1971; CTCRI, 1977; Nayar, 1986). The effect of nitrogen levels was significant upto 80 kg N ha^{-1}. Increased rates of potassium fertilization significantly enhanced the available N content (Table 40 a). Corroboratory results were reported in cassava (Nayar, 1986), taro (Rajasree, 1993) and arrowroot (Veena, 2000) under intercropping situation. In this study all the organic manures interacted strongly to higher rates of nitrogen nutrition in 98-99. The observed main effects itself justifies their combined effects. In addition, there is evidence of nitrogen x potassium interaction in the first year, as indicated by the fact that simple effect comparisons were significant.

All levels of N also led to higher available N content especially at higher rates of K. Maintenance of higher available N status due to higher N and K replenishments is almost a rule. Pushpakumari (1989) experienced increase in available N status with higher fertilization in *D. alata* intercopped in coconut.

5.3.8.2.2 Available phosphorus

Green manuring significantly enhanced available P content in 98-99 (Table 40 a). Several laboratory and field studies also focuses on similar results (Hundal *et al.*, 1987; Singh *et al.*, 1988). Enhancement in the available P content of soil due to green manuring was also noticed by Nayar *et al.* (1993) in cassava. Utilization of insoluble phosphates through the well developed root system of green manures and its subsequent mineralization (Gu and Wen, 1981; Singh, 1984) coupled with the mineralization of organically bound P due to the interaction of organic acids with soil components during the course of decomposition of green manures (Bin, 1983; Watanabe, 1984) would have enriched the pool of available P in the first season itself. However by two crop harvests, the mineralized P from the different manures remained fairly constant due to almost similar effects of organic manures on phosphorus transformation in the soil.

Nitrogen supply did not significantly affect the available P content of the soil in both the years. On the other hand, increasing levels of potassium enhanced the available phosphorus content during both the years. Maintenance of higher available P content at higher levels of K is well known.

5.3.8.2.3 Available potassium

Like N and P, a significant build up of available K status of the soil was observed after 98-99 harvest in plots that received sunhemp incorporation (Table 40a). Nayar *et al.* (1993) also observed similar effect of cowpea green manuring in cassava. This is attributed to the organic acid dissolution of insoluble K minerals consequent to green manure decomposition (Agboola, 1974) and recycling of K from the subsurface layer by the extensive root system of the legume (Hargrove, 1986). As explained earlier, the various organic manures

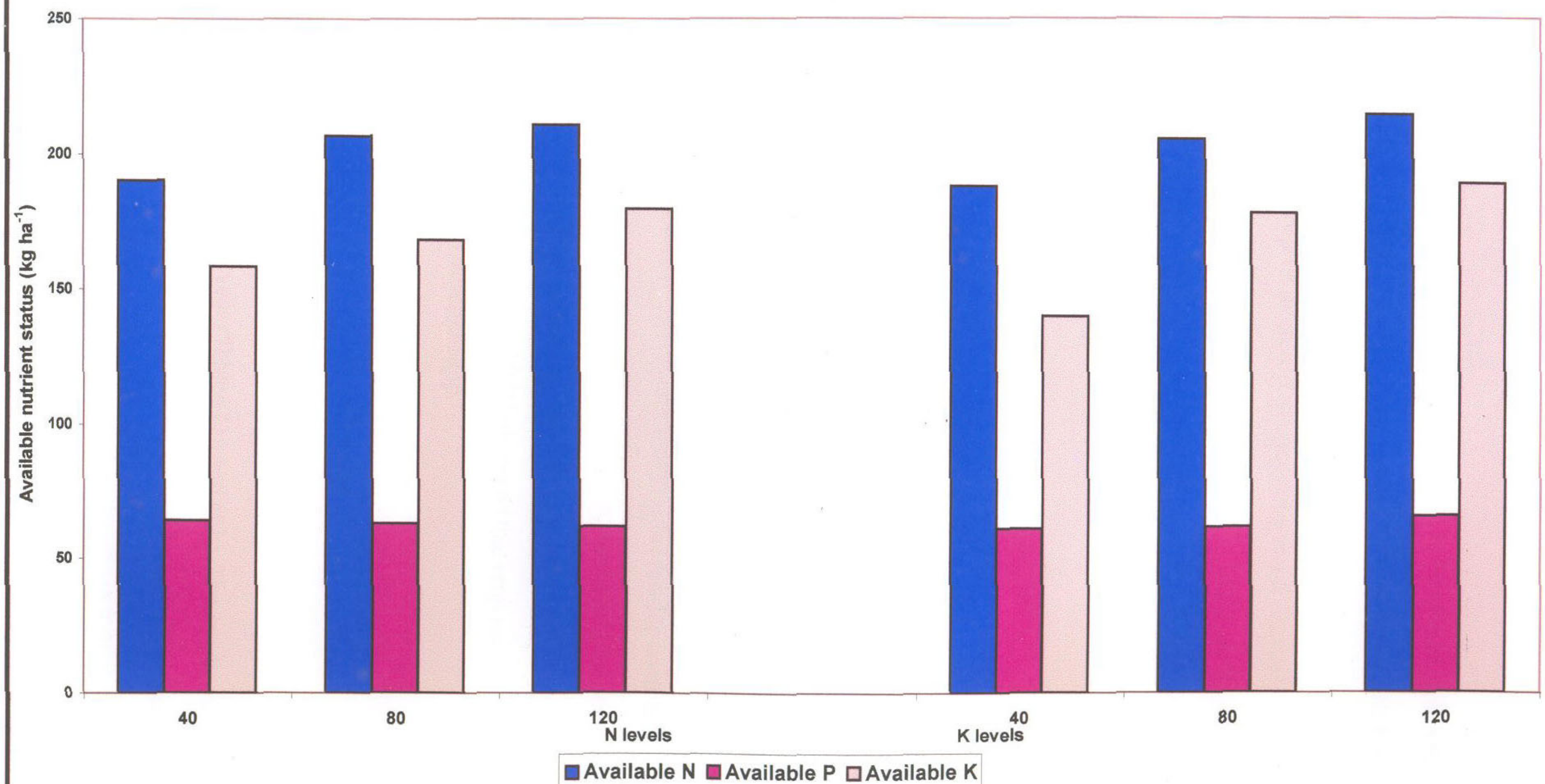


Fig. 17 Available nutrient status of the soil at the termination of the experiment as influenced by applied nitrogen and potassium

affected the available K status of the soil to the same extent in the second year in the present study. Higher rates of N or K supplementation significantly enhanced available K content of the soil in both the seasons. The present result is in accordance with the earlier reports in other tuber crops grown as pure crop or intercrop in coconut garden (Rajasree, 1993; Nayar 1986; Ramesan, 1991; Mohankumar and Sadanandan, 1991 ; Veena, 2000). The apparent responses in the individual effects were also closely reflected in the two way interactions viz., OxN, OxK and NxK (Table 40b) .(Fig.17 illustrates the available nutrient status at the end of two years of experimentation)

5.3.8.2.4 Organic carbon

The different organic manures maintained almost the same organic carbon contents in both the years (Table 40a). As Russell (1973) stated, the green manures are not effective per unit of carbon in increasing the organic matter content of the soil when compared to other organic manures particularly FYM because of their greater decomposability and lesser dry matter content. Further , higher temperature prevalent in tropics accelerates the degradation of organic manures. The chief source of soil organic matter is the residue contributed by the current crop, which was almost similar in the different organic manures in the present study. The higher rates of nitrogen and potassium resulted in higher tuber yields with comparatively lesser crop residues. Kabeerathumma *et al.* (1991) observed that crop residue recycling in *D. rotundata* was the least among *Dioscorea* spp.

5.3.8.3 Nutrient balance sheet

5.3.8.3.1 Balance sheet for available nitrogen

Available N showed a net negative balance in both the years, however lower net losses were discernible in the second year (Tables 41a and 41b). The results support the finding of Sadanandan and Mahapatra (1973a). The net loss or gain of N was arrived at by deducting the expected N balance in the soil from the actual N balance or available N content of the soil . Though the soil of the research site was rated as low for available N content slightly higher soil test values at the establishment of the experiment in 1998 as compared to that of 1999 resulted in higher expected nutrient balance in all the treatments.But the corresponding actual nutrient balance was considerably lower which led to a lower net loss of N. High mobility of N and its rapid loss through leaching and volatalization are other factors to explain the net loss incurred in the balance sheet for nitrogen. However, at the commencement of second season experiments in 1999 the available N content was substantially lower than that at the establishment of the experiment in 1998. This factor coupled with comparatively greater addition through green manure (Table 46), slightly lesser crop removal on account of lower tuber yield and lower leaching loss due to the low receipt of rainfall during the second year resulted in comparatively lower net losses of available N in all the treatments in 99-00.

Several reports have indicated net gains of N in crop sequences involving legumes/ green manures viz., groundnut - jute - rice (Sadanandan and Mahapatra, 1973a), soybean - wheat (Raghuwanshi *et al.,* 1991) and dhaincha - wheat (Binod Kumar *et al.,* 2000). Comparatively lower net loss of N in this experiment was also observed in sunhemp incorporated plots. The apparent lower net loss of N in green manured plots may be due to the less susceptibility of N derived from green manure to leaching than fertilizer N on account of slow release of N from green manure. Furthermore, the incorporation of green manure at times when the yam crop had put forth sufficient canopy growth facilitated synchrony in the rate of N mineralization with that of N uptake by the crop and reduced the substantial loss of N from the soil - plant system enhancing the efficiency of green manure - N. Lastly, addition from biological N fixation though considered negligible might have also helped in promoting the N status of the soil. Increasing levels of N tended to enhance the N losses in both the seasons. Sadanandan and Mahapatra (1973a) also observed that the rate of N loss increases as the quantity of applied fertilizers and manures increases. On the other hand, incremental doses of potassium reduced the loss considerably due to better utilization of N.

Table 46. Biomass and nutrient contribution from green manure sunhemp

Treatments	Biomass addition			
	98-99		99-00	
	Fresh (t ha^{-1})	Dry (kg ha^{-1})	Fresh (t ha^{-1})	Dry (kg ha^{-1})
$o_3n_1k_1$	0.87	236.16	4.55	1401.67
$o_3n_1K_2$	1.97	536.68	7.25	2233.05
$o_3n_1k_3$	2.46	670.25	5.33	1641.85
$o_3n_2k_1$	2.48	676.35	4.53	1396.74
$o_3n_2k_2$	2.35	641.40	5.76	1774.09
$o_3n_2k_3$	2.47	674.28	4.00	1231.49
$o_3n_3k_1$	2.98	813.46	4.69	1444.00
$o_3n_3k_2$	2.14	583.22	4.24	1307.25
$o_3n_3k_3$	1.91	521.09	3.56	1096.02
$o_3n_0k_0$	0.85	233.30	3.43	1055.83

Treatments	Nutrient addition (kg ha^{-1})					
	98-99			99-00		
	N	P	K	N	P	K
$o_3n_1k_1$	6.21	0.59	4.77	36.86	3.50	28.31
$o_3n_1K_2$	14.11	1.34	10.84	58.73	5.58	45.11
$o_3n_1k_3$	17.63	1.68	13.54	43.18	4.10	33.17
$o_3n_2k_1$	17.79	1.69	13.66	36.73	3.49	28.21
$o_3n_2k_2$	16.87	1.60	12.96	46.66	4.44	35.84
$o_3n_2k_3$	17.73	1.69	13.62	32.39	3.08	24.88
$o_3n_3k_1$	21.39	2.03	16.43	37.98	3.61	29.17
$o_3n_3k_2$	15.34	1.46	11.78	34.38	3.27	26.41
$o_3n_3k_3$	13.70	1.30	10.53	28.83	2.74	22.14
$o_3n_0k_0$	6.14	0.58	4.71	27.77	2.64	21.33

5.3.8.3.2 Balance sheet for available phosphorus

Deficit balance sheet for available P were noticed in all the treatments in 98-99 as well as in 99-00 (Tables 42a and 42b). Sadanandan and Mahapatra (1973b) and Raghuwanshi *et al.* (1991) also reported similar results. Major portion of P added as manures and fertilizers might have undergone reversion. The rate of release of P from mussooriephos is very slow and whatever quantity that was released might have been absorbed by the crop and the remaining P might have existed in the unavailable form in the soil. Further temporary conversion of mineralized inorganic form to organically bound ligands might have reduced the available P status to the present crop,though the same is available in the long run (Russell,1973). Hence the actual P balance could never been up to the expected P balance which is theoretically computed on the assumption that 100% mineralization of organic P takes place. The higher test value for available P at the initiation of the experiment also might have further enhanced the expected P balance. These factors led to negative balance sheet for available P. However considerable decrements in net losses were observed in 99-00 since there was slight increase in the content of available P at the end of second crop cycle compared to that at the start of the research.

Of the organic manures tried, incorporation of sunhemp resulted in comparatively lower losses in both the seasons. The greater mineralization of organically bound P consequent to decomposition of sunhemp could have enriched the available pool of phosphorus and lowered the magnitude of net loss of P. A declining trend in the net loss of P was observed with increasing levels of N and K in the first season due to better utilization of P at higher rates of N and K. However in the subsequent year, higher rates of N slightly enhanced the net loss of P due to higher N/P ratio wherein the increased supply of N might have limited the mineralization of organic P as pointed out by Tisdale *et al.* (1995).

5.3.8.3.3 Balance sheet for available potassium

The available K status of the soil was in general enhanced in most of the treatments in the first year leading to positive K balance (Table 43a). However in the succeeding year negative balance for K was observed (Table 43b). When compared to the initial soil test value for available K, available K status observed at the start of the second season experiment was higher and thus the expected K balance was higher for that year. Moreover, the actual K content of the soil was not as high as the theoretically computed expected K balance of the soil which led to greater losses of K.

In 98-99, a distinct gain in the quantity of available K or in other words positive K balance was observed due to green manuring as a result of greater release of K^+ in soil solution from the insoluble K minerals by organic acids or carbon dioxide formed during green manure decomposition and due to greater recycling of subsurface K (Table 43a). In the second year, the general observed trend of net loss of K (negative balance) though reflected in the green manured plots also, was considerably reduced due to beneficial effects of green manuring on available K (Table 43b). Medium levels of N and K maintained net gains in the first year. In the next year, incremental doses of N tended to reduce the net loss due to build up of available K at higher rates of N (Tables 43a and 43b). However, higher potassium nutrition favoured greater losses in the second year due to the reasons already stated by Sadanandan and Mahapatra (1973a).

The results of the nutrient balance sheet studies indicate that excessive leaching and mineralization under the influence of high rainfall (mean annual rainfall during the experimental period of 1899 mm), slightly greater nutrient uptake by the yam crop than the net available reserve excluding losses, negligible recycling of nutrients from the vegetative parts for the current season crop, low cation exchange capacity and organic matter status of the soil and the impossibility to achieve the theoretical rate of mineralization from the organic sources in coconut garden under partial shade might have led to negative net changes in the available status of N, P and K and resulted in deficit balance sheets for these nutrients.

5.3.9. Economic analysis

Inspite of high cost of coir pith compost, application of coir pith compost @ 5 t ha^{-1} along with 80 kg each of N and K_2O ha^{-1} fetched maximum net return (Rs 36,187 ha^{-1})due to maintenance of higher yield. Though green manure incorporation is costly, due to lower cost of green manure seeds compared to FYM or coir pith compost and reasonably high yield, green manuring combined with application of 120 kg N and 40 kg K_2O ha^{-1} proved profitable(Rs 35,657 ha^{-1}) and computed maximum BCR (1.54). Due to comparable tuber yield and lower production cost, application of FYM @ 10 t ha^{-1}, 80 kg N and 120 kg K_2O ha^{-1} also generated reasonable profit (Rs 34,720 ha^{-1})and BCR (1.53) (Table 44).

Presently, coconut farming is not very profitable due to severe disease and pest incidence and lesser market price for coconuts. Intercropping assumes importance in this context. The present study reveals that intercropping white yam in coconut garden is economical due to generation of employment opportunities and higher net income (Rs. 31,525 ha^{-1}) (Table 45) besides providing high energy food.

SUMMARY

SUMMARY

A research programme was undertaken at the Instructional Farm of the College of Agriculture, Vellayani, Thiruvananthapuram during May to February in 1998-1999 and 1999-2000 to evaluate the production potential of white yam as an intercrop in coconut garden and to standardize agrotechniques for intercropping. The investigation was programmed as three separate experiments conducted simultaneously. In experiment I, the effect of five growth promoting substances (viz., thiourea 2%, potassium nitrate 2%, IAA 1000 ppm, wood ash and cowdung slurry) and a control were evaluated for their effects on sprouting of yam setts in completely randomized design. With a view to optimize plant population and sett size for intercropping white yam in coconut garden, factorial combination of three spacings (60x60 cm, 75x75 cm, 90x90 cm) and three sett sizes (100 g, 200 g, 300 g) replicated thrice was arranged in randomized block design in experiment II. In the third experiment to develop a nutrient management schedule for white yam under intercropping situation, three sources of organic manures (viz., FYM, coir pith compost, *in situ* green manuring using sunhemp) in main plots and combination of three levels each of N and K (40, 80, 120 kg ha^{-1}) apart from n_0k_0 control in sub plots replicated twice were evaluated in split plot design. The salient findings emanated from the research are briefed below:

Of the growth promoting substances, sett treatment using thiourea 2% induced early, uniform, better sprouting and produced longer sprouts that eventually led to the establishment of a vigorous crop.

Regardless of spacings, higher sprouting per cent and longer sprouts were observed with 300 g setts. White yam canopy size enhanced with increase in spacing. Efficient allocation of photoassimilates for storage in tubers was favoured by the widest spacing, 90x90 cm resulting in highest harvest index. Total dry matter production, dry matter accumulation in tubers as well as its partitioning ratio to tubers (HI) were notably higher with 300 g setts. In general, maximum total biomass was observed when setts of 300 g size were planted closely at 60 x 60 cm.

The length, girth and weight of tubers were positively influenced by 90x90 cm spacing. Setts of 300 g appreciably favoured these yield attributes. Hence optimum tuber yield (17.87 t ha^{-1}) and higher harvest index (0.64) were obtained from 300 g setts spaced at 90x90 cm. Maintaining the same plant population by planting a lesser sett size (200 g) also resulted in higher tuber yield (16.52 t ha^{-1}) and harvest index (0.60). Wider spacing (90x90 cm) also produced better quality tubers by accumulating more starch (23.70 %) in tubers.

To sum up, planting white yam setts of size 200 g at a spacing of 90x90 cm so as to accommodate 9000 plants ha^{-1} of coconut garden proved viable due to generation of additional employment, higher net return (Rs. 19, 363 ha^{-1}) and benefit-cost ratio (1.31).

Growth response of white yam to various organic manures indicated that application of coir pith compost (CPC) favoured crop growth conditions by producing longer plants and retaining more number of leaves. Incremental rates of N fertilization enhanced vine length and leaf retention, with maximum values at 120 kg N ha^{-1}. Moderate supply of potassium increased vine length. Potassium nutrition at 120 kg K_2O ha^{-1} retained maximum number of leaves particularly during the active growth stages. However towards harvest, potash nutrition at 120 kg ha^{-1} reduced the canopy size.

Higher dry matter accumulation in leaves, vines, tubers and thereby in the whole plant were obtained due to coir pith compost application. N supply at higher rates increased the leaf and vine dry matter production almost throughout the crop growth. Maximum shoot biomass was obtained at 120 kg N ha^{-1}. Accumulation of biomass in tuber was favoured by 80 kg N ha^{-1} in 98-99 and 120 kg N ha^{-1} in 99-00. Potassium nutrition at 120 kg ha^{-1} was beneficial in promoting leaf, vine and tuber dry matter production and resulted in greater whole plant biomass.

Growth analysis of white yam intercropped in coconut garden revealed that maximum LAI was discernible in plots that received coir pith compost. Applied nitrogen as well as potassium at higher rates tended to enhance LAI substantially. Higher NAR and CGR values were also computed from plants treated with coir pith compost. Increasing levels of nitrogen were influential in enhancing these growth indices. N application at 120 kg ha^{-1} proved inevitable for attaining higher photosynthetic efficiency during the initial growth phase as revealed from the higher magnitude of these parameters. Towards harvest, a decline in NAR and RGR values were obtained at higher rates of nitrogen nutrition. Enhanced levels of potassium also promoted NAR, CGR and RGR values during the initial and active growth phases.

Similar tuber bulking rates were observed due to the effect of various organic manures. Though N nutrition was beneficial in promoting bulking rate, the effect due to higher levels was not pronounced. Increasing levels of K tended to slightly enhance the bulking rates.

Different organic manures effected almost similar rates of dry matter partitioning to tubers (HI). Medium rates of N nutrition resulted in higher HI whereas potassium at higher rates increased the HI irrespective of N levels.

Incremental doses of nitrogen resulted in significant increase in the interception of PAR with maximum value at 120 kg N ha^{-1} at the active growth stage. A significant OxN interaction also occurred at this stage.

Higher rates of applied nitrogen was found to enhance chlorophyll 'a', 'b' and total chlorophyll contents at the grand growth period of the crop.

Organic manures, levels of N and K or their interactions failed to exert any influence on the proline content at the active growth stage.

The various organic manures had similar effects in promoting tuber weight, length and girth of tubers. Tuber weight increased considerably upto 80 kg N ha^{-1}. However, the length and girth of tubers remained unaffected by N nutrition. On the other hand, potassium at higher levels favoured all these attributes. Maximum weight, length and girth of tuber was obtained at 120 kg K_2O ha^{-1}. Higher tuber weights were also realized from the interactions, CPCx80 kg N ha^{-1} and CPC x 80kg K_2O ha^{-1}. Of the NxK interactions,80 kg N and 80 kg

K_2O ha^{-1} in 98-99(2.42 kg) and 120 kg N and 120 kg K_2O ha^{-1} in 99-00 (1.78 kg) yielded tubers with greatest weights. On the whole, the interaction CPC x 80 kg N ha^{-1} x 80 kg K_2O ha^{-1} maintained higher tuber weights during the two years of experimentation.

Tuber yield variation was similar to that of mean tuber weight in this research. There was no conspicuous variation in tuber yield among the different organic manures which implies the suitability of coir pith compost or green manures as alternatives to FYM, the common organic manure currently used. Tuber yield response was pronounced upto 80 kg N ha^{-1}. Tuber yield responded positively to higher rates of potassium nutrition upto 120 kg ha^{-1}. The interactions, CPC x 80 kg N ha^{-1}, CPCx80 kg K_2O ha^{-1} and 80 kg N ha^{-1} x 80 kg K_2O ha^{-1} also proved beneficial for higher yields. These results clearly indicates that N:K ratio of 1:1 is ideal for obtaining maximum tuber yield in white yam under intercropping situation. Application of 5 t ha^{-1} of coir pith compost along with 80 kg N ha^{-1} and 80 kg K_2O ha^{-1} maintained highest yields in both the seasons.

Tuber quality in terms of dry matter, starch and crude protein were markedly improved by coir pith compost application. Higher rates of N and K enhanced dry matter content in tuber. The starch content of tuber was appreciably higher at 120 kg K_2O ha^{-1}. Medium level of N accumulated higher starch content. The crude protein content of tuber indicated an increasing trend with increasing levels of N. Potassium nutrition at 40 kg ha^{-1} resulted in higher crude protein content. Crude fibre content were lowered at highest levels of N and K. Medium levels of N and K promoted vitamin C content.

Of the various organic manures evaluated, coir pith compost treated plants registered significantly higher uptake of N and K, though its effect on uptake of P was not profound. Significant export of N, P and K by white yam was observed at 80 kg N ha^{-1} in the first year and 120 kg N ha^{-1} in the second year. Crop uptake of N and P was promoted by K supply at 80 kg ha^{-1} in 98-99 and at 120 kg ha^{-1} in 99-00. Maximum plant uptake of K resulted due to K fertilization at 120 kg K_2O ha^{-1} in both the years.

Computation of use efficiency of applied N and K in the current research provides clear evidence that green manuring registered significantly higher agronomic efficiency of applied N or K in the second year. The physiological efficiency of applied N or K remained same for the different organic manures in both the years. Enhanced N supply diminished the agronomic and physiological efficiency of N. Increasing levels of K tended to enhance the agronomic efficiency of N considerably with maximum efficiency computed from 120 kg K_2O ha^{-1}. Physiological efficiency of N remained unaffected by different levels of K. Higher rates of potassium nutrition also reduced the agronomic efficiency of K, whereas physiological efficiency of K did not vary widely among K levels. The agronomic efficiency of potassium was promoted at higher rates of applied N.

Different organic manures, rates of applied N or K or their interactions did not show appreciable variation in the moisture content and physical parameters of the soil as well as the status of total N, P and K in the soil.

On the other hand, the treatments significantly affected the available nutrient status of the soil. Green manuring enhanced the available N, P and K status of the soil profoundly. Higher rates of N increased the available N and K contents of the soil, though P content was unaffected. Potassium supplementation at the highest dose led to appreciable build up of available N, P and K in the soil. However, there was no significant variation in the organic carbon content of the soil due to these treatments.

Studies on the nutrient balance sheet for available N, P and K indicated deficit balance sheets for these nutrients at the end of two years of experimentation. Green manuring proved beneficial in lowering the net losses incurred in the nutrient balance sheets. Addition of higher rates of N and K favoured greater loss of the respective nutrients. However, the enhanced supply of one nutrient led to reduction in the loss of the other nutrient.

Economic analysis of the various treatments showed that application of coir pith compost @ 5 t ha^{-1} along with 80 kg N, 60 kg P_2O_5 and 80 kg K_2O ha^{-1} maintained higher yield (24.61 t ha^{-1}) besides generating employment opportunities, higher net income (Rs. 36,187.00 ha^{-1}) and benefit - cost ratio (1.42).

Economic evaluation of coconut - white yam intercropping system reveals that the system is profitable since it generates net income to the tune of Rs. 31,525 ha^{-1} and BCR of 1.33.

The results summarized here clearly suggest the suitability of raising white yam *(D. rotundata)* var. Sree Priya as a profitable intercrop in coconut garden. It also implies that planting setts of size 200 g at a spacing of 90x90 cm accommodating 9000 plants ha^{-1} was beneficial for realizing higher yield and good quality tubers. It is also noteworthy that uncontrollable losses of nutrients in the soil-plant system, the high soil exhausting nature of *D. rotundata* and negligible recycling of nutrients through crop residues necessitates continuous replenishments of the soil with organic manure and fertilizers. The current research brings out the suitability of coir pith compost and green manure as possible alternatives to FYM and the need of application of 80 kg N, 60 kg P_2O_5 and 80 kg K_2O ha^{-1} for maintaining high yield of good quality tubers when continuously intercropped in coconut garden. Furthermore such a system provides gainful employment and fetches high return.

FUTURE LINE OF RESEARCH

- ★ *On farm research to popularise white yam as an intercrop in coconut gardens in different agroclimatic zones of Kerala.*

- ★ *Since staking or trailing is a costly affair in yam production, it is imperative to assess the production potential of dwarf, non trailing genotypes of white yam in coconut based cropping system.*

- ★ *Future research should also focus on developing agronomic practices for dwarf, non trailing genotypes of white yam under intercropping situation.*

- ★ *Further research is required to explore the feasibility of in situ green manuring using cowpea at preplanting of white yam and conjoint use of biofertilizers and chemical fertilizers. Detailed studies on the nutrient dynamics of such a system is also necessary.*

- ★ *Scope of integration of white yam with fruit crops (banana) and other perennial trees in homesteads and formulation of management practices for such systems.*

REFERENCES

REFERENCES

Abdul Baki, A.A. and Anderson, J.D.1970. Viability and leaching of sugars from germinating barley crop. *Crop Sci.* **10** : 31-34

Aduayi, E.A. 1979. Nutrient composition of white yam *(Dioscorea rotundata)* leaves sampled at various portions on the stake as influenced by nitrogen fertilization. *Commun. Soil Sci. Pl. Analysis.* **10** : 927-939

Aduayi, E.A. and Okpon, S.N. 1980. Role of continuous nitrogen fertilization on nutrient composition of leaves sampled at various stages of growth and on yield of yam *(Dioscorea rotundata). Commun. Soil Sci. Pl. Analysis.* **11** : 267 - 282

Agboola, A.A. 1974. Problems of improving soil fertility by the use of green manuring in tropical farming system. *Organic Materials as Fertilizers.* Soil Bulletin No.17. Food and Agriculture Organisation, Rome, Italy, pp. 147-152

AICRP. 1983. *Report of All India Co-ordinated Tuber Crops Improvement Project.* Seventh All India Workshop on tuber crops (other than potato), November 7-9, 1983, Central Tuber Crops Research Institute, Thiruvananthapuram, p.74

AICRP. 1999. *Annual Report 1998-99.* All India Co-ordinated Research Project and ICAR Ad hoc Research Schemes on Tuber crops (other than potato). Central Tuber Crops Research Institute, Thiruvananthapuram, p. 75

Akatsuka, T. and Nelson, O.E. 1966. Starch granule- bound adenosine diphosphate glucosyl transferase of maize seeds. *J. Biol. Chem.* **241.** 2280-2286

*Akoroda, M.O. 1985. Dynamics of sprout emergence in Guinea yams. *Zeitschrift-fur-Acker-und-Pflanzenbau.* **154** (1) : 16-24

Alexandratos, N. 1995. *World Agriculture: Towards 2010 - An FAO Study.* Food and Agriculture Organisation and John Wiley and Sons, New York, p.134

Aminoff, D., Binkely, W.W., Schaffer, R. and Mawry, R.W. 1970. Analytical methods for carbohydrates. *The Carbohydrate Chemistry and Biochemistry.* Academic Press, New York, pp. 760-764

AOAC. 1975. *Official Methods of Analysis.* Twelfth edition . Association of Official Agricultural Chemists, Washington, D.C, p.218

Ashokan, P.K. and Sreedharan, C. 1977. Influence of levels and time of application of potash on growth, yield and quality of tapioca. *J. Root Crops.* **3** (2) : 1-4

Audus,L.J.1972. *Plant Growth Substances-Chemistry and Physiology.* Leonard Hill,London, p.533

Austin, R.B. 1994. Crop breeding opportunities. *Physiology and Determination of Crop Yield* (eds. Boote, K.J., Benett, J.M., Sindair, T.R. and Paulsen, G.M.). Madison, Wisconsin, USA, ASA, CSSA and SSSA. pp. 567-586

Azih, V.A. 1976. Effect of different rates of N, P and K fertilizers on the yield and storage quality of yellow yam *(Dioscorea cayenensis). J. Root Crops.* **2** (2) : 1-6

Baker, E.F. I. 1964. Plant population and crop yield. *Nature.* **204:** 856-857

Bala Nambisan and Indira, P. 1993. Investigations on rapid propagation techniques and seed storage of edible yams *(Dioscorea* sp.*)* and aroids *(Amorphophallus* sp.*)* to economise the seed inputs in their cultivation. *Final Report of AP Cess Fund Scheme.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.82

Bates, J.S., Waldren, R.P. and Teave, I.D. 1973. Rapid determination of free proline for water stress studies. *Pl. Soil.* **39** : 205-209

Behura, A.K. and Swain, D. 1997. A note on response of yam to different levels of nitrogen and potash. *Orissa J. Hort.* **25** (1) : 99-100

Bin,J.1983. Utilization of green manure for raising soil fertility. *Soil Sci.* **135**:65-69

Binod Kumar., Roysharma, R.P. and Singh, S.B. 2000. Balance sheet of soil nitrogen in wheat *(Triticum aestivum)* based crop sequence. *Indian J. Agron.* **45** : 227-231

Blackman, J.G. 1919. The compound interest law and plant growth. *Ann. Bot.* **33** : 353-360

Bourke, R.M. 1985. Influence of nitrogen and potassium fertilizers on growth of sweet potato *(Ipomoea batatas)* in Papua New Guinea. *Field Crops Res.* **12** : 363-375

Bouyoucos, C.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* **54:** 464-465

Brady, N.C. 1996. *The Nature and Properties of Soils*, Tenth edition. Prentice Hall of India Private Ltd., New Delhi, p.621

Bryan, H.H. and Mcmillan, R.T. 1975. Effects of growth regulators on dormancy, shoot growth and yield of *Dioscorea alata L. Proc.Trop.Reg. Amer. Soc. Hort. Sci.***19**:239-246

Buttery, B.R. 1970. Effect of variation in leaf area index on growth of maize and soybeans. *Crop Sci.* **10** : 9-13

Campbell, J.S., Chukwueke, V.O., Terriba, F.A. and Ho-A-Shu, H.V.S. 1962. Some physiological investigations into the white Lisbon yam *(Dioscorea alata*L.*)* I.The breakage of the rest period in tubers by chemical means. *Emp. J. Exp. Agric.* **30** : 108-114

Chapman, T. 1965. Some investigations into factors limiting yields of the white Lisbon Yams (*Dioscorea alata)* under Trinidad conditions. *Trop. Agric.* **4 :** 145-151

CIAT. 1975. *Annual Report*. Centro Internacional de Agricultura Tropicale, Cali, Columbia, pp.B1-B57

CIAT. 1977. *Annual Report.*Centro Internacional de Agricultura Tropicale, Cali, Columbia, pp. B1-B76

Cochran, W.G. and Cox. G.M. 1965. *Experimental Designs* Asia Pub. House.p.611

Coursey, D. 1967. *Yams.* Tropical Products Institute, Longmans, Green and Co. Ltd., London, p.230

CTCRI. 1971. *Annual Report.* Central Tuber Crops Research Institute,Thiruvananthapuram, p.102

CTCRI. 1973. *Annual Report.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.104

CTCRI. 1976. *Annual Report.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.106

CTCRI. 1977 *Annual Report.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.155

CTCRI. 1979. *Annual Report.* Central Tuber Crops Research Insitute, Thiruvananthapuram, p.226

CTCRI. .1982. *Annual Report.*Central Tuber Crops Research Institute, Thiruvananthapuram, p.200

CTCRI.1992.*Annual Report 1991-92.*Central Tuber Crops Research Institute, Thiruvananthapuram, p. 126

CTCRI. 1998a. *Tuber Crops Varieties Released by CTCRI.* Technical Bulletin Series 24. Central Tuber Crops Research Institute, Thiruvananthapuram, p.40

CTCRI. 1998b. *Annual Report 1997-98.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.164

CTCRI. 2000a. *Annual Report 1998-99.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.145

CTCRI. 2000b. *Annual Report 1999-2000.* Central Tuber Crops Research Institute, Thiruvananthapuram, p.150

Dhua, R.S., Ghosh, S.K., Biswas, J., Mitra, N. and Sen, H. 1988. Effect of some chemicals on sprouting, growth and corm yield of *Amorphophallus campanulatus. J. Root Crops.* **14** (2) : 47-49

Eagle, A.J., Bird, J.A., Horwath, W.R., Linquist, B.A., Brouder, S.M., Hill, J.E., and Kessel, C.V. 2000. Rice yield and nitrogen utilization efficiency under alternative straw management practices. *Agron. J.* **92** : 1096-1103

Egbe, T.A. and Treche, S. 1984. Variability in the chemical composition of yams grown in Cameroon. *Tropical Root Crops - Production and Uses* in *Africa* (eds. Terry, E.R., Doku, E.V., Arene, O.B. and Mahungu, N.M.). Proceedings of the Second Triennial Symposium of the International Society for Tropical Root Crops,1983.International Development Research Centre, Canada, pp. 152-156

Enyi, B.A.C. 1970. Growth studies in Chinese yam (*Dioscorea esculenta*). *Proceedings of the Second International Symposium on Tropical Root Crops, Honolulu, Hawaii.* **2** (1) : pp.102-103

Enyi, B.A.C. 1972. Effect of staking, nitrogen and potassium on growth and development in lesser yams : *Dioscorea esculenta. Ann. Appl. Biol.* **72** : 211-219

Enyi, B.A.C. 1973 . The effect of time of planting and nitrogen application on growth, development and yield of lesser yam (*Dioscorea esculenta*). *Nigerian J. Sci.* 7 (2):93-103

Escasinas, A.B. and Escalada, R.G. 1984. Crop rotation of sweet potato, cassava and gabi with legumes as a cultural management system. *Ann. trop. Res.* **6** : 63-76.

*Espindola, J.A.A., Almeida, D.L. De., Guerra, J.G.M., Silva, E.M.R. Da. and Souza, F.A. De. 1998. Effect of green manures on mycorrhizal colonization and yield of sweet potatoes. *Pesquisa Agropecuaria Brasileira.* **33** (3) : 339-347

Evans, L.T. 1975. The physiological basis of crop yield. *Crop Physiology Some Case Histories* (ed. Evans, L.T) .Cambridge University Press, London, pp. 327-348

Ferguson, T.U., Haynes, P.H. and Spence, J.A. 1984. The effect of sett size, sett type and spacing on some aspects of growth, development and yield in white Libson yams (*D. alata* L.). *Proceedings of the Sixth Symposium of International Society for Tropical Root Crops , February 21-26, 1983*, Centro Internacional de la Papa, Lima,Peru, pp.649-655

Gaztambide, S. and Cibes, H.R. 1975. Nutritional deficiencies of yams (*Dioscorea* spp.) *J.Agric. Univ.Puerto Rico.* **59** :264-273

Gbedolo, Y.M. 1986. Factors limiting yam production in Benin. *Tropical Root Crops: Root Crops and the African Food Crisis* (eds.Terry, E.R., Akoroda, M.O. and Arene, O.B.).Proceedings of the Third Triennial Symposium of the International Society for Tropical Root Crops, 1986,International Development Research Centre, Ottawa, Cananda, pp.57-60

Geetha, K. and Nair, K.P.M. 1993 .Effect of N and K in coleus. *J. trop. Agric.* **31:** 198-203

George, J. 1995. *Rapid Seed Yam Production Technology.* Technical Bulletin Series : 19. Central Tuber Crops Research Institute, Thiruvananthapuram, p. 21.

Girardin, O., Nindjin, C., Farah, Z., Escher, F., Stamp, P. and Otokore, D. 1998. Effect of storage system and sprout removal on post-harvest yam *(Dioscorea* spp.) fresh weight losses. *J. Agric. Sci.* **130** (3) : 329-336

*Gomes, J. DEC., Carvalho, P.C.L. DE., Carvelho, F.L.C. and Rodrigues, E.M. 1983. Use of organic fertilizer in the recovery of low fertility soils planted to cassava. *Revista Brasileira de Mandioca.* **2** (2) : 63-67

Gomez,K.A. and Gomez,A.A.1984.*Statistical Procedures for Agricultural Workers*. Second edition. John Wiley and Sons,New York, p.680

Gooding, E.G.B. and Hoad, R.M. 1967. Problems of yam cultivation in Barbados. *Proceedings of the First International Symposium on Tropical Root Crops, April 2 -8,1967* (eds.Tai,E.A.,Charles,W.B.,Iton,E.F.,Haynes,P.H.and Leslie,K.A.). University of West Indies, St.Augustine,Trinidad, pp. 137-151

Gu, R.S. and Wen,Q.X. 1981.Cultivation and application of green manure in paddy fields in China. *Paddy Soils*. Science Press, Beijing. pp. 207-219

Gunasena, H.P.M., Silva, N.T.M. and Martin, M.P.L.D. 1980. Effect of spacing and nitrogen on growth and yield of manioc, (*Manihot esculenta)* grown as intercrop under coconut. *Journal of the National Science Council of Sri Lanka.* **8** (1): 1-10

Gupta, R.P. and Dakshinamoorthi, C. 1980. *Procedures for Physical Analysis of Soil and Collection of Agrometeorological data.* Indian Agricultural Research Institute, New Delhi, p.116

Gurnah, A.M. 1974. Effects of spacing, sett weight and fertilizers on yield and yield components in yams. *Expl Agric.* **10** : 17-22

Gyorgy, P. and Pearson, W.N. 1967 . *The Vitamins Chemistry-Physiological Method.* Second edition . Academic Press, New York, Vol **VII** : pp.235-238

Hargrove,W.L.1986.Winter legumes as nitrogen source for no-till grain sorghum. *Agron. J.* **78**:70-74

Howeler, R.H.. 1993. Agronomy research in the Asian cassava network towards better production with the soil degradation. *Proceedings of the Fifth Regional Workshop on Cassava Breeding,Agronomy Research and Technology Transfer in Asia, November* 2-6,1993, Central Tuber Crops Research Institute,Thiruvananthapuram, pp.368-409

*Hundal, H.S., Biswas, C.R. and Vig, A.C. 1987.The utilization by rice of P from different ^{32}P labelled green manure.*Biol. Wastes.* **22** : 97-105

Hunt, L.A., Wholey, D.W. and Cock, J.K. 1977. Growth physiology of cassava (*Manihot esculenta* Crantz). *Field Crop Abstract.* **30** (2): 77-91

Ibrahim, M.N.M., Raveendranath, S. and Balasubramoniam, S. 1983. Studies on root and tuber crops grown in association with coconut. 1. Survey on root and tuber crops found under coconut and the morphological characterization of edible aroids. *Cocos.* **1** : 17-30

Igwilo, N. 1989. Reponse of yam cultivars to staking and fertilizer application. *Trop. Agric.* **66** : 38-42

*Igwilo, N., Mbanaso, E.N.A., Onyia, G.O.C. and Atu, U.G. 1988. Inhibition of sprouting by gibberellic acid in the preservation of seed and ware yam. *Beitrage Zur Tropischen Landwirtschaft and veterinarmedizin* .**26** (2) : 145-154

Inasi, K.A., Philip, J., Alice Antony., Sreekumar, K., Nair, R.R. and Kunju, U.M. 1996. Crop production strategies of tuber crops intercropped with coconut in reclaimed alluvial soils. *Tropical Tuber Crops-Problems, Prospects and Future Strategies* (eds.Kurup, G.T., Palaniswami, M.S., Potty, V.P., Padmaja, G., Kabeerathumma, S. and Santha, V. Pillai). Oxford and IBH Publishing Co. Private Ltd., New Delhi, pp. 264-273

Irizarry, H., Geonaga, R. and Chardon, U. 1995. Nutrient uptake and dry matter yield in the 'Gunung yam' (*Dioscorea alata)* grown on an ultisol without vine support. *J. Agric. Univ. Puerto Rico.* **79** . 121-130

Irizarry, H. and Rivera, E. 1985. Nutrient uptake and dry matter production by intensively managed yams grown in an ultisol. *J. Agric. Univ. Puerto Rico.* **69** :1-9

Irving, H. 1956. Fertilizer experiments with yams in Eastern Nigeria. *Trop. Agric.* **33** : 67-68

Jackson, M.L. 1973. *Soil Chemical Analysis.* Second edition. Prentice Hall of India Private Ltd., New Delhi. p.498

Johnston, M. and Onwueme, I.C. 1998. Effect of shade on photosynthetic pigment in the tropical root crops : yam, taro, tannia, cassava and sweet potato. *Expl Agric.* **34** : 301-312

Kabeerathumma, S. and Mohankumar, C.R. 1994. Agrotechniques and nutritional requirements of yams. *Advances in Horticulture* : *8. Tuber Crops* (eds. Chadha, K.L. and Nayar, G.G). Malhotra Publishing House, New Delhi , India, pp. 293-311

Kabeerathumma, S., Mohankumar, B. and Nair, P.G. 1987. *Nutrient Uptake and Their Utilization by Yams,Aroids and Coleus*. Technical Bulletin Series 10. CTCRI, Thiruvananthapuram, p.34

Kabeerathumma, S., Mohankumar, B. and Nair, P.G. 1991. Nutrient uptake and their utilization pattern by yams at different growth stages. *J. Root Crops.* **17** (1) : 26-30

*Kamara, A.Y. and Lahai, M.T. 1997. Differential response of sweet potato *(Ipomoea batatas)* to green manuring with elephant grass *(Pennisetum purpureum)* and spear grass *(Imperata cylindrica)* on a ferralitic soil in Sierra Leone. *Tropenlandwirt.* **98** : 229-235

Kang, B.T. and Wilson, J.E. 1981. Effect of mound size and fertilizers on white Guinea yam *(Dioscorea rotundata)* in Southern Nigeria. *Pl. Soil.* **61** : 319-327

Kasele, I.N., Mahn, S.K., Oputa, C.O.and Vine, P.N. 1983.Effect of shade,nitrogen and potassium on cassava. *Tropical Root Crops : Production and Uses in Africa* (eds.Terrry,E.R.,Doku,E.V.,Arene.O.B. and Mahungu,N.M.). International Development Research Centre, Ottawa, Canada, pp.55-58.

Katyal, J.C. 1977. Influence of organic matter on the chemical and electrochemical properties of some flooded soils. *Soil Boil. Biochem.* **9**: 259-266

KAU. 1996. Kerala Agricultural University. *Package of Practices: Recommendations. Crops 1996.* Directorate of Extension, Mannuthy,Thrissur, pp.50-52

Kayode, G.O. 1984. Effects of sett size and spacing on tuber yield of white Guinea yams *(Diosocorea rotundata)* in the rainforest and savanna zones of Nigeria. *Expl Agric.* **20** : 53-57.

Khind, C.S., Josan, A.S. and Beri V. 1985. N release from *Sesbania* green manure and effect of time of application of N fertilizer on lowland rice. *Int. Rice Res. Inst. Newsl.* **10** (4) :26-27

King, G.A., and Risimeri, J.B. 1992. Effects of plant density, height of staking and variety on yield and yield components of the lesser yam (*Dioscorea esculenta). Trop. Agric.* **69** :129-132

Koli, S.E. 1973. The response of yam *Dioscorea rotundata* to fertilizer application in northern Ghana. *J. Agric. Sci.* **80** (2) : 245-249

Kpeglo, K.D., Obigbesan, G.O. and Wilson, J.E. 1980. Yield and shelf-life of white yam as influenced by fertilizer. *Tropical Root Crops Research Strategies for the 1980's* (eds.Terry,E.R.,Oduro,K.A.and Caveness,F.).International Development Research Centre,Canada, pp.198-203

Kumar, D.A., Indira, P. and Bala Nambisan. 1998. Effect of light and growth regulators on sprouting of *Amorphophallus* tubers. *Trop. Sci.* **38** : 187-189

Liu, S.Y. 1989. Cultivation techniques for enhancing productivity and processing quality of yam (*Dioscorea alata* L.) Coconut - Lisbon. *J.Agric. Res. China.* **38** (3) : 312-325

Lyonga, S. 1976. Production investigations on edible yams (*Dioscorea* spp.) in the Western and North Western highland savannah zone of the United Republic of Cameroon. *Proceedings of theThird Symposium of the International Society for Tropical Root Crops,* December 2-9,1973 (ed.Leakey,C.L,A.). International Institute of Tropical Agriculture, Ibadan, Nigeria,pp.255-269

Lyonga, S.N. 1982. Agronomic effects and economic importance of fertilizer on yams in Cameroon. In : *Root Crops in Eastern Africa.* International Development Research Centre, Ottawa,Canada, pp.81-85

Lyonga, S.N. 1984. Studies on fertilization of yam (*Dioscorea* spp.) and yam tuber storage in Cameroon. *Proceedings of the Sixth Symposium of the International Society for Tropical Root Crops, February 21-26, 1983,*Centro Internacional de la Papa,Lima, Peru, pp.616-617

*Macedo, L.D.S. and Santos, E.S.D. 1998. Study of the effects of irrigation frequency, plant density and nitrogen rates on yams. *Revista Brasileira de Engenharia Agricola e Ambiental* . **2** (1) : 37-41

Maheswarappa, H.P., Nanjappa, H.V. and Hegde, M.R. 1997. Influence of sett size, plant population and organic manures on yield components, yield and qualitative characters of arrow root grown as intercrop in coconut garden. *J. Root Crops.* **23** (2) : 131-137

Maheswarappa, H.P., Nanjappa, H.V. and Hegde, M.R. 1999. Influence of organic manures on yield of arrow root ,soil physico-chemical and biological properties when grown as intercrop in coconut garden. *Ann. agric. Res.* **20** : 318-323

Makunga, O.H.D., Pearman, I., Thomas, S.M. and Thorne, G.N. 1978. Distribution of photosynthate produced after anthesis in tall and semi-dwarf winter wheat as affected by nitrogen fertilizer. *Ann. Appl. Biol.* **88**: 429-437

Martin, F.W. and Cabanillas, E. 1976. Stimulating the sprouting of yam tubers with ethephon. *J. Agric. Univ. Puerto Rico*. **60** : 592-596

*Mattos, P.L.P., De Souza, L. DA. S., Caldas, R.C. and Dantas, J.L.L. 1980. Utilization of the free space between double rows of cassava by *Crotalaria juncea* L. Cruz das Almas - BA, Brazil, *Empresa Brasileria de Pesquisa Agropecuaria.* Centro Nacional de pesquisa de mandioca e Fruticultura Communicado tecnico no. **7 :** p.7

Mc Kenzie, B.A. and Hill, G.D. 1991. Intercepted radiation and yield of lentils *(Lens culinaris)* in Canterbury, New Zealand.*J.Agric.Sci.* **117** : 339-346

Mc Neal, F.N., Berg, M.A., Brown, P.L. and Mc Guire, C.F. 1971. Productivity and quality response of five spring wheat genotypes, *Triticum aestivum* L. to nitrogen fertilizer. *Agron. J.* **63** : 908-910

Mohandas, P.N. and Sethumadavan, P. 1980. Effect of graded doses of nitrogen, phosphorus and potassium on the quality of colocasia. *Proceedings of National Seminar on Tuber Crops Production Technology, November 21-22,*1980 .Tamil Nadu Agricultural University,Coimbatore, pp. 185-188

Mohankumar, C.R., Mandal, R.C., Nair,G.M. and Hrishi, N. 1976. Effect of farm yard manure and NPK on cassava. *Proceedings of the Fourth Symposium of the International Society for Tropical Root Crops,August 1-7,1976* (eds.Cock,J.,Mac Intyre,R. and Graham,M.).Centro Internacional de Agricultura Tropicale,Cali, Columbia, pp.122-124

Mohankumar, C.R. and Nair G.M. 1979. Note on the effect of planting material and levels of farm yard manure on the yield of *Dioscorea alata. J. Root Crops.* **5** (1) & (2) : 67-68

Mohankumar, C.R., Nair, G.M., James George., Ravindran, C.S. and Ravi ,V. 2000. *Production Technology of Tuber Crops.* Central Tuber Crops Research Institute, Thiruvananthapuram, pp. 22-30

Mohankumar, C.R. and Nair, P.G. 1990. Production potential and economics of tuber crops based cropping systems for lowlands. *Indian. J. Agron.* **35**: 44-49

Mohankumar, C.R. and Sadanandan, N. 1991. Changes in NPK status of the soil as affected by continuous cropping and levels of NPK application in taro in ultisol. *J. Root Crops.* 17 (1) : 73-74

Monteith, J.L. and Elston, J. 1983. Performance and productivity of foliage in the field. *The Growth and Functioning of Leaves* (eds..Dale,J.E.and Milthrope,F.L.) Cambridge University Press,London,UK, pp.449-518

Moorthy, S.N. and Nair, S.G. 1989. Studies on *Dioscorea rotundata* starch properties. *Starch.* **41** : 81-83

Mozie, O. 1987. The effect of 2,4 - D and other plant growth regulators on sprout formation in *Dioscorea rotundata* Poir (white yams) in storage. *Trop. Sci.* **27** : 229-232

Nagarajah, S., Neue, H.U. and Alberto, M.C.R. 1989. Effect of *Sesbania, Azolla* and rice straw incorporation on the kinetics of NH_4, K, Fe, Mn, Zn and P in some flooded rice soils. *Pl. Soil.* **116:** 37-48

Nair, G.M. 1994. Nutrient-moisture interaction under phasic stress irrigation of sweet potato in summer rice fallows. *Ph. D. Thesis,* Kerala Agricultural University, Thrissur, p.213

Nair, P.G. and Aiyer, R.S. 1985. Effect of potassium nutrition on cassava **(1)** growth, yield components and yield. *J. Root Crops.* **11** (1&2) : 23-28

Nair, P.K.R., Rama Varma and Nelliat, E.V. 1974. Intercropping for enchanced profits from coconut plantation. *Indian Fmg.* **24** (4) : 11-13

Nair, S.G., Abraham, K. and Nayar, G.G. 1987. Two high yielding selections of white yam *(Dioscorea rotundata* Poir*). J. Root Crops* .**13** (2) : 103-109

Nair,S. R.C. 1985. Effect of seed size and fertility levels on the yield and quality of *Dioscorea esulenta* (Lour). Burk. *M.Sc. Ag. Thesis,* Kerala Agricultural University, Thrissur, p.113

Nair, V.M. 1982. Potash nutrition of tapioca *(Manihot esculenta* Crantz). *Ph. D. Thesis,* Kerala Agricultural University, Thrissur, p.218

Nambiar, I.P.S., Sadanandan, N. and Kunju, U.M. 1976. Effect of CCC (2-Chloroethyl trimethyl ammonium chloride) on growth and yield of sweet potato. *Agric.Res. J. Kerala.* **14** : 189-190

Nayar, T.V.R. 1986. Production potential of cassava *(Manihot esculenta* Crantz*)* intercropped in coconut gardens. *Ph.D. Thesis,* Kerala Agricultural University, Thrissur, p.197

Nayar, T.V.R. and Mohankumar, B. 1989. Soil fertility management in cropping systems involving tuber crops. *Silver Jubilee Commemmoration Volume, 1963-88.* Central Tuber Crops Research Institute, Thiruvananthapuram, pp. 49-51

Nayar, T.V.R., Mohankumar, B. and Potty V.P. 1993. Low cost soil fertility management practices for cassava. *Turrialba.* **43** : 247-253

Nayar, T.V.R. and Nair, P.G. 1992. Productivity of *Amorphophallus paeoniifolius Dioscorea alata* and *Xanthosoma sagittifolium* in association with Nendran banana. (Musa, AAB). *J. Root Crops.* **18** (2) : 103-107

Nayar, T.V.R. and Potty, V.P. 1996. Biomass productivity and nutrient uptake in green manure cowpea-cassava sequential cropping system. *Tropical Tuber Crops- Problems, Prospects and Future Strategies* (eds.Kurup, G.T., Palaniswami, M.S., Potty,V.P., Padmaja, G., Kabeerathumma, S. and Santha V. Pillai). Oxford and IBH Publishing Co. Private Ltd., New Delhi, pp.194-199

Nayar, T.V.R. and Sadanandan, N. 1991. Effect of plant population and growth regulators on cassava intercropped in coconut gardens. II. Yield components, yield and tuber quality. *J. Root Crops.* **17** (1) : 39-43

Nayar, T.V.R. and Suja, G. 1996. Intercropping *Dioscorea* with banana var. Nendran (Musa, AAB). *J. Root Crops.* **22** (2) : 115-120

Nayar, T.V.R and Suja,G. 1999. Plant density for intercropping *Dioscorea* in coconut gardens. *Tropical Tuber Crops : In Food Security and Nutrition* (eds. Balagopalan, C., Nayar, T.V.R., Sundaresan, S., Premkumar,T. and Lakshmi, K.R.). Oxford & IBH Publishing Co. Private Ltd., New Delhi. pp. 351-356

Nayar, T.V.R., Suja,G. and Byju,G. 2000. Effect of plant density and levels of manuring on productivity of Banana - Dioscorea intercropping system. *International Symposium on Tropical Root and Tuber Crops , ISOTUC III,* January 19-22, 2000, Central Tuber Crops Research Institute,Thiruvananthapuram. *Abstract*: 49

Nnodu, E.C., Alozie, S.O. 1992. Using gibberrellic acid to control sprouting of yam tubers. *Trop. Agric.* **69** : 329-332

Novoa, R. and Loomis, R.S. 1981. Nitrogen and plant production. *Pl. Soil.* **58:**177-204

Nwinyi, S.C.O. 1983. Optimal time for fertilization of *Dioscorea rotundata. Tropical Root Crops: Production and Uses in Africa* (eds. Terry , E.R., Akoroda, M.O.and Arene, O.B.and Mahungu, N.M.). International Development Research Centre, Canada. pp.136-137

Nwoke, F.I.O., Njoku, E. and Okonkwo, S.N.C. 1973. The effect of size of seed yams on yield of individual plants of *Dioscorea rotundata. Proceedings of the Third Symposium of the International Society for Tropical Root Crops, December 2-9, 1973* (ed.Leakey,C.L.A.). International Institute of Tropical Agriculture,Ibadan, Nigeria, pp.154-156

Nwoke, F.I.O., Njoku, E. and Okonkwo, S.N.C. 1984. Effect of sett size on yield of individual plants of *Dioscorea rotundata* Poir. *Trop. Agric.* **61** : 99-101

Obigbesan, G.O. 1973. The influence of potash nutrition on the yield and chemical composition of some tropical root and tuber crops. *International Potash Institute Coloquinon Tenth Abidyen,* Ivory coast, pp.439-451

Obigbesan, G.O. and Agboola, A.A. 1978. Uptake and distribution of nutrients by yams (*Dioscorea* spp.) in Western Nigeria. *Expl Agric.* **14** : 349-355

Obigbesan, G.O., Agboola, A.A. and Fayemi, A.A.A. 1977. Effect of potassium on tuber yield and nutrient uptake of yams. *Proceedings of the Fourth Symposium of the International Society for Tropical Root Crops, August 1-7, 1976* (eds. Cock, J., Mac Intyre, R. and Graham, M.). Centro Internacional de Agricultura Tropicale, Cali, Columbia, pp. 104-107

Ollivier, J., Daniel, C. and Braconnier, S. 1994. Food crop intercropping with young coconut palms examples in Vanuatu. *Oleagineux.* **49** : 91-108

Onjo, M., Okanmoto, S., Hayashi, M. 1999. Studies on the development and growth of tubers of yams *(Dioscorea* spp.) 3. Effects of gibberellins on growth, enlargement and dormancy of tubers of *D. alata* L. *Jap. J. trop. Agric.* **43** (2) : 65-70

Onwueme, I.C. 1972. Influence of the weight of the planted tuber on the vegetative performance of white yam (*Diocorea rotundata* Poir*)* plants. *Nigerian Agric.J.* **9** (2) : 170-173

Onwueme, I.C. 1973. The sprouting process in yam *(Dioscorea* spp.*)* tuber pieces. *J. Agric. Sci. Camb.* **81** : 375-379

Onwueme, I.C. 1975. Tuber formation in yam (*Dioscorea* spp.) : Effect of moisture stress; contribution of the parent sett. *J. Agric. Sci. Camb.* **85**: 267-269

Onwueme, I.C. 1978 . Sett weight effects on time of tuber formation and on tuber yield characteristics in water yams (*Dioscorea alata* L.*). J. Agric. Sci.* **91** (2) : 317-319

Onwueme, I.C. 1982. Tuber physiology in yams *(Dioscorea* spp.*)* and its agricultural implications. *Proceedings of the Fifth International Symposium on Tropical Root and Tuber Crops, September 17-21, 1979* (eds. Belen, E.H. and Villanueva, M.). Philippine Council for Agriculture and Resources Research, Laguna, Philippines, pp. 235-243.

Onwueme, I.C. and Charles, W.B. 1994. *Tropical Root and Tuber crops - Production, Perspectives and Future Prospects.* FAO production and protection paper. 126, Rome, pp.51-173

Onwueme, I.C. and Fadayomi, O. 1980. A labour - saving system of yam production through weed control with herbicides, the elimination of staking, and cropping at high density. *J. Agric. Sci. Camb.* **95** : 641-654

Oriuwa, L.O. and Onwueme, I.C. 1980. Determining the optimum spacing and sett weight for growing yams (*Dioscorea* spp.) without stakes. *Quarterly J. Int. Agric.* **19** (5):24

Otu, O.I. and Agboola, A.A. 1991. The suitability of *Glyricidia sepium in situ* live stake on the yield and performance of white yam (*Dioscorea rotundata*). *Tropical Root Crops in a Developing Economy* (eds. Ofori, F and Hahn, S.K.). Proceedings of the Ninth Symposium of the International Society for Tropical Root Crops, 1991, Government of Ghana, Accra, Ghana. pp. 360-366

Passam, H.C. 1977. Sprouting and apical dominance of yam tubers. *Trop. Sci.* **19** : 29-39

Patel, B.M. and Mehta, H.M. 1987. Effect of FYM, spacing and N application on chemical constituents of elephant foot yam (*Amorphophallus campanulatus*). *Gujarat Agric. Univ. Res. J.* **13** (1) : 46-47

Pearman, I., Thomas, S.M. and Thorne, G.N. 1977. Effects of nitrogen fertilizer on growth and yield of spring wheat. *Ann. Bot.* **41** : 93-108

Pido, N.L. and Edeo, D.G. 1988. Effect of sett weight and seeding rate on the yield of tungui (*D. esculenta* Lour). *Philippine J. Crop Sci.* **13** (1) : 2-12

Pillai, N.G., Mohankumar, B., Nair P.G., Kabeerathumma, S. and Mohankumar, C.R. 1987. Effect of continuous application of manures and fertilizers on the yield and quality of cassava in laterite soil. *Proceedings of National Symposium on Production and Utilisation of Tropical Tuber Crops, November 27-29, 1985* (eds. Ramanujam, T., Rajendran, P.G., Thankappan, M., Balagopal, C. and Nair, R.B.). Central Tuber Crops Research Institute, Thiruvananthapuram, pp. 109 - 114

Potty, V.P. 1978. Occurrence of vesicular arbuscular mycorrhizae in certain tuber crops. *J. Root Crops.* **4** (1) : 49-50

Prabhakar, M. and Nair, G.M. 1987. Green manuring *in situ* : a substitute for FYM to cassava. *J. Root Crops.* **13** (2) : 125-126

Prema, L., Thomas, E.J. and Aiyer, R.S. 1975. The usefulness of sensory method of analysis by taste panel in differentiating the quality of cassava tubers in different treatments. *Agric. Res. J. Kerala.* **13** : 141-145

Premraj, S. 1980. Studies on the effect of N and K on the growth and development of colocasia (*Colocasia esculenta* (L.) Schott). *M.Sc. (Hort) Thesis,* Tamil Nadu Agricultural University, Coimbatore.p.118

Purea, M. and Mataora, T. 1995. Mineral nutrition of root crops in Cook Islands. *Mineral Nutrient Disorders of Root Crops in the Pacific* (eds.Craswell,E.T.,Asher,C.J. and Sullivan,O.J.N.).Proceedings of a Workshop,1995 , Nukualofa Kingdom of Tonga,pp.130-132

Pushpakumari, R. 1989. Fertilizer management of minor tuber crops in coconut based cropping system. *Ph. D. Thesis*, Kerala Agricultural University, Thrissur, p.278

Pushpakumari, R. and Sasidhar, V.K. 1992 a. Influence of shade on growth attributes of minor tuber crops. *J. Root Crops.* **18** (1) : 64-67

Pushpakumari, R. and Sasidhar, V.K. 1992 b. Yield variations of yams and aroids as influenced by shade intensities. *Indian J. Pl.Physiol.* **35** : 345-350

Pushpakumari, R. and Sasidhar, V.K. 1992 c. Fertilizer management of yams and aroids in coconut based cropping system. *J. Root Crops.* **18** (2) : 99-102

Raghuwanshi, R.K.S., Umat, R., Nema, M.L. and Dubey, D.D. 1991. Balance sheet of nitrogen, phosphorus and potash in soil as influenced by wheat (*Triticum aestivum*) based crop sequences. *Indian J. Agron.* **36** : 322-325

Rajasree, G. 1993. Nutrient management for intercropped *Colocasia esculenta* var. Thamarakannan. *M.Sc.(Ag) Thesis,* Kerala Agricultural University, Thrissur, p.106

Rajendran, N., Nair, P.G. and Kumar, B.M. 1976. Potassium fertilization of cassava in acid laterite soils. *J. Root Crops.* **2** (2) : 35-38

Ramesan, K.K. 1991. Nutritional requirement of arrow root (*Maranta arundinacea* L.) as pure crop. *M.Sc. (Ag) Thesis,* Kerala Agricultural University, Thrissur,p.92

Ramesan, K.K., Ahmed, P. and Oommen, M. 1996. Management of major plant nutrients for producing quality rhizomes of arrow root. *Proceedings of the eighth Kerala Science Congress, January 27-29,1996* (ed.Iyengar,P.K.). State Committee on Science,Technology and Environment,Thiruvananthapuram, pp.133-134

Rao, G., Selvaraj, G.Y., Bammi, R.K. and Randhawa, G.S. 1975. Effect of different levels of nitrogen , phosphate and potash on yield and diosgenin content of *Dioscorea floribunda. Indian J. Hort.* 32:168-170

Ravi, V. and Chowdhury, S.R. 1989. A method for leaf area determination in *Dioscorea. J. Root Crops.* **15** (1) : 45-48

Ravindran, C.S. and Bala Nambisan, 1987. Effect of FYM and NPK on the yield and quality of sweet potato. *J. Root Crops.* **13** (1) : 35-39

*Rodriguez, C.J., Martinez, R.L.A., Rodriguez, P.J.M. and Morales, M.J.O. 1989. Nutrient uptake and utilization co-efficients for fertilizers and soil nutrients in a yam *(Dioscorea alata)* crop. *Ciencia y Tecnica en la Agricultura, Viandas Tropicales.* **12**(1): 59-73

Rouanet, G. 1967. Experiments on yams in Guadoloupe. *Proceedings of the First International Symposium on Tropical Root Crops, April 2-8,1967* (eds. Tai,E.A.,Charles,W.B.,Iton,E.F.,Haynes,P.H. and Leslie,K.A.). University of West Indies, St.Augustine, Trinidad, pp.152-158

Russell, E.W. 1973. *Soil Conditions and Plant Growth.* Tenth edition. Longman Group Ltd,London. p.849

Sadanandan, N. and Mahapatra, I.C. 1973a. Studies in multiple cropping-balance sheet of nitrogen in various cropping patterns. *Indian J. Agron.* **18** : 323-327

Sadanandan, N. and Mahapatra, I.C. 1973 b. Studies on multiple cropping balance sheet of total and available phosphorus in various cropping patterns. *Indian. J. Agron.* **18** : 459-463

Samarawira, I. 1983. Effect of thiourea treatments on the induction and development of buds in white yam *(Dioscorea rotundata* Poir*)* tubers .*Trop. Agric.* **60** : 128-130

*Santos, ES.D. and Macedo, L.D.S. 1998. Irrigation management, plant density and mineral fertilizer application for yam cultivation. *Revista Brasileira de Engenharia Agricolae Ambiental.* **2** (1): 32-36

Saraswat, V.N. and Chettiar, T.S. 1976. Effect of organic and inorganic sources of nitrogen on cassava (*Manihot utilissima* L.). *Indian Agriculturist.* **20** (1) : 23-26

Sasidhar, V.K. and Sadanandan, N. 1976. Tapioca after cowpea gives higher yield. *Indian Fmg.* **26** (2) : 23

Sen, H. and Das, P.K. 1991. Relative performance of newly introduced white yam (*Dioscorea rotundata* Poir) in Gangetic plains of West Bengal. *J. Root Crops.* **17** (2) : 150-151

Sevenorio, P.L. and Escalada, R.G. 1983. Effect of stage of decomposition of green manure on the growth and yield of sweet potato. *Ann. trop. Res.* **5** (2) : 61-68

Sharfuddin, A.F.M. and Voican, V. 1984. Effect of plant density and NPK dose on the chemical composition of fresh and stored tubers of sweet potato. *Indian J. Agric.Sci.* **54**:1094-1096

Shyu, Y.T. and Chang, H.H. 1978. Effects of phosphorus and potassium levels and plant spacing on the yield and protein content of *Dioscorea alata* L. *J. Agric. Res. China.* **27** (4): 315-324

*Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.N., Debald, H.A., Kester, E.B. and Klick, J.T. 1965. *Quality Evaluation Studies of Foreign and Domestic rices*. Technical Bulletin No.1331. Services, U.S.A, pp. 1-86

Singh, N.T. 1984. Green manure as sources of nutrients in rice production. *Organic Matter and Rice.* International Rice Research Institute, Los Banos, Laguna, Philippines, pp. 217-228

Singh, Y., Khind, C.S. and Singh, B. 1991. Efficient management of leguminous green manures in wetland rice. *Advances in Agronomy* (ed.. Brady, N.C.). Academic Press, San Diego, California, pp. 136-181.

Singh, K.D., Mandal, R.C. and Maini, S.B. 1973 a. A note on effect of nitrogen levels on tuber yield and quality of *Dioscorea alata. Indian J. Agron.* **18** : 100-101

Singh, K.D., Mandal, R.C., Maini, S.B. and Magoon M.L. 1973 b. Influence of nitrogen and potash fertilization on tuber yield and quality of *Dioscorea esculenta. Indian J. Agron.* **18** : 17-21

Singh, Y., Singh, B. and Khind, C.S. 1992. Nutrient transformation in soils amended with green manures. *Advances in Soil Science:* **20** : Springer - Verlag, New York, pp. 237-297

*Singh, Y., Singh, B., Maskina, M.S. and Mellu, O.P. 1988. Effect of organic manure,crop residues and green manure(*Sesbania aculeata)* on nitrogen and phosphorus transformations in a sandy loam at field capacity and water logged condition.*Biol. Fertil. Soils.* **6** : 183-187

Singh, D.N., Tripathy, P., Sahu, A. and Nandi, A. 1994. Effect of spacing and planting material size on growth and yield of *Dioscorea alata. J. Root Crops* .**20** (2) : 81-84

Sobulo, R.A. 1972. Studies on white yam (*Dioscorea rotundata).* II Changes in nutrient content with age. *Expl Agric.* **8** : 107-115

Squire, G.R. 1990. *The Physiology of Tropical Crop Production.* C.A.B. International, Wallingford, Oxon, UK, p.236

Squire, J.S. 1981. Effect of green manure on cassava yield. *Tropical Root Crops*: *Research Strategies for the 1980's* (eds. Terry, E.R.,Oduro, K.A.and Caveness,F.). International Development Research Centre, Ottawa, Canada, p. 260.

Starnes, W.J. and Hadley, H.H. 1965. Chlorophyll content of various strains of soybeans. *Crop Sci.* **25** : 259-260

Stephens, D. 1956. Fertilizer trials 1948-51. *New Gold Cst Frm. I.* p. 9

Subbiah, B.V. and Asija, L.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* **25** : 259-260

Susan John, K., Mohankumar, C.R., Ravindran, C.S. and Prabhakar, M. 1998. Long term effect of manures and fertilizers on cassava production and soil productivity in an acid ultisol. *Proceedings of a National Workshop on Long-Term Soil Fertility Management through Integrated Plant Nutrient Supply, April 2-4,1988* (eds. Swarup, A., Reddy, D.D.and Prasad R.N.). Indian Institute of Soil Science, Bhopal, India., pp.318-325

*Swarup, A. 1987. Effect of pre submergence and green manuring (*Sesbania aculeata)* on nutrition and yield of wetland rice (*Oryza sativa* L.) on a sodic soil. *Biol. Fertil. Soils.* **5**: 203-208

Thampan, P.K. 1979. *Cassava.* Kerala Agricultural University, Trichur, India, p.242

Thomas, S.M., Thorne, G.N. and Pearman, I. 1978. Effect of nitrogen on growth, yield and photorespiratory activity in spring wheat. *Ann. Bot.* **42**: 827-837

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. 1995. *Soil Fertility and Fertilizers,* Fifth edition. Prentice Hall of India Private. Ltd., New Delhi, p.638

*Tiwari, K.N., Tiwari, S.P. and Pathak, A.N. 1980. Studies on green manuring of rice in double cropping system in a partially reclaimed saline sodic soil. *Indian J. Agron.* **25**: 136-145

Toyohara, H., Tanifuji, H., Iric, K., Takahashi, M., Myoda, T. and Kikuchi, F. 1998. Effect of seed tuber size on growth and development of yam (*Dioscorea alata L). Jap. J. trop. Agric.* **42** (4) : 282-287

Tyagi, M.C., Sharma,B. and Singh, M.P. 1976. Yam can check baby boom. *Intensive Agriculture.* **14**(8) : 22-23

Umanah, E.E. 1977. Effects of different rates of NPK fertilizers on yield and storage properties of white yam. *Proceedings of the Third Symposium of the International Society for Tropical Root Crops, December 2-9, 1973* (ed. Leakey, C.L.A.).International Institute of Tropical Agriculture, Ibadan,Nigeria, pp. 359-361

Varghese, P.T., Nair, P.K.R., Nelliat, E.V., Ramavarma and Gopalasundaram, P. 1978. Intercropping with tuber crops in coconut garden. *Proceedings PLACROSYM I,* Placrosym standing committee, Kasaragod, India, pp. 399-415

Veena Vidhyadharan. 2000. Integrated nutrient management for arrow root (*Maranta arundinacea L.)* under partial shade. *M.Sc. (Ag) Thesis,* Kerala Agricultural University, Thrissur, p.107

Vijayan, M.R. and Aiyer, R.S. 1969. Effect of nitrogen and phosphorus on the yield and quality of cassava. *Agric. Res. J. Kerala.* **7** : 84-90

Villanueva, M.R. 1986. Technology for yam and taro production in South East Asia. *Radix.* **8** : 1-6

Watanabe, I. 1984. Anaroebic decomposition of organic matter in flooded rice soils. *Organic Matter and Rice.* International Rice Research Institute, Los Banos, Laguna, Philippines, pp.229-234

Watson, D.J. 1947. Comparative physiological studies on the growth of field crops.I..Variation in net assimilation rate and leaf area between species and varieties, and within and between years. *Ann.Bot.N.S.* **11** : 41-76

Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. *Ann. Bot.* **23:** 431-439

Wickham, L.D., Passam, H.C. and Wilson, L.A. 1984. Dormancy responses to post-harvest application of growth regulators in *Dioscorea* spp. 1.Responses of bulbils, tubers and tuber pieces of three *Dioscorea* species.*J. Agric. Sci. Camb.* **102:** 427-432

Wilson, G.F. and Kang, B. T. 1981. *Developing Stable and Productive Biological Cropping Systems for the Humid Tropics : a Scientific Approach to Organic Farming.* Butterworth, London, UK, p.228

Yoder, R.E. 1936. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. *J. Amer. Soc. Agron.* **28** : 337 - 351

Young, A. 1976. Soil fertility, soil survey and land evaluation. *Trop. Soils Soil Survey. Camb.* **26**:291

Zaag, P.V., Fox, R.L., Kwakye, P.K. and Obigbesan, G.O. 1980. The phosphorus requirement of yams (*Dioscorea* spp.). *Trop. Agric.* **57** : 97-106

* Originals not seen

APPENDICES

Appendix - I

Weather parameters during the crop growth period (monthly averages)

Sl.No.	Month	Temperature(^{0}C)		Relative humidity%	Total rainfall (mm)	Evaporation (mm)		No.of rainy days
		Max.	Min.			Total	Average	
I y (98-99)								
1.	May ' 98	32.85	25.93	81.04	214.00	133.60	4.31	14
2.	June ' 98	30.67	24.63	85.13	270.10	107.20	3.57	25
3.	July ' 98	29.67	24.12	83.89	108.70	105.10	3.39	17
4.	Aug ' 98	29.94	24.25	85.65	139.30	104.10	3.36	13
5.	Sep ' 98	29.52	24.72	85.33	312.80	105.20	3.51	21
6.	Oct ' 98	29.65	23.65	87.63	424.60	93.70	3.02	18
7.	Nov ' 98	30.08	23.22	82.63	356.00	92.00	3.07	15
8.	Dec ' 98	30.61	22.79	86.08	142.40	77.10	2.48	26
9.	Jan ' 99	31.15	21.98	84.58	5.20	99.00	3.19	3
10.	Feb ' 99	31.40	22.75	82.04	78.60	107.80	3.85	4
II y (99-00)								
1.	May ' 99	30.50	24.04	89.11	408.50	93.20	3.01	23
2.	June ' 99	29.48	23.91	85.25	397.40	87.60	2.92	18
3.	July ' 99	29.00	23.45	84.09	164.20	94.86	3.06	21
4.	Aug ' 99	29.69	22.95	83.23	108.40	116.56	3.76	16
5.	Sep ' 99	31.12	23.89	78.58	10.60	134.70	4.49	8
6.	Oct ' 99	28.96	23.26	86.80	374.90	71.90	2.32	21
7.	Nov ' 99	29.79	23.17	81.78	156.80	85.20	2.84	13
8.	Dec ' 99	30.71	21.67	81.77	6.60	86.49	2.79	4
9.	Jan '2000	30.92	21.71	77.95	18.40	103.54	3.34	4
10.	Feb '2000	30.88	22.69	77.84	102.20	114.84	3.96	6

Appendix II
Nutrient addition through manures and fertilizers

Treatments	Nutrient addition (kg ha^{-1})					
	98-99			99-00		
	N	P	K	N	P	K
$o_1n_1k_1$	90.00	80.00	80.00	90.00	80.00	80.00
$o_1n_1k_2$	90.00	80.00	120.00	90.00	80.00	120.00
$o_1n_1k_3$	90.00	80.00	160.00	90.00	80.00	160.00
$o_1n_2k_1$	130.00	80.00	80.00	130.00	80.00	80.00
$o_1n_2k_2$	130.00	80.00	120.00	130.00	80.00	120.00
$o_1n_2k_3$	130.00	80.00	160.00	130.00	80.00	160.00
$o_1n_3k_1$	170.00	80.00	80.00	170.00	80.00	80.00
$o_1n_3k_2$	170.00	80.00	120.00	170.00	80.00	120.00
$o_1n_3k_3$	170.00	80.00	160.00	170.00	80.00	160.00
$o_1n_0k_0$	50.00	80.00	40.00	50.00	80.00	40.00
$o_2n_1k_1$	108.00	63.00	95.00	108.00	63.00	95.00
$o_2n_1k_2$	108.00	63.00	135.00	108.00	63.00	135.00
$o_2n_1k_3$	108.00	63.00	175.00	108.00	63.00	175.00
$o_2n_2k_1$	148.00	63.00	95.00	148.00	63.00	95.00
$o_2n_2k_2$	148.00	63.00	135.00	148.00	63.00	135.00
$o_2n_2k_3$	148.00	63.00	175.00	148.00	63.00	175.00
$o_2n_3k_1$	188.00	63.00	95.00	188.00	63.00	95.00
$o_2n_3k_2$	188.00	63.00	135.00	188.00	63.00	135.00
$o_2n_3k_3$	188.00	63.00	175.00	188.00	63.00	175.00
$o_2n_0k_0$	68.00	63.00	55.00	68.00	63.00	55.00
$o_3n_1k_1$	46.21	60.59	44.77	76.87	63.51	63.32
$o_3n_1K_2$	54.12	61.34	90.84	98.73	65.58	125.11
$o_3n_1k_3$	57.63	61.68	133.54	83.18	64.11	153.17
$o_3n_2k_1$	97.79	61.70	53.66	116.74	63.50	68.22
$o_3n_2k_2$	96.87	61.60	92.96	126.66	64.44	115.83
$o_3n_2k_3$	97.73	61.69	133.62	112.39	63.08	144.88
$o_3n_3k_1$	141.40	62.04	56.44	157.98	63.61	69.17
$o_3n_3k_2$	135.34	61.46	91.78	154.38	63.27	106.41
$o_3n_3k_3$	133.70	61.31	130.53	148.83	62.74	142.14
$o_3n_0k_0$	27.77	62.64	21.33	27.77	62.64	21.33

Appendix III

Average input costs and market price of produce

Items	Cost
INPUTS	
a. Labour	
1. Man labourer	Rs. 137.30 day^{-1}
2. Women labourer	Rs. 137.30 day^{-1}
b. Cost of seeds	
1. Seed tuber	Rs. 5.00 kg^{-1}
2. Sunhemp seed	Rs. 17.25 kg^{-1}
c. Cost of manures and fertilizers	
1. Farmyard manure	Rs. 374 t^{-1}
2. Coir pith compost	Rs 5.00 kg^{-1}
3. Urea	Rs. 4.00 kg^{-1}
4. Mussoriephos	Rs. 3.00 kg^{-1}
5. Muriate of potash	Rs. 4.00 kg^{-1}
d. Cost of other items	
1. Choodi coir for trailing	Rs. 27.85 kg^{-1}
2. G.I. wire for trailing	Rs. 37.00 kg^{-1}
OUTPUT	
Market price of yam tuber	Rs. 5.00 kg^{-1}

RESOURCE MANAGEMENT FOR INTERCROPPING WHITE YAM (*Dioscorea rotundata* Poir) IN COCONUT GARDEN

BY

SUJA, G.

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Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani - Thiruvananthapuram

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ABSTRACT

Intercropping Asiatic yams viz., greater yam *(Dioscorea alata)* and lesser yam *(Dioscorea esculenta)* in coconut gardens is a common practice. The recently introduced African white yam *(Dioscorea rotundata),* despite its superior tuber yield and quality has not yet found an appropriate place in the coconut based cropping system. Field experiments were conducted at College of Agriculture, Vellayani during 1998-99 and 1999-2000 to assess the performance of white yam variety Sree Priya as an intercrop in coconut garden, to evaluate the effect of growth promoting substances on sprouting and to standardize plant population, sett size and nutrient management practices for white yam under intercropping situation.

Five growth promoting substances (thiourea 2%, potassium nitrate 2%, IAA 1000 ppm, wood ash and cowdung slurry) and a control were evaluated for their effects on sprouting of white yam setts in CRD. Sett treatment using thiourea 2% induced early, uniform and better sprouting and established a vigorous crop.

Factorial combination of three spacings (60x60 cm, 75x75 cm , 90x90 cm) and three sett sizes (100 g, 200 g, 300g) arranged in RBD comprised the second experiment. Planting white yam setts of size 200 g at a spacing of 90x90 cm so as to accommodate 9000 plants ha^{-1} of coconut garden resulted in better sprouting and canopy size, higher harvest index, optimum tuber yield and higher profit.

The response of white yam to three organic manures (FYM,coir pith compost and *in situ* green manuring using sunhemp) assigned to main plots and combination of three levels each of nitrogen and potassium (40,80, 120 kg ha^{-1}) apart from n_0k_0 control in subplots was tested in split plot design. Application of coir pith compost increased vine length, number of functional leaves, LAI, leaf, vine, tuber and whole plant biomass, NAR, CGR, and plant uptake of N and K. Coir pith compost application led to marked improvements in tuber quality by enhancing dry matter, starch and crude protein contents . There was no conspicuous

variation in HI, bulking rate, weight, length and girth of tubers and tuber yield among the organic manures. This implies the suitability of coir pith compost and green manure as alternatives to FYM, the common organic manure currently used.

Higher rates of nitrogen nutrition promoted all the above growth attributes, though a decline in NAR and RGR values were observed at harvest. Nitrogen supply at higher rates also enhanced chlorophyll contents and interception of PAR at the active growth phase of the crop. Tuber yield response was pronounced upto 80 kg N ha^{-1}. Higher rates of nitrogen enhanced dry matter and crude protein contents and lowered crude fibre content in tubers. Moderate nutrition of nitrogen promoted vitamin C content. N supplementation at higher rates favoured crop uptake of N, P and K as well as enhancement of the available status of N and K in the soil.

Potassium nutrition at 120 kg ha^{-1} retained maximum number of leaves and favoured dry matter accumulation in leaves, vines and tubers. Physiological parameters like LAI, NAR, CGR, RGR and HI were also promoted by higher rates of applied potassium. Potassium at higher rates favoured weight, girth and length of tuber and maximum tuber yield was obtained at 120 kg ha^{-1}. Applied potassium at 120 kg ha^{-1} yielded better quality tubers with appreciable starch content and lower fibre content. Vitamin C content of tuber was promoted by medium potash nutrition. Higher rates of K enhanced crop uptake of N, P and K and at the same time resulted in appreciable build up of available N, P and K in the soil.

The balance sheet for available N, P and K indicated deficit balance. Green manuring enhanced the available N, P and K status of the soil profoundly, lowered net losses incurred in the nutrient balance sheets and promoted the agronomic efficiency of N and K fertilizers. Enhanced supply of N and K favoured greater loss of the respective nutrients and lowered their use efficiencies, whereas addition of one nutrient at higher rates reduced the loss of the other nutrient and promoted its efficiency.

Application of coir pith compost @ 5 t ha^{-1} along with 80 kg N, 60 kg P_2O_5 and 80 kg K_2O ha^{-1} maintained higher tuber yield and generated higher profit from white yam under intercropping situation. To sum up, depending upon availability, FYM, coir pith compost or green manure can be used as organic manure with equal efficiency for white yam intercropped in coconut garden. The N:K ratio of 1:1 proved ideal. On the whole, coconut - white yam intercropping system proved profitable due to generation of net return of Rs. 31,525 ha^{-1} and BCR of 1.33.