Strategies for Off Season Production of Coleus in the Southern Zone of Kerala

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(2012-11-152)

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by

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Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I , hereby declare that this thesis entitled **"Strategies for Off Season Production of Coleus in the Southern Zone of Kerala"** is a bonafide record of research work done by me during the course of research and 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.

Vellayani, **Anju , V. S**

10-10-2014. (2012-11-152)

CERTIFICATE

Certified that this thesis entitled **"Strategies for Off Season Production of Coleus in the Southern Zone of Kerala"** is a record of research work done independently by Ms. Anju, V.S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ANJU, V.S

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LIST OF ABBREVIATIONS

@	At the rate of
BCR	Benefit cost ratio
cm	Centimetre
CTCRI	Central Tuber Crops Research Institute
CPC	Coir pith compost
et al	Co –workers/co-authors
CD	Critical difference
^{o}C	Degree Celsius
FYM	Farmyard manure
Fig.	Figure
g	Gram
ha	Hectare
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
m	Metre
MAP	Months after planting
N	Nitrogen
NS	Non significant
P	Phosphorus

%	Per cent
K	Potassium
Rs ha^{-1}	Rupees per hectare
SEm	Standard error of means
t ha^{-1}	Tonnes per hectare
UI	Utilization index
var.	Variety

INTRODUCTION

1. INTRODUCTION

Coleus (*Plectranthus rotundifolius*) is a minor tuber crop, the tubers of which are used as vegetable. Unlike other vegetables, coleus tubers possess good keeping quality. It belongs to the family Labiatae. The plant is a small herbaceous bushy annual growing to a height of 30-60 cm. It has succulent stem and aromatic leaves. Leaves are petiolate, opposite and rounded to ovate in shape with serrated margins. The tubers are preferred for their particular aromatic flavour and sweetness. The tubers can be used as medicine for curing dysentery and in the treatment of certain eye disorders (Mohankumar *et al*., 2000). Besides being rich in carbohydrates or starch, the tubers are also rich in minerals like calcium and iron and certain vitamins including thiamine, riboflavin, niacin and ascorbic acid.

Coleus is a season bound crop. The released varieties of coleus namely Sree Dhara from Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram and Nidhi from Regional Agricultural Research Station, Pattambi are recommended for planting during July-October (KAU, 2011). Both varieties have duration of five months and average yield of 25 t ha^{-1}.

There is a great scope for off season production of coleus using photoinsensitive varieties. The tubers fetch a higher price in the market due to great demand during off season. Mareen and Radhakrishnan (2004) identified one photoinsensitive tissue culture mutant and Kerala Agricultural University (KAU) has released it as the variety (var.) Suphala in 2006. It is a tissue culture mutant derived from local cultivar and is suited for year round cultivation. It is a high yielding (15.93 t ha^{-1}) variety with a duration of 120-140 days (KAU, 2007). Atul (2012) obtained an average yield of 20.99 t ha^{-1} for the var. Suphala with organic nutrition during the normal planting season of July- October. The var. Suphala was found to be early maturing than the var. Sree Dhara during the normal planting season and had bigger sized tubers. But the performance of this variety has not been evaluated during off season in the southern zone of Kerala.

For exploiting the yield potential of the var. Suphala during the off season, it is necessary to fix the ideal time of planting and follow optimum nutrient management practices. Since coleus is a crop with great export potential, organic production assumes importance. But no comparative study on the effects of organic and integrated nutrient management for off season production of coleus has been done.

Considering the above facts, the present study entitled "Strategies for off season production of coleus in the southern zone of Kerala" was undertaken to fix the ideal time of planting and nutrient management for off season production of coleus var. Suphala and to work out the economics of cultivation.

REVIEW OF LITERATURE

1. REVIEW OF LITERATURE

Coleus is a photosensitive crop, the recommended time of planting of which is during July-October (KAU, 2011). Kerala Agricultural University has released a photoinsensitive var. Suphala which is adapted for year round cultivation. The performance of the var. Suphala has to be evaluated during off season in the southern zone of Kerala for which purpose the present study was undertaken. Hence the relevant literature on the effect of date of planting and application of nitrogen (N), phosphorus (P) and potassium (K) through chemical fertilizers, organic manures and biofertilizers on growth, yield and quality of coleus and nutrient uptake by the crop are reviewed in this chapter. Wherever sufficient information is lacking, relevant literature on other tuber crops are also reviewed.

2.1 DATE OF PLANTING

Coleus is a seasonal starchy aromatic tuber crop grown mainly for vegetable purpose (Vimala, 1994). Seasonal variations (different time of planting) has a significant influence on yield and quality of tubers. According to Singh and Mandal (1976), the best planting season of this crop under Kerala condition is from August to October. Planting during the first week of October recorded the highest tuber yield (30.4 t ha^{-1}) while planting in June recorded luxuriant vegetative growth.

Vasudevan and Jos (1989) found that some of the gamma ray induced mutants are tolerant to day length and these could be used as off season crop so that the tubers will be available throughout the year. Mareen (2002) conducted a study for induction of variability for high yield and photoinsensitivity in coleus. Later, Mareen and Radhakrishnan (2004) reported one promising photoinsensitive tissue culture mutant. In 2006, KAU has released this mutant as the var. Suphala which is adapted for year round cultivation.

Performance of coleus planted during different seasons was evaluated at Pattambi, Kerala during 2004 – 2006 including varieties like Nidhi, Sree Dhara and cultivar M13 (KAU, 2008). Ideal planting season for coleus in the central zone of Kerala was found to be between the first fortnight of July and first fortnight of August. Yield was low for early and late planted crops. Late planted crops produced bulged stem rather than early formed tubers.

Time of planting is an important aspect for the successful cultivation of sweet potato because most of the varieties are season bound. From a study conducted to determine the optimum time of planting of sweet potato from September to March 1986-87 and 1987-88 at Nadia, Mukhopadhyay *et al*. (1991) reported that February- March planted crops produced greater LAI, November 30 planting yielded greater dry matter production and planting of cuttings in March markedly increased the vine yield while October 30 was found conducive to obtain maximum tuber yield with the highest number and weight of tubers per plant.

Dayal and Sharma (1993) and Nedunchezhiyan and Byju (2005) reported remarkable influence of planting time on growth and yield of sweet potato. They have reported that June-July planting was the best time for rainfed sweet potato. According to Nedunchezhiyan and Reddy (2006), planting of sweet potato during second fortnight of July resulted in maximum benefit cost ratio (BCR) under rainfed conditions. Kushwah *et al*. (2011) concluded that sweet potato can be planted from July 15 to August 1 under rainfed conditions for maximum yield and economic returns.

2.2 EFFECT OF NUTRIENTS

2.2.1Effect of Nitrogen

2.2.1.1 Effect of N on Growth Characters

Geetha (1983) found that the growth characters of coleus like plant height, plant spread, number of functional leaves and leaf area index (LAI) showed an increasing trend with increasing rates of N application upto 120 kg ha^{-1}.

In sweet potato, Oomen (1989) recorded an increase in vine length, number of branches and LAI when N supply was increased from 50 to 100 kg ha^{-1}

2.2.1.2 Effect of N on Yield and Yield Components

Geetha (1983) obtained the highest number and weight of marketable tubers per plant due to application of 120 kg N ha^{-1} whereas the highest percentage weight of marketable tubers per plant was obtained due to application of 90 kg N ha^{-1} only. Although an increasing trend in tuber yield due to incremental doses of N was observed, N @ 60 kg ha^{-1} was sufficient to produce higher tuber yield. Nitrogen @ 60 kg ha^{-1} was as good as 90 kg and 120 kg ha^{-1} in producing higher dry matter and utilization index (UI).

Prasad and Rao (1986) reported that N at 75 kg ha^{-1} recorded the highest yield in sweet potato under Bhubaneswar conditions. Singh *et al.* (1986) observed, from field experiments in Bihar, that increasing rates of N from 0 to 80 kg ha^{-1} increased the tuber yield of sweet potato. Oomen (1989) obtained maximum number of tubers per plant of sweet potato with 100 kg N ha^{-1} while tuber weight per plant and tuber yield were maximum with 75 kg N ha^{-1}. The leaf and stem dry matter were higher with 100 kg N ha^{-1} but tuber dry matter was the highest with 75 kg N ha^{-1}.

2.2.1.3 Effect of N on Quality Attributes

According to Geetha (1983), N had no effect on starch content of tubers but the protein content increased with increasing levels of N upto 90 kg ha^{-1}.

In sweet potato, Oomen (1989) found that the starch and protein contents of the tuber were significantly influenced by N application upto to 100 kg ha^{-1}.

2.2.1.4 Effect of N on Nutrient Uptake

In coleus, Geetha (1983) noticed the highest uptake of N and K at the highest level of N applied (120 kg ha^{-1}).

Oomen (1989) obtained the highest uptake of N and K by sweet potato with 100 kg N ha^{-1} while the effects of 75 and 100 kg N ha^{-1} were comparable.

2.2.1.5 Effect of N on Soil Nutrient Status

Oomen (1989) found that application of 100 kg N ha^{-1} for sweet potato resulted in maximum available N content of the soil while N level had no significant influence on the available P and K contents of the soil after the experiment.

2.2.2 Effect of Phosphorus

Phosphorus plays an important role in energy transformations and metabolic processes in plants. In general, P is required in smaller quantities for tuber crops compared to other nutrients (Kabeerathumma et *al*. 1987; Nair *et al*. 1988).

2.2.2.1 Effect of P on Growth Characters

According to Archana and Swadija (2000), the growth characters of coleus like plant height, number of branches, plant spread and LAI were not influenced by P application.

Oomen (1989) also observed in sweet potato that different levels of P did not exert any significant effect on vine length. The medium level of P application (50 kg P_2O_5 ha^{-1}) increased the leaf, stem and tuber dry matter of sweet potato.

2.2.2.2 Effect of P on Yield and Yield Components

Thyagarajan (1969) reported that levels of P (0, 30 and 60 kg P_2O_5 ha^{-1}) had no significant effect on the yield of coleus. Geetha (1983) found that 30 kg P_2O_5 ha^{-1} is sufficient for economic production of coleus. Archana and Swadija (2000) also observed no significant variation in yield components like number of tubers per plant, number of marketable tubers per plant and mean tuber weight and in tuber yield of coleus by increasing the level of P from 30 to 60 kg P_2O_5 ha^{-1}. Utilisation index was also not influenced by P levels.

Navarro and Padda (1983) and Nicholaides *et al.* (1985) found that applied P had no effect on the yield of sweet potato. However, Oomen (1989) reported that higher levels of P influenced tuber number, mean tuber weight, tuber yield and tuber dry matter of sweet potato. According to Ravindran and Nair (1994), a dose of 25 to 50 kg P_2O_5 is considered optimum for sweet potato.

2.2.2.3 Effect of P on Quality Attributes

In coleus, Archana and Swadija (2000) observed that levels of P had no significant influence on the starch and protein contents of the tuber. Comparable results have been reported by Oomen (1989) in sweet potato.

2.2.2.4 Effect of P on Nutrient Uptake

According to Archana and Swadija (2000), uptake of P by coleus increased significantly with increase in the level of P from 30 to 60 kg P_2O_5 but uptake of N and K were not influenced by P levels.

Significant influence of P application on the uptake of N, P and K by sweet potato was reported by Oomen (1989). Higher levels of P showed increased uptake of these nutrients.

2.2.2.5 Effect of P on Soil Nutrient Status

Archana (2001) observed that application of different levels of P for coleus did not produce any significant variation in available N, P and K contents of the soil after the experiment.

Available N and K contents in the soil were not significantly influenced by the different levels of P application for sweet potato (Oomen, 1989). But significant increase in available P in the soil was noticed with incremental doses of phosphorus.

2.2.3 Effect of Potassium

Tuber crops require adequate supply of K as it is involved in the synthesis and translocation of carbohydrates. Potassium also acts as a catalyst for a number of enzymes like starch synthetase, aldehyde dehydrogenase and glucosidase. It also increases the resistance of plants to moisture stress and pests and diseases. Potassium deficiency not only reduces tuber yield but also unfavourably affects the quality characters.

2.2.3.1 Effect of K on Growth Characters

Geetha (1983) reported that K levels had no significant effect on plant height of coleus. But K levels showed significant difference in number of branches at 60 and 90 DAP and significant influence on number of functional leaves and LAI at 60 DAP.

In an experiment in sweet potato with 50, 75 and 100 kg K_2O ha^{-1},Oomen (1989) found that the length of vine and number of branches increased with incremental doses of K, higher values being recorded at the highest level of K tried.

Devi (1990) also found that application of 100 kg K_2O ha^{-1} resulted in the maximum vine length of sweet potato. But Nair and Nair (1992) and Nair (1994) reported that the different levels of K had no influence on the length of vine. According to Devi (1990) and Nair (1994), the number of branches was not influenced by different levels of K. No significant variation in LAI during different growth stages of sweet potato was observed by Oomen (1989) and Devi (1990).

2.2.3.2 Effect of K on Yield and Yield Components

In coleus, Geetha (1983) observed that K at the rate of 60 kg K_2O ha^{-1} was sufficient to obtain higher number and weight of tubers per plant and number of marketable tubers per plant. But application of K at 120 kg K_2O ha^{-1} produced the highest tuber yield. Maximum dry matter yield of coleus was obtained at 120 kg K_2O ha^{-1}. Potash at the rate of 90 kg ha^{-1} was as good as 120 kg ha^{-1} in producing higher utilization index.

According to Oomen (1989), the yield components of sweet potato like number of tubers per plant, mean length and girth of tuber and mean tuber weight increased significantly with increased levels of potassium. Devi (1990) and Patil *et al.* (1992) reported that maximum number of tubers per plant of sweet potato was obtained with 100 kg K_2O ha^{-1} while Mukhopadhyay *et al.* (1992) and Nair and Nair (1992) reported maximum number of tubers at 75 kg K_2O ha^{-1}.

Potassium influenced tuber yield of sweet potato through an increased diversion of dry matter to tubers (Bourke, 1985). Nicholaides *et al.* (1985) obtained a linear increase in yield of sweet potato due to K application especially in soils of low potassium. Hegde *et al.* (1986) in an experiment with 30, 60 and 90 kg K_2O ha^{-1} obtained the highest yield of 11.6 t ha^{-1} of sweet potato with 90 kg K_2O ha^{-1}. Prasad and Rao (1986) reported yield increase of sweet potato with increase in K application upto 75 kg K_2O ha^{-1} and thereafter a decrease. But Elizabeth and Kunju (1989) observed an increasing trend in tuber yield in response to the application of incremental doses of potassium. Oomen (1989) and Devi (1990) obtained the highest tuber yield of sweet potato with the highest level of K tried (100 kg K_2O

ha^{-1}). However, Mukhopadhyay *et al.* (1992) and Nair and Nair (1992) reported that tuber yield increased with increase in K level upto 75 kg K_2O ha^{-1} and thereafter decreased.

According to Oomen (1989), the dry matter production of tuber, stem and leaves of sweet potato was significantly influenced by K and the maximum dry matter production was observed with 100 kg K_2O ha^{-1}. Corroboratory findings have been reported by Devi (1990) and Mukhopadhyay *et al.* (1993) in sweet potato.

2.2.3.3 Effect of Potassium on Quality Attributes

Geetha (1983) observed in coleus that 90 kg K_2O ha^{-1}gave higher starch content of tuber. But potash levels had no effect on protein content.

Das and Behera (1989) observed a progressive increase in starch content of tuber of sweet potato as the dose of potash was increased from 0 to 150 kg ha^{-1}. Oomen (1989) found that the starch content was influenced by K application with the highest content at 100 kg K_2O ha^{-1}. Patil *et al.* (1990), Devi (1990) and Mukhopadhyay *et al.* (1993) also obtained similar results.

According to Oomen (1989) and Patil *et al.* (1990), higher doses of K increased the protein content of sweet potato. But Devi (1990) and Nair and Nair (1992) reported that different levels of K had no significant effect on crude protein content of the tuber.

2.2.3.4 Effect of K on Nutrient Uptake

In coleus, Geetha (1983) noticed that different levels of K produced significant increase in the uptake of N and K with maximum at 120 kg K_2O ha^{-1} which was the highest level of K tried.

In sweet potato, Oomen (1989) observed that increasing levels of K increased N, P and K uptake with higher values being recorded at 100 kg K_2O ha^{-1}. Devi (1990) obtained significantly higher P and K uptake at100 kg K_2O ha^{-1}. Uptake of N was not influenced by K levels. Mukhopadhyay *et al.* (1993) and Nair (1994) found that N and K uptake showed a steady increase with increase in K application whereas P uptake was not influenced.

2.2.3.5 Effect of K on Soil Nutrient Status

In sweet potato, Oomen (1989) and Devi (1990) found that K at 100 kg K_2O ha^{-1} increased available N and K contents of the soil after the experiment but exerted no significant effect on available P content.

2.3 EFFECT OF ORGANIC MANURES

2.3.1 Effect of Farmyard Manure

Farmyard manure (FYM) is the most commonly used organic manure. It is considered as a good source of both macro and micro nutrients. It has both direct and residual effects in plant nutrition.

Among different organic sources, FYM was found to be the best source of organic manure for higher dry matter production of coleus irrespective of growth stages (Archana and Swadija, 2000). Farmyard manure had positive influence on yield components like number and weight of tubers and weight of marketable tubers per plant and tuber yield. The highest tuber yield was produced by FYM as the organic source. Net income and BCR were maximum when FYM was used. Different sources of organic manure had no significant influence on utilization index. Neither the starch nor the protein content of tuber was affected by the organic sources. Higher uptake of N, P and K was recorded by FYM as the organic source. Available N, P and K contents of soil after the experiment was not influenced by the organic sources.

Gaur *et al.* (1984) reported 30.6% increase in yield of sweet potato due to FYM application over control.

The profound influence of FYM on number of rhizomes per plant and yield of arrowroot was reported by Maheswarappa *et al.* (1997) and Veenavidyadharan and Swadija (2000).

2.3.2 Effect of Coir pith Compost

Coir pith, an organic waste obtained during the process of separation of fibre from coconut husk, is normally resistant to biodegradation due to high content of lignin. Its accumulation leads to environmental pollution. Coir pith can be used as a soil conditioner and as an organic manure after composting with *Pleurotus* sp.

From a study conducted in coleus, Archana and Swadija (2000) observed that FYM can be substituted with coir pith compost (CPC) and neem cake in equal proportions if there is scarcity of FYM and if CPC is easily available. The positive effect of CPC may be because of its higher water holding capacity and better nutrient uptake by the crop.

Suja (2001) reported that application of CPC to white yam increased vine length, number of functional leaves, LAI, biomass production and uptake of nutrients. Coir pith compost led to marked improvement in tuber quality by enhancing dry matter, starch and protein contents. There was no conspicuous variation in tuber yield and harvest index among the organic manures. Available N, P and K status of the soil after the experiment did not vary significantly due to application of different organic manures.

The tuber yield as well as quality attributes of cassava in lowland showed no conspicuous variation due to application of FYM or CPC indicating the possibility of substitution of FYM with CPC (Pamila *et al.* 2006 and 2011).

2.4 EFFECT OF BIOFERTILIZERS

Biofertilizer is a renewable source of energy and cost effective supplement to chemical fertilizers. They help to economize on the high investment recorded for fertilizer use as far as N and P are concerned (Panday and Kumar, 2002). Good responses have been reported in many crops in recent years by the use of biofertilizers like *Azospirillum*, *Azotobacter* and P solubilising bacteria. Improvement in plant growth and development by the production of plant growth hormones like IAA, GA and cytokinins by P solubilizers was observed by Sattar and Gaur (1987).

Recently, KAU has developed a microbial consortium, PGPR mix I. It is a compatible consortium of N, P and K biofertilizers (KAU, 2009). In coleus, Atul

(2012) observed that application of PGPR mix I exerted profound influence on yield components, tuber yield, dry matter production and utilization index. Application of PGPR mix I increased the net income. No significant variation in quality characters of tuber such as starch and protein contents was observed. Application of PGPR mix I improved the status of available P and K in soil after a crop of coleus.

2.5 COMBINED EFFECT OF ORGANIC MANURES AND BIOFERTILIZERS

According to Atul (2012), coleus has great potential for organic cultivation. Application of 100% RD of NPK (60:60:100 kg ha) through organic manures (6 t FYM + 3 t CPC + 3 t wood ash ha^{-1}) along with PGPR mix I and the RD of FYM @ 10 t ha^{-1} is necessary for getting higher yields of organic coleus during the normal planting season.

Dhanya (2011) reported that nutrient sources tested namely FYM, poultry manure and CPC were equally effective on the growth and yield of sweet potato. The full RD of nutrients through organic manures was required for expressing the yield potential of the crop and organic production system was found economically feasible.

Organic farming is a viable strategy in elephant foot yam for getting high yield of good quality corms besides maintaining soil fertility (Suja *et al.*, 2006 and 2008). On farm trials revealed the superiority of organic farming over farmer's practice and conventional practice (POP - FYM @ 25 t ha^{-1} + NPK @ 100:50:150 kg ha^{-1}) in elephant foot yam (Suja *et al.* 2010).

According to Suja *et al.* (2009), field experiments indicated the superiority of organic farming compared to integrated nutrient management (FYM + chemical fertilizers to supply RD of NPK) in producing higher yields of tannia.

Swadija *et al.* (2011) reported the economic feasibility of organic nutrition of arrow root intercropped in the homesteads. The study indicated the sufficiency of FYM @ 15 t ha^{-1} along with biofertilizers (*Azospirillum* and phosphobacteria) for realizing higher rhizome yield of 18.62 t ha^{-1}, net return of Rs.74450 and BCR of 1.99.

2.6 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT

Integrated nutrient management aims at efficient and judicious use of different sources of plant nutrients such as organic manures, fertilizers and biofertilizers in an integrated manner so as to get maximum economic yield without any deleterious effect on physico-chemical and biological properties of soil. The basic concept of integrated nutrient management is maintenance and possible improvement of soil fertility for sustained productivity on a long-term basis. Integrated nutrient management improves the soil physical conditions in terms of soil structure, aggregate stability, soil moisture retentivity and hydraulic conductivity (Panda, 2011).

In coleus, Thyagarajan (1969) reported that 60:60:120 kg NPK ha^{-1} along with 5 t ha^{-1} of FYM may be applied for higher tuber production. Hrishi and Mohankumar (1976) suggested a nutrient dose of 80:60:80 kg N, P_2O_5 and K_2O for coleus. Geetha and Nair (1993) suggested integrated application of FYM @ 10 t ha^{-1} along with 60:30:120 kg NPK ha^{-1} for economic production of coleus. Kabeerathumma *et al.* (1987) reported that a crop of coleus yielding 25.7 t of tuber removed 106.7 kg N, 13.2 kg P and 107.4 kg K ha^{-1}. CTCRI (2006) and KAU (2011) have recommended 60:60:100 kg NPK ha^{-1} along with 10 t ha^{-1} of FYM for coleus.

For sweet potato, the combination of FYM @ 10 t ha^{-1} and 75:50:75 kg NPK ha^{-1} recorded significantly superior tuber yield (Ravindran and Nair, 1994).

Increased yield of arrow root intercropped in the coconut garden due to the combined application of FYM and NPK was reported by Maheswarappa *et al*. (1997) and Veenavidhyadharan and Swadija (2000).

According to Mohankumar *et al*. (2000), the combined use of NPK and FYM in cassava could produce a yield increase of four times higher when FYM or any of the nutrients (N, P or K) applied individually.

Kolambe *et al.* (2013) reported that integrated nutrient management treatment i.e. FYM @ 10 t + 100% RD of NPK through fertilizers resulted in higher crop growth and tuber yield of elephant foot yam and generated higher net income followed by organic treatment i.e. vermicompost @ 5 t ha^{-1} + Azospirillum @ 5 kg ha^{-1} + phosphorus solubilizing bacteria @ 5 kg ha^{-1} + ash @ 5 t ha^{-1} during two years of experimentation. Protein content of corm was not affected significantly due to the different treatments. After harvest of the crop, organic carbon content was found to be significantly higher due to the application of organic manures whereas soil physical and chemical properties were not significantly affected.

A critical review of literature indicated that it is high time that the fertilizer recommendation of coleus has to be modified based on research results. There is scope for off season production of coleus adopting the photoinsensitive var. Suphala. Atul (2012) studied the performance of this variety during the normal planting season from July to October with organic nutrition. The performance of this variety has to be evaluated with organic and integrated nutrient management during off season in the southern zone of Kerala. Hence the present study is undertaken to evolve strategies for off season production of coleus in the southern zone of Kerala.

MATERIALS AND METHODS

2. MATERIALS AND METHODS

The present investigation was carried out at College of Agriculture, Vellayani to fix the ideal time of planting and nutrient management for off season production of coleus var. Suphala and to work out the economics of cultivation. The details of the materials used and the methods adopted are presented in this chapter.

3.1 MATERIALS

3.1.1 Experimental Site

The experiment was conducted at the Instructional Farm attached to College of Agriculture, Vellayani which is situated at 8.5° North latitude and 76.9° East longitude at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental site was sandy clay loam belonging to the order Oxisol of Vellayani series. The important physico-chemical properties of soil and methods adopted for analysis are presented in Table 1. The soil was acidic with a pH of 4.62. It was high in organic carbon and available P and low in available N and K contents.

3.1.3 Cropping History of the Field

The experimental area was lying fallow prior to this experiment.

3.1.4 Season

The field experiment was conducted during November 2013 to May 2014.

3.1.5 Weather Conditions

Vellayani experiences warm humid tropical climate. The weekly averages of weather parameters viz. maximum and minimum temperatures and relative humidity and total rainfall received during the cropping period have been collected from the meteorological observatory at College of Agriculture, Vellayani and presented in Appendix I and illustrated in Fig. 1.

Table 1. Physico-chemical properties of the soil of experimental site

Sl.no	Parameter	Content	Method
A.	Mechanical composition		
1.	Coarse sand (%)	45.90	International pipette method (Piper, 1966)
2.	Fine sand (%)	23.70	
3.	Silt (%)	8.60	
4.	Clay (%)	22.60	
Texture- Sandy clay loam			
B .	Chemical composition		
1.	pH	4.62	pH meter with glass electrode (Jackson, 1973)
2.	Organic carbon (%)	1.15	Wet oxidation method (Walkely and Black, 1934)
3.	Available N (kg ha^{-1})	213.26	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
4.	Available P (kg ha^{-1})	35.20	Bray colorimetric method (Jackson, 1973)
5.	Available K (kg ha^{-1})	102.00	Neutral normal ammonium acetate method (Jackson, 1973)

Table 2.Nutrient content of organic manures

Organic manure	Nutrient content (%)		
	N	P_2O_5	K_2O
Farmyard manure	0.52	0.48	0.34
Coir pith compost	1.16	0.08	0.80
Wood ash	0.88	1.28	2.28

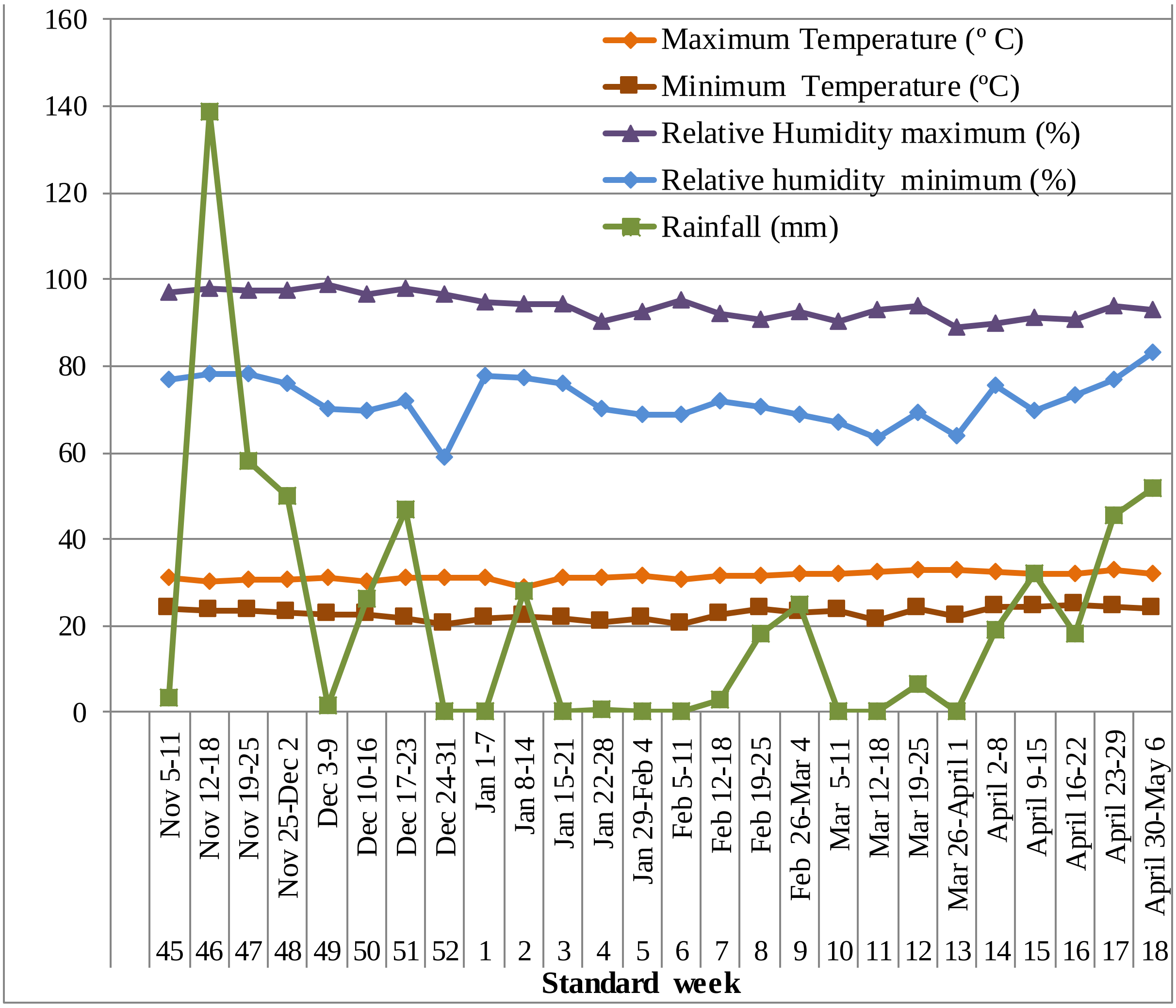

Figure 1. Weather data during the cropping period (November 2013-May 2014)

3.1.6 Planting Material

Coleus var. Suphala released from KAU, Vellanikkara, Thrissur was used as test crop for the investigation. It is suited for year round cultivation with a duration of 120-140 days (KAU, 2011).

3.1.7 Manures and Fertilizers

Organic manures used in the experiment were FYM, CPC and wood ash. They were analysed for their nutrient contents and the values are given in Table 2.

The fertilizers used were urea containing 46 % N, rajphos containing 20 % P_2O_5 and muriate of potash containing 60 % K_2O.

The biofertilizer used was PGPR mix I which was received from the department of Microbiology, College of Agriculture, Vellayani.

3.2 METHODS

3.2.1 Details of Treatments

The treatments consisted of four dates of planting and three nutrient management practices.

i) Date of planting (D)

d_1-November 15

d_2-December 1

d_3-December 15

d_4-January 1

ii) Nutrient management (N)

n_1- RD (60:60:100 kg NPK ha^{-1}) through inorganic fertilizers

n_2- RD through organic manures (6 t FYM + 3 t CPC + 3 t wood ash ha^{-1} + PGPR mix 1)

n_3- Modified nutrient dose (60:30:120 kg NPK ha^{-1}) through inorganic fertilizers

Treatment combinations

d_1n_1	d_2n_1	d_3n_1	d_4n_1
d_1n_2	d_2n_2	d_3n_2	d_4n_2
d_1n_3	d_2n_3	d_3n_3	d_4n_3

3.2.2 Experimental Design and Layout

The experiment was laid out in split plot design with four dates of planting in four main plots and three nutrient management practices in three sub plots in each main plot. The layout plan is given in Fig. 2.

The details of the layout are given below:

Design	- Split plot
Treatment combinations	- 12
Replication	- 4
Total number of plots	- 48
Plot size (sub plot)	- 3 m x 3 m
Spacing	- 30 cm x 15 cm

3.2.3 Details of Cultivation

3.2.3.1 Nursery

Stem cuttings of the var. Suphala were procured from AICRP on Medicinal and Aromatic Plants, College of Horticulture, KAU, Vellanikkara, Thrissur and multiplied in the primary and secondary nurseries to get sufficient planting material for the experiment. For the primary nursery, a small area adjacent to the experimental site was cleared and dug well, stubbles were removed, clods were broken and raised beds were made. FYM @ 1kg m^{-2} was mixed with the soil. Stem cuttings of length of 10-15cm of coleus var. Suphala were planted at a spacing of 30 cm x 15 cm during the second week of July 2013. Another area was prepared similarly for the secondary nursery and stem cuttings from the primary nursery were planted in the secondary nursery during the second week of September 2013. Healthy and vigorous cuttings of length of 10-15 cm from the apical portions were taken for planting in the main field.

3.2.3.2 Preparation of Main Field

The experimental area was cleared, tilled, dug twice, stubbles were removed and clods were broken. The field was laid out as per the design and raised beds of 15 cm height were taken in each plot.

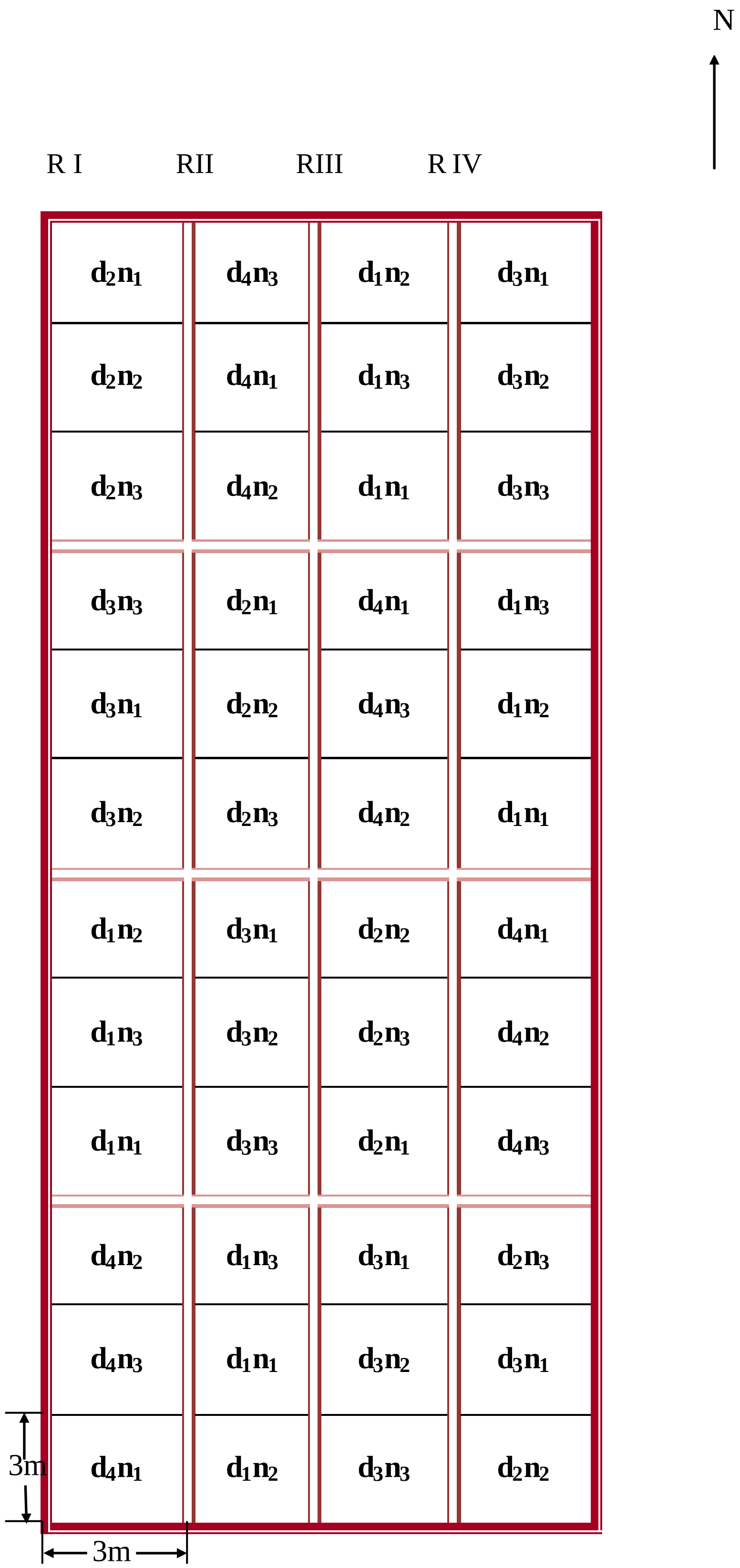

Figure 2. Lay out plan of the experiment

3.2.3.3 Application of Manures and Fertilizers

Neem cake @ 1 t ha^{-1} and FYM @ 10 t ha^{-1} were applied uniformly to all the plots at the time of land preparation. The required quantities of FYM and CPC as per the treatments were applied as basal dose to n_2 plots and appropriate quantity of wood ash as per the treatment was applied six weeks after planting and incorporated into soil. Half of the calculated quantities of urea and muriate of potash and full quantity of rock phosphate were applied to n_1 and n_3 plots as basal dose and half of urea and muriate of potash were top dressed six weeks after planting and mixed with soil.

The biofertilizer, PGPR mix I was applied in n_2 plots @ 30 kg ha^{-1}. Coleus cuttings were treated with 2 % slurry of PGPR mix I before planting and the remaining quantity of the biofertilizer was applied in the root zone mixed with FYM in the ratio 1:25 after planting the treated cuttings.

3.2.3.4 Planting

Coleus cuttings taken from the nursery were planted in the main field on November 15, December 1, December 15 and January 1 as per the treatments. Shade was provided immediately after planting and uniform irrigation was given.

3.2.3.5 After Cultivation

Gap filling was done a week after planting to have uniform stand of the crop for each date of planting. The first intercultural operation, weeding and earthing up were done three weeks after planting. Second weeding, application of wood ash and fertilizers as per the treatments and earthing up were done six weeks after planting.

3.2.3.6 Harvest

The crop was harvested by the third week of March 2014 for d_1 plots, first week of April for d_2 plots, third week of April for d_3 plots and first week of May for d_4 plots. Harvesting was done by digging out tubers carefully and the tubers were separated from the shoot portion. The border rows and observational plants were harvested separately from each plot.

Plate 1.General view of the experimental field

3.3 BIOMETRIC OBSERVATIONS

Single row of plants all round each plot was left out as border row. Five plants were selected randomly from the net plot and tagged as observational plants.

3.3.1 Growth Characters

Growth characters were recorded from the five observational plants at monthly intervals from planting upto harvest and average was worked out.

3.3.1.1 Plant Height

Height of the plant was measured from base of plant to the tip of the growing point and expressed in cm.

3.3.1.2 Number of Branches per Plant

Numbers of branches per plant were counted and recorded.

3.3.1.3 Number of Leaves per Plant

Number of functional leaves at the time of observation were counted and recorded.

3.3.1.4 Leaf Area Index (LAI)

The leaf area was worked out by adopting the non-destructive method developed by Ravi *et al.* (2011) and LAI was calculated as suggested by Watson (1947).

3.3.2 Yield and Yield Components

3.3.2.1 Number of Tubers per Plant

Total number of tubers from the observational plants was counted and their average was worked out and recorded.

3.3.2.2 Number of Marketable Tubers per Plant

Marketable tubers were separated based on visual observation and average number recorded.

3.3.2.3 Percentage of Marketable Tubers per Plant

Percentage of marketable tubers per plant was worked out from number of tubers and number of marketable tubers per plant.

3.3.2.4 Weight of Tubers per Plant

Weight of tubers from the observational plants were recorded and average was worked out.

3.3.2.5 Weight of Marketable Tubers per Plant

Weight of marketable tubers from the observational plants was recorded and average was worked out.

3.3.2.6 Percentage Weight of Marketable Tubers per Plant

Percentage weight of marketable tubers per plant was worked out from weight of tubers and weight of marketable tubers per plant.

3.3.2.7 Tuber Yield per Hectare

Yield of tubers obtained from each net plot was recorded and expressed in t ha^{-1}.

3.3.3 Physiological Parameters

3.3.3.1 Dry Matter Production

Dry matter production was recorded at harvest. The sample plants uprooted were separated into leaves, stem and tubers. Fresh weight of each part was recorded and sub samples were taken for estimating the dry weight. The sub samples were dried in a hot air oven at 70 ± 5 ^{O}C to constant dry weight. Then the dry weight of each part was worked out and total dry matter production was computed in t ha^{-1}.

3.3.3.2 Utilization index

It is the ratio of tuber yield to top yield on fresh weight basis. This was worked out from the tuber weight and top weight of observational plants.

3.3.4 Quality Attributes of Tuber

3.3.4.1. Starch Content

Starch content of tuber was estimated by using potassium ferricyanide method (Ward and Pigman, 1970). The values were expressed as percentage on dry weight basis.

3.3.4.2 Protein Content

Protein content (%) of tuber on dry weight basis was calculated by multiplying N content (%) in tuber with the factor 6.25 (Simpson *et al.*, 1965).

3.4 CHEMICAL ANALYSIS

3.4.1 Soil Analysis

Soil samples were taken from the experimental area before and after the experiment. The composite sample from the experimental area before the experiment was analysed for mechanical composition and physico -chemical properties (Table 1). After the experiment, soil samples collected from each plot were analysed for soil pH. The composit samples collected from each plot were air dried, powdered and passed through a 2 mm sieve and analysed for available N, P and K contents using the standard procedures as indicated in Table 1. The soil samples passed through 0.2 mm sieve were used for organic carbon estimation.

3.4.2 Plant Analysis

The observational plants uprooted were used for analysis of N, P and K contents at harvest. The tuber and shoot portion were analysed separately. The samples were dried in a hot air oven at 70 ± 5 ^{0}C till constant weights were obtained. The plant samples were then ground to pass through a 0.5 mm mesh sieve and digested for the analysis of nutrients.

3.4.2.1 N Uptake

The N content in plant sample was estimated by the modified micro kjeldhal method (Jackson, 1973) and uptake of N was calculated by multiplying the N content of tuber and shoot portion with the respective dry weights and summing up the values. The uptake values were expressed in kg ha^{-1}.

3.4.2.2 P Uptake

The P content in plant sample was colorimetrically determined by wet digestion of sample and colour development by ascorbic acid method and read in a Spectrophotometer (Bray and Kurtz, 1964). The uptake was calculated by multiplying P content of tuber and shoot portion with the respective dry weights and summing up the values. The uptake values were expressed in kg ha^{-1}.

3.4.2.3 K Uptake

The K content in plant sample was determined by flame photometer method (Piper, 1966). The uptake of K was found out by multiplying K content of tuber and shoot portion with the respective dry weights and summing up the values. The uptake values were expressed in kg ha^{-1}.

3.5 INCIDENCE OF PEST AND DISEASE

Incidence of pest and disease was monitored throughout the cropping period. Soil samples were analysed for nematode population during the cropping period.

3.6 ECONOMICS OF CULTIVATION

The economics of cultivation of the crop in terms of net income and BCR was worked out as follows.

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

BCR = Gross income (Rs ha^{-1}) ÷ Cost of cultivation (Rs ha^{-1})

3.7 STATISTICAL ANALYSIS

The experimental data was analysed statistically by applying the technique of analysis of variance (ANOVA) for split plot experiment and the significance was tested by F test (Cochran and Cox, 1965). Wherever F test was significant in ANOVA, the critical difference (CD) is provided. Important correlations were also worked out.

RESULTS

3. RESULTS

The field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from November 2013 to May 2014 to fix the ideal time of planting and nutrient management for off season production of coleus var. Suphala and to work out the economics of cultivation. The experiment was laid out in split plot design assigning four dates of planting in four main plots and three nutrient management practices in three subplots in each main plot with four replications. The experimental data was statistically analyzed and the results are presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Height of the Plant

The data on the effect of date of planting and nutrient management and their interaction on height of coleus plant at monthly intervals are presented in Table 3.

In general, plant height increased from 1 MAP to 4 MAP.

The plant height was significantly influenced by date of planting at all growth stages. At 1 MAP, the effects of planting on November 15 (d_1) and December 1 (d_2) on plant height were on par but significantly higher than late planting. There was no significant difference in plant height due to planting on December 15 (d_3) or January 1 (d_4). Planting on November 15 produced the tallest plant at 2 MAP and 3 MAP while the effects of other dates of planting later than November 15 were on par. At 4 MAP, planting on November 15 produced the tallest plants followed by planting on December 1. The effects of planting on December 15 and January 1 were on par and significantly inferior to the effects of earlier planting.

The plant height was also significantly influenced by nutrient management at all stages of growth. At all stages, modified nutrient dose (n_3) produced the tallest plants and the effects of RD through fertilizers (n_1) and RD through organic manures (n_2) were on par except at 3 MAP when n_1 was superior to n_2 treatment.

Table 3. Effect of date of planting and nutrient management on plant height

Treatments	Plant height (cm)			
	1 MAP	2 MAP	3 MAP	4 MAP
Date of planting (D)				
d_1-Nov 15	11.78	21.88	25.74	32.77
d_2-Dec 1	12.40	15.58	21.84	27.81
d_3-Dec 15	9.95	15.03	21.59	25.03
d_4-Jan 1	9.84	15.64	20.62	24.51
SEm(±)	0.40	0.54	0.69	0.99
CD(0.05)	1.280	1.717	2.198	3.180
Nutrient management (N)				
n_1-RD-fertilizers	10.62	16.46	21.89	25.21
n_2-RD-organic manures	10.70	15.64	20.64	26.02
n_3-Modified dose - fertilizers	11.65	19.00	24.79	31.35
SEm(±)	0.40	0.41	0.42	0.41
CD(0.05)	0.630	1.188	1.22	1.207
Interaction				
d_1n_1	11.30	21.84	25.00	32.00
d_1n_2	11.30	19.04	23.38	28.75
d_1n_3	12.76	24.74	28.84	37.56
d_2n_1	12.51	15.59	22.01	25.17
d_2n_2	12.13	14.50	20.75	28.42
d_2n_3	12.55	16.67	22.75	29.84
d_3n_1	9.59	14.84	20.42	21.09
d_3n_2	9.38	13.67	19.01	24.00
d_3n_3	10.88	16.59	25.34	30.00
d_4n_1	9.10	13.59	20.17	22.59
d_4n_2	10.01	15.34	19.42	22.92
d_4n_3	10.42	18.01	22.26	28.02
SEm(±)	0.44	0.81	0.84	0.83
CD(0.05)	NS	NS	NS	2.414

NS- Non significant

The interaction effects on plant height was significant only at 4 MAP (Table 3). At 4 MAP, the tallest plants were produced by the treatment combination d_1n_3 (37.56 cm) and significantly lower values were recorded by d_3n_1, d_4n_1 and d_4n_2 which were on par.

4.1.2 Number of Branches per Plant

The effect of treatments on number of branches per plant at monthly intervals is presented in Table 4.

The number of branches per plant increased from 1 MAP upto 3 MAP and declined at 4 MAP.

Date of planting significantly influenced number of branches per plant at all growth stages except 4 MAP. Planting on November 15 (d_1) and December 1 (d_2) produced significantly more number of branches than planting on December 15 (d_3) and January 1(d_4) but there was no significant difference between d_1 and d_2 as well as between d_3 and d_4 treatments.

Nutrient management significantly influenced number of branches per plant at all growth stages. The highest number of branches per plant was produced by the modified nutrient dose (n_3) at all growth stages. The effects of n_1 and n_2 were on par at all stages except 1 MAP.

None of the interaction effects on number of branches per plant were significant.

4.1.3 Number of Leaves per Plant

The data on number of leaves per plant as influenced by the treatments are given in Table 5.

Similar to number of branches per plant, leaf number per plant increased from 1 MAP upto 3 MAP and declined at 4 MAP.

Number of leaves per plant was significantly influenced by date of planting at all growth stages. Planting on November 15 (d_1) recorded higher number of leaves per plant followed by planting on December 1 (d_2) at all growth stages except 1 MAP.

Table 4. Effect of date of planting and nutrient management on number of branches per plant

Treatments	Number of branches per plant			
	1 MAP	2 MAP	3 MAP	4 MAP
Date of planting(D)				
d_1-Nov 15	8.01	9.95	10.86	9.23
d_2-Dec 1	8.14	9.45	10.65	9.11
d_3-Dec 15	6.39	8.25	9.73	9.03
d_4-Jan 1	5.89	8.06	9.45	8.48
SEm(±)	0.19	0.33	0.23	0.49
CD(0.05)	0.620	1.054	0.741	NS
Nutrient management (N)				
n_1-RD-fertilizers	7.12	8.79	9.84	8.82
n_2-RD-organic manures	6.79	8.46	9.65	8.44
n_3-Modified dose - fertilizers	7.41	9.52	11.02	9.63
SEm(±)	0.13	0.12	0.13	0.22
CD(0.05)	0.393	0.352	0.380	0.637
Interaction				
d_1n_1	7.90	9.51	10.26	9.17
d_1n_2	7.98	9.67	10.59	8.67
d_1n_3	8.14	10.67	11.75	9.84
d_2n_1	8.50	9.67	10.59	8.75
d_2n_2	7.26	8.75	9.69	8.92
d_2n_3	8.67	9.92	11.67	9.67
d_3n_1	6.42	8.17	9.59	8.76
d_3n_2	6.17	7.50	9.42	8.67
d_3n_3	6.59	9.08	10.17	9.67
d_4n_1	5.67	7.84	8.92	8.59
d_4n_2	5.75	7.92	8.92	7.50
d_4n_3	6.25	8.42	10.51	9.34
SEm(±)	0.27	0.24	0.26	0.44
CD(0.05)	NS	NS	NS	NS

NS- Non significant

Table 5.Effect of date of planting and nutrient management on number of leaves per plant

Treatments	Number of leaves per plant			
	1 MAP	2 MAP	3 MAP	4 MAP
Date of planting (D)				
d_1-Nov 15	47.50	92.01	98.53	75.45
d_2-Dec 1	51.56	64.67	77.48	62.95
d_3-Dec 15	31.60	53.78	67.72	45.89
d_4-Jan 1	31.61	50.56	61.23	43.11
SEm(±)	1.24	2.93	2.77	3.09
CD(0.05)	3.952	9.364	8.853	9.886
Nutrient management (N)				
n_1-RD-fertilizers	40.06	62.21	74.87	55.98
n_2-RD-organic manures	38.08	59.84	69.08	49.98
n_3-Modified dose - fertilizers	43.57	73.72	84.77	64.59
SEm(±)	1.11	1.09	0.98	0.64
CD(0.05)	3.244	3.205	2.880	1.865
Interaction				
d_1n_1	47.01	88.67	95.67	74.34
d_1n_2	46.59	86.00	91.50	68.75
d_1n_3	48.92	101.35	108.42	83.25
d_2n_1	51.50	60.84	76.25	61.51
d_2n_2	49.00	59.17	71.51	58.00
d_2n_3	54.17	74.00	84.67	69.34
d_3n_1	30.74	49.84	67.50	45.17
d_3n_2	26.74	48.00	58.16	37.50
d_3n_3	37.34	63.50	77.51	55.01
d_4n_1	31.00	49.50	60.01	42.92
d_4n_2	30.00	46.17	55.17	35.67
d_4n_3	33.84	56.02	68.51	50.75
SEm(±)	2.22	2.19	1.97	1.28
CD(0.05)	NS	NS	NS	NS

NS- Non significant

But there was no significant difference in leaf number due to planting on December 15 (d_3) or January 1 (d_4).

Regarding nutrient management, modified nutrient dose (n_3) produced significantly higher number of leaves per plant at all growth stages. At 1 MAP and 2 MAP, n_1 and n_2 were on par but at 3 MAP and 4 MAP, n_1 was significantly superior to n_2 in its effect on leaf number.

The interaction effects were not significant.

4.1.4 Leaf Area Index

The effect of treatments on LAI at monthly intervals is given in Table 6.

Date of planting significantly influenced LAI at all growth stages. Leaf area index showed a decreasing trend with delay in planting. Planting on November 15 (d_1) recorded the highest LAI and planting on January 1 (d_4) recorded the lowest index.

Nutrient management also significantly influenced LAI at all growth stages. Modified nutrient dose (n_3) recorded the highest LAI followed by n_1 which was significantly superior to n_2 at all stages.

The interaction effects on LAI were also significant at all growth stages except 2 MAP (Table 6). The treatment combination d_1n_3 recorded the highest LAI at all growth stages which was significantly superior to all other treatment combinations.

4.2 YIELD AND YIELD COMPONENTS

The data on the effect of date of planting and nutrient management on yield and yield components at harvest are presented in Table 7 to 9.

4.2.1 Number of Tubers per Plant

It is observed from Table 7 that number of tubers per plant was significantly influenced by date of planting. Planting on November 15 (d_1) produced the highest number of tubers per plant (12.1) followed by planting on December 1 (d_2) which was significantly superior to later dates of planting. There was no significant

Table 6.Effect of date of planting and nutrient management on leaf area index

Treatments	Leaf area index			
	1 MAP	2 MAP	3 MAP	4 MAP
Date of planting (D)				
d_1-Nov 15	1.32	2.83	2.01	1.57
d_2-Dec 1	1.17	2.10	1.86	1.10
d_3-Dec 15	1.03	1.46	1.34	0.96
d_4-Jan 1	0.93	1.30	1.08	0.86
SEm(±)	0.001	0.06	0.04	0.03
CD(0.05)	0.026	0.187	0.111	0.099
Nutrient management (N)				
n_1-RD-fertilizers	1.09	1.81	1.50	1.05
n_2-RD-organic manures	0.95	1.64	1.37	0.96
n_3-Modified dose- fertilizers	1.29	2.31	1.85	1.36
SEm(±)	0.01	0.03	0.02	0.02
CD(0.05)	0.027	0.080	0.07	0.053
Interaction				
d_1n_1	1.31	2.75	1.89	1.51
d_1n_2	1.03	2.55	1.76	1.46
d_1n_3	1.64	3.18	2.37	1.73
d_2n_1	1.18	2.01	1.79	0.99
d_2n_2	0.99	1.76	1.61	0.89
d_2n_3	1.33	2.54	2.17	1.43
d_3n_1	0.99	1.36	1.31	0.89
d_3n_2	0.93	1.17	1.19	0.76
d_3n_3	1.18	1.85	1.51	1.24
d_4n_1	0.90	1.12	0.99	0.80
d_4n_2	0.85	1.08	0.92	0.73
d_4n_3	1.05	1.69	1.34	1.04
SEm(±)	0.02	0.05	0.04	0.05
CD(0.05)	0.026	NS	0.130	0.157

NS- Non significant

Table 7.Effect of date of planting and nutrient management on number of tubers per plant

Treatments	Number of tubers per plant	Number of marketable tubers per plant	Percentage of marketable tubers per plant
Date of planting (D)			
d_1-Nov 15	12.10	7.04	57.89
d_2-Dec 1	9.04	5.25	57.66
d_3-Dec 15	8.46	4.83	56.83
d_4-Jan 1	8.17	4.33	52.83
SEm(±)	0.18	0.18	0.54
CD(0.05)	0.580	0.380	1.726
Nutrient management (N)			
n_1-RD-fertilizers	9.31	5.06	54.26
n_2-RD-organic manures	7.47	4.09	54.77
n_3-Modified dose- fertilizers	11.53	6.94	59.88
SEm(±)	0.19	0.11	0.63
CD(0.05)	0.543	0.310	1.850
Interaction			
d_1n_1	12.13	6.75	55.91
d_1n_2	9.50	5.25	55.40
d_1n_3	14.63	9.13	62.36
d_2n_1	8.50	4.75	55.66
d_2n_2	7.38	4.13	56.09
d_2n_3	11.25	6.88	61.23
d_3n_1	8.38	4.63	55.25
d_3n_2	6.50	3.63	55.79
d_3n_3	10.50	6.25	59.43
d_4n_1	8.25	4.13	50.23
d_4n_2	6.50	3.38	51.79
d_4n_3	9.72	5.50	56.49
SEm(±)	0.37	0.12	1.27
CD(0.05)	NS	0.620	NS

NS- Non significant

difference in tuber number per plant between planting on December 15 (d_3) and planting on January 1 (d_4).

Among nutrient management practices, modified nutrient dose (n_3) recorded significantly higher number of tubers per plant followed by RD through fertilizers (n_1) and RD through organic manures (n_2) in that order.

The interaction effects were not significant.

4.2.2 Number of Marketable Tubers per Plant

The treatments significantly influenced number of marketable tubers per plant (Table 7). Number of marketable tubers per plant showed a decreasing trend with delay in planting. The highest number (7.04) was recorded by November 15 planting (d_1) and the lowest number (4.33) by January 1 planting (d_4).

Regarding nutrient management, modified nutrient dose (n_3) recorded significantly higher number of marketable tubers per plant (6.94) followed by RD through fertilizers (n_1) which was significantly superior to RD through organic manures (n_2).

With respect to D x N interaction (Table 7), the treatment combination d_1n_3 recorded the highest number of marketable tubers per plant. The lowest number of marketable tubers per plant was recorded by d_4n_2.

4.2.3 Percentage of marketable Tubers per Plant

The data in Table 7 showed significant effects of date of planting and nutrient management on percentage of marketable tubers per plant.

No significant effect on percentage of marketable tubers per plant was observed when planted on November 15 (d_1), December 1 (d_2) and December 15 (d_3). But late planting on January 1 (d_4) recorded significantly lower percentage (52.83 %) of marketable tubers per plant.

Modified nutrient dose (n_3) recorded significantly higher percentage of marketable tubers per plant (59.88 %) while the effects of RD through fertilizers (n_1) and RD through organic manures (n_2) were on par.

Interaction effects were not significant.

4.2.4 Weight of Tubers per Plant

It is evident from Table 8 that the weight of tubers per plant was significantly influenced by date of planting and nutrient management.

As in the case of tuber number per plant, tuber weight per plant was significantly higher (89.5 g) when planted on November 15 (d_1) followed by planting on December 1 (d_2). No significant difference in tuber weight per plant was observed when planted on December 15 (d_3) or January 1 (d_4).

Modified nutrient dose (n_3) recorded significantly higher tuber weight per plant (91.9 g) followed by RD through fertilizers (n_1). The RD through organic manures (n_2) recorded the lowest value.

The interactions failed to express significant effect.

4.2.5 Weight of Marketable Tubers per Plant

Similar to tuber weight per plant, weight of marketable tubers per plant was significantly influenced by date of planting and nutrient management (Table 8).

Among dates of planting, November 15 planting (d_1) produced the highest weight of marketable tubers per plant (81.67g). Weight of marketable tubers per plant decreased with delay in planting, the lowest value being recorded by January 1 planting (d_4).

Modified nutrient dose (n_3) produced the highest weight of marketable tubers per plant (81.56 g) which was significantly superior to other two treatments. The RD through fertilizers (n_1) recorded significantly higher weight of marketable tubers per plant than RD through organic manures (n_2).

Interaction effects were not significant with respect to this parameter.

4.2.6 Percentage Weight of Marketable Tubers per Plant

The percentage weight of marketable tubers per plant followed the same trend as that of percentage of marketable tubers per plant (Table 8).

Although date of planting recorded significant effect on percentage weight of marketable tubers per plant, the effects of planting on November 15 (d_1), December 1

Table 8.Effect of date of planting and nutrient management on weight of tubers per plant

Treatments	Weight of tubers per plant (g)	Weight of marketable tubers per plant (g)	Percentage weight of marketable tubers per plant
Date of planting (D)			
d_1-Nov 15	89.50	81.67	91.28
d_2-Dec 1	83.13	74.17	89.01
d_3-Dec 15	76.75	66.25	86.06
d_4-Jan 1	76.75	57.92	75.26
SEm(±)	1.80	1.18	1.66
CD(0.05)	3.072	3.770	5.295
Nutrient management (N)			
n_1-RD-fertilizers	79.30	66.88	84.08
n_2-RD-organic manures	74.13	61.56	82.79
n_3-Modified dose-fertilizers	91.90	81.56	89.26
SEm(±)	1.56	1.32	0.86
CD(0.05)	4.554	3.857	2.504
Interaction			
d_1n_1	86.25	77.50	89.85
d_1n_2	83.00	73.75	89.06
d_1n_3	99.25	93.75	94.48
d_2n_1	79.38	70.00	88.06
d_2n_2	76.00	66.25	87.33
d_2n_3	94.00	86.25	91.78
d_3n_1	75.75	63.75	84.15
d_3n_2	68.75	57.50	83.74
d_3n_3	85.75	77.50	90.30
d_4n_1	75.75	56.25	74.24
d_4n_2	68.75	48.75	71.10
d_4n_3	85.75	68.75	80.48
SEm(±)	3.12	2.64	1.71
CD(0.05)	NS	NS	NS

NS- Non significant

(d_2) and December 15 (d_3) were on par (86.06 – 91.28 %). Late planting on January 1 (d_4) recorded significantly lower value (75.26 %).

Significantly higher percentage weight of marketable tubers per plant (89.26 %) was noted for the modified nutrient dose (n_3). The effects of RD through fertilizers (n_1) and RD through organic manures (n_2) were on par.

The interaction effects were not significant.

4.2.7 Tuber Yield

The tuber yield per ha as influenced by date of planting and nutrient management as well as their interaction are presented in Table 9.

It is noted that the tuber yield was significantly influenced by date of planting and nutrient management.

Planting on November 15 (d_1) produced the highest tuber yield of 14.89 t ha^{-1} followed by planting on December 1 (d_2- 12.8 t ha^{-1}). The tuber yield showed a declining trend with delay in planting. Late planting on January 1 (d_4) produced significantly lower yield of 10.71 t ha^{-1}.

Regarding nutrient management, modified nutrient dose through fertilizers (n_3) recorded significantly higher tuber yield of 14.36 t ha^{-1}. The RD through fertilizers (n_1) recorded significantly higher tuber yield (12.39 t ha^{-1}) than the same dose through organic manures (n_2).

The D x N interaction failed to express any significant effect on tuber yield (Table 9). However, the treatment combination d_1n_3 recorded the highest tuber yield of 16.9 t ha^{-1} followed by d_1n_1 and d_2n_3. On each date of planting, the treatment combination involving modified nutrient dose (d_1n_3, d_2n_3, d_3n_3 and d_4n_3) recorded higher tuber yield than the respective treatment combinations involving n_1 and n_2 .

4.3 PHYSIOLOGICAL PARAMETERS

The data pertaining to the effect of treatments on total dry matter production at harvest and utilization index are given in Table 10.

Table 9.Effect of date of planting and nutrient management on tuber yield

Treatments	Tuber yield (t ha^{-1})
Date of planting (D)	
d_1-Nov 15	14.89
d_2-Dec 1	12.80
d_3-Dec 15	11.82
d_4-Jan 1	10.71
SEm(±)	0.28
CD(0.05)	0.911
Nutrient management (N)	
n_1-RD-fertilizers	12.39
n_2-RD-organic manures	10.94
n_3-Modified dose-fertilizers	14.36
SEm(±)	0.130
CD(0.05)	0.381
Interaction	
d_1n_1	14.70
d_1n_2	13.10
d_1n_3	16.90
d_2n_1	12.62
d_2n_2	11.16
d_2n_3	14.63
d_3n_1	11.63
d_3n_2	10.05
d_3n_3	13.79
d_4n_1	10.57
d_4n_2	9.46
d_4n_3	12.09
SEm(±)	0.26
CD(0.05)	NS

NS- Non significant

4.3.1 Dry Matter Production

Total dry matter production was significantly influenced by date of planting (Table 10). The highest dry matter production (5.73 t ha^{-1}) was noticed when planted on November 15 (d_1). The dry matter production showed a declining trend with delay in planting as in the case of tuber yield, the lowest value (3.66 t ha^{-1}) being recorded when planted on January 1(d_4).

Nutrient management practices significantly influenced dry matter production similar to the effect on tuber yield. Modified nutrient dose (n_3) registered the highest dry matter production (5.59 t ha^{-1}). The RD through fertilizers (n_1) could register significantly higher dry matter production of 4.47 t ha^{-1} compared to the same dose through organic manures (n_2- 4.06 t ha^{-1}).

The effects of interactions on total dry matter production were not significant.

4.3.2 Utilization Index

It is observed from Table 10 that utilization index varied significantly due to date of planting. Utilization index was maximum (1.39) when planted on November 15 (d_1). No significant difference was observed in UI when planted on December 1 (d_2) or on December 15 (d_3). Late planting on January 1 (d_4) registered the lowest UI of 1.28 but was on par with December 15 planting.

Among nutrient management practices, modified nutrient dose (n_3) registered significantly higher utilization index of 1.42 followed by RD through fertilizers (n_1 -1.33). The RD through organic manures (n_2) registered the lowest UI of 1.24.

None of the interactions were significant with respect to this parameter.

4.4 QUALITY ATTRIBUTES OF TUBER

The average values of starch and protein contents of tuber on dry weight basis as affected by the treatments are furnished in Table 11.

4.4.1 Starch Content

The data in Table 11 revealed no significant difference in starch content of tuber due to date of planting.

Table 10.Effect of date of planting and nutrient management on total dry matter production and utilization index

Treatments	Total dry matter production (t ha^{-1})	Utilization index
Date of planting (D)		
d_1-Nov 15	5.73	1.39
d_2-Dec 1	5.18	1.34
d_3-Dec 15	4.26	1.31
d_4-Jan 1	3.66	1.28
SEm(±)	0.06	0.01
CD(0.05)	0.175	0.036
Nutrient management (N)		
n_1-RD-fertilizers	4.47	1.33
n_2-RD-organic manures	4.06	1.24
n_3-Modified dose -fertilizers	5.59	1.42
SEm(±)	0.06	0.01
CD(0.05)	0.173	0.042
Interaction		
d_1n_1	5.38	1.38
d_1n_2	4.96	1.29
d_1n_3	6.83	1.48
d_2n_1	4.99	1.35
d_2n_2	4.39	1.25
d_2n_3	6.15	1.43
d_3n_1	4.06	1.32
d_3n_2	3.73	1.21
d_3n_3	4.99	1.41
d_4n_1	3.44	1.30
d_4n_2	3.18	1.21
d_4n_3	4.38	1.37
SEm(±)	0.12	0.03
CD(0.05)	NS	NS

NS- Non significant

Table 11.Effect of date of planting and nutrient management on quality attributes

Treatments	Quality attributes	
	Starch %	Protein %
Date of planting (D)		
d_1-Nov 15	71.83	7.12
d_2-Dec 1	71.63	7.06
d_3-Dec 15	71.48	6.60
d_4-Jan 1	70.80	6.59
SEm(±)	0.36	0.16
CD(0.05)	NS	NS
Nutrient management (N)		
n_1-RD-fertilizers	71.36	6.83
n_2-RD-organic manures	70.54	6.69
n_3-Modified dose - fertilizers	72.41	7.04
SEm(±)	0.11	0.10
CD(0.05)	0.33	NS
Interaction		
d_1n_1	71.85	7.00
d_1n_2	70.85	6.66
d_1n_3	72.80	7.69
d_2n_1	71.45	7.00
d_2n_2	70.85	7.17
d_2n_3	72.60	7.00
d_3n_1	71.55	6.66
d_3n_2	70.65	6.66
d_3n_3	72.25	6.66
d_4n_1	70.60	6.66
d_4n_2	69.80	6.31
d_4n_3	72.00	6.83
SEm(±)	0.23	0.21
CD(0.05)	NS	NS

NS- Non significant

The starch content of tuber varied significantly with nutrient management. It was the highest (72.41%) with the modified nutrient dose (n_3) followed by RD through fertilizers (n_1). The RD through organic manures (n_2) resulted in comparatively lower starch content of 70.54%.

The interactions registered no significant effect on starch content.

4.4.1 Protein Content of the Tuber

It is observed from Table 11 that there was no significant variation in the protein content of tuber due to date of planting, nutrient management and their interaction.

4.5 UPTAKE OF NUTRIENTS

The results of the effect of date of planting, nutrient management and their interaction on the uptake of N, P and K are presented in Table 12.

Uptake of N, P and K significantly decreased with delay in planting. The highest uptake of N, P and K were registered when planted on November 15 (d_1) and the lowest values when planted late on January 1 (d_4).

With respect to nutrient management, significantly higher uptake of N, P and K were registered by the modified nutrient dose through fertilizers (n_3) than RD through fertilizers (n_1). The RD through fertilizers (n_1) recorded significantly higher uptake of nutrients than the same dose through organic manures (n_2).

The interaction D x N exerted significant effect on nutrient uptake. The treatment combinations d_1n_3, d_2n_3, d_3n_3 and d_4n_3 registered significantly higher uptake of nutrients and d_1n_2, d_2n_2, d_3n_2 and d_4n_2 registered lower uptake of nutrients. The highest uptake of nutrients was noted for the treatment combination d_1n_3 followed by d_2n_3.

4.6 SOIL ANALYSIS AFTER THE EXPERIMENT

The data on soil analysis after the experiment are summarized in Table 13.

4.6.1 Soil Reaction

Soil reaction in terms of pH was significantly influenced by the treatments (Table 13).

Table 12.Effect of date of planting and nutrient management on uptake of nutrients

Treatments	Nutrient uptake (kg ha^{-1})		
	N uptake	P uptake	K uptake
Date of planting (D)			
d_1-Nov 15	65.40	29.70	134.92
d_2-Dec 1	53.67	26.04	110.22
d_3-Dec 15	36.48	20.46	77.69
d_4-Jan 1	31.19	14.23	67.22
SEm(±)	0.95	0.48	2.43
CD(0.05)	3.049	1.524	7.768
Nutrient management (N)			
n_1-RD-fertilizers	44.22	23.00	92.01
n_2-RD-organic manures	38.75	18.53	79.85
n_3-Modified dose -fertilizers	57.09	26.28	120.68
SEm(±)	0.66	0.39	1.17
CD(0.05)	1.932	1.159	3.412
Interaction			
d_1n_1	58.35	31.39	124.31
d_1n_2	55.44	23.93	110.57
d_1n_3	82.40	33.79	169.87
d_2n_1	50.97	24.95	99.54
d_2n_2	43.77	21.33	94.09
d_2n_3	66.27	31.83	137.03
d_3n_1	37.05	21.32	77.56
d_3n_2	28.76	16.85	59.93
d_3n_3	43.64	23.29	95.59
d_4n_1	30.52	14.46	66.62
d_4n_2	27.02	12.03	54.81
d_4n_3	36.06	16.20	80.24
SEm(±)	1.32	0.79	2.34
CD(0.05)	3.863	2.318	6.820

NS- Non significant

Planting on November 15 (d_1) or December 1(d_2) or December 15 (d_3) did not show any significant difference in the soil pH (4.96 to 5.05) after the experiment. Late planting on January 1 (d_4) registered lower pH (4.84) than other dates of planting.

With respect to the nutrient management, significantly lower pH was observed in fertilizer applied plots (n_1 and n_3) compared to organically manured plots (n_2). The effects of n_1 and n_3 were on par.

The interaction effects on soil pH were significant (Table 13). Lower pH was observed in fertilizer applied plots (d_1n_1, d_1n_3, d_2n_1, d_2n_3, d_3n_1, d_3n_3, d_4n_1, and d_4n_3) than organically manured plots on all dates of planting (d_1n_2, d_2n_2, d_3n_2 and d_4n_2).

4.6.2 Organic Carbon

The data presented in Table 13 revealed no significant difference in the organic carbon content of the soil after the experiment due to date of planting.

Organic carbon content of the soil after the experiment was significantly influenced by nutrient management practices. The highest organic carbon content of 1.28 % was observed in organically manured plots (n_2) and the lowest (1.06 %) with RD through fertilizers (n_1).

With respect to interaction effects (Table 13), the treatment combinations involving only organic manures on each date of planting (d_1n_2, d_2n_2 and d_3n_2 and d_4n_2) registered significantly higher organic carbon content in the soil than other treatment combinations involving fertilizers. The effects of the treatment combinations d_1n_2, d_2n_2 , d_3n_2 and d_4n_2 were on par.

4.6.3 Available Nitrogen

There was significant variation in the content of available N in the soil after the experiment due to date of planting and nutrient management (Table 13).

Planting on November 15 (d_1) resulted in the highest content (265.5 kg ha^{-1}) of available N in the soil after the experiment followed by planting on December 1 (d_2). The effects of planting on December 15 (d_3) and January 1 (d_4) were on par.

Table 13.Effect of date of planting and nutrient management on soil reaction and nutrient status after the experiment

Treatments	pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Date of planting (D)					
d_1-Nov 15	4.96	1.15	265.50	61.69	178.52
d_2-Dec 1	4.99	1.12	224.77	59.72	184.69
d_3-Dec 15	5.05	1.15	216.39	52.02	171.45
d_4-Jan 1	4.84	1.20	200.72	46.55	172.69
SEm(±)	0.03	0.04	7.42	0.93	4.08
CD(0.05)	0.104	NS	23.735	2.960	NS
Nutrient management (N)					
n_1-RD-fertilizers	4.61	1.06	230.50	59.99	163.12
n_2-RD-organic manures	5.64	1.28	214.80	54.43	153.70
n_3-Modified dose-fertilizers	4.64	1.12	235.20	50.57	213.70
SEm(±)	0.03	0.01	2.71	0.85	2.19
CD(0.05)	0.087	0.042	7.920	2.470	6.390
Interaction					
d_1n_1	4.73	1.19	269.68	66.74	161.56
d_1n_2	5.48	1.29	257.15	59.18	166.24
d_1n_3	4.65	0.98	269.68	59.16	207.76
d_2n_1	4.60	0.94	225.80	65.34	169.12
d_2n_2	5.71	1.29	216.43	58.90	164.92
d_2n_3	4.68	1.13	232.08	54.93	220.05
d_3n_1	4.56	1.03	216.40	57.19	155.68
d_3n_2	5.97	1.28	203.85	53.23	146.16
d_3n_3	4.64	1.14	228.93	45.64	212.52
d_4n_1	4.52	1.09	210.13	50.68	166.10
d_4n_2	5.41	1.27	181.90	46.42	137.48
d_4n_3	4.60	1.22	210.13	42.54	214.48
SEm(±)	0.06	0.03	5.43	1.69	4.381
CD(0.05)	0.174	0.084	NS	NS	12.788

NS- Non significant

Regarding nutrient management, the effects of RD through fertilizers (n_1) and modified nutrient dose through fertilizers (n_3) were on par. Significantly lower content of available N in the soil after the experiment was observed in organically manured plots.

Interactions registered no significant effect on available N content of the soil after the experiment.

4.6.4 Available Phosphorus

Date of planting and nutrient management had significant influence on available P content in the soil after the experiment (Table 13).

Early planting on November 15 (d_1) or December 1 (d_2) showed significantly higher available P in the soil than late planting on December 15 (d_3) or January 1 (d_4).

The RD through fertilizers (n_1) recorded significantly higher available P in the soil after the experiment than the same dose through organic manures (n_2). Modified nutrient dose through fertilizers (n_3) registered the lowest content of available P in the soil after the experiment.

The interaction effects were not significant.

4.6.5 Available Potassium

No significant variation was observed in the content of available K in the soil after the experiment due to date of planting (Table 13).

With regard to nutrient management, modified nutrient dose through fertilizers (n_3) registered significantly higher content of available K in the soil after the experiment. Organically manured plots registered significantly lower content of available K in the soil after the experiment.

The treatment combinations involving modified nutrient dose through fertilizers on all dates of planting (d_1n_3, d_2n_3, d_3n_3 and d_4n_3) registered significantly higher available K content, but their effects were on par.

4.7 INCIDENCE OF PEST AND DISEASE

Attack of leaf roller was found in two or three plants in three plots during the end of January 2014 for which neem based pesticide was uniformly sprayed in all plots. During the third week of March, incidence of mealy bug was observed which was controlled by a uniform spray of *Verticillium*.

No incidence of disease was noticed.

Soil samples collected from the field during the cropping period were analysed for the presence of nematodes. There was no nematode in the soil samples analysed and no symptom of nematode attack in the crop.

4.8 ECONOMICS OF CULTIVATION

The effects of treatments on economics of cultivation worked out in terms of net income and BCR are shown in Table 14a and 14b.

4.8.1 Net income

The result in Table 14a indicated that net income varied significantly due to date of planting and nutrient management practices.

Net income showed a declining trend with delay in planting with the highest net income of Rs.167525 ha^{-1} being registered when planted on November 15 (d_1) and the lowest net income of Rs.62858 ha^{-1} being registered when planted on January 1 (d_4).

Modified nutrient dose through fertilizers (n_3) registered the highest net income of Rs.163900 ha^{-1}. The RD through fertilizers (n_1) recorded significantly higher net income of Rs.11356 ha^{-1} than the same dose through organic manures (n_2- Rs.49875 ha^{-1}).

With respect to interaction effects (Table 14 b), the treatment combination d_1n_3 recorded the highest net income, followed by d_1n_1, d_2n_3, d_3n_3, d_2n_1 and d_4n_3 in that order. The treatment combinations d_3n_2 and d_4n_2 (late planting with organic nutrition) registered drastic reduction in net income.

4.8.2 Benefit cost ratio

The data in Table 14a and 14b revealed the significant effect of treatments on BCR which followed the same trend as that on net income.

Table 14a.Effect of date of planting and nutrient management on economics of cultivation

Treatments	Net income (Rs ha^{-1})	BCR
Date of planting (D)		
d_1-Nov 15	167525	1.84
d_2-Dec 1	115275	1.58
d_3-Dec 15	90796	1.46
d_4-Jan 1	62858	1.32
SEm(±)	7120	0.04
CD(0.05)	22779	0.114
Nutrient management (N)		
n_1-RD-fertilizers	113566	1.58
n_2-RD-organic manures	49875	1.22
n_3-Modified dose -fertilizers	163900	1.84
SEm(±)	3261	0.02
CD(0.05)	9520	0.049

Table 14b.Interaction effect of date of planting and nutrient management on economics of cultivation

Treatments	Cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	BCR
d_1n_1	195950	367563	171613	1.88
d_1n_2	223500	326875	103375	1.46
d_1n_3	194975	422563	227588	2.17
d_2n_1	195950	315563	119613	1.61
d_2n_2	223500	278875	55375	1.25
d_2n_3	194975	365813	170838	1.88
d_3n_1	195950	290625	94675	1.48
d_3n_2	223500	251250	27750	1.13
d_3n_3	194975	344938	149963	1.77
d_4n_1	195950	264313	68363	1.35
d_4n_2	223500	236500	13000	1.06
d_4n_3	194975	302188	107213	1.55

Cost of cultivation per ha excluding the treatments = Rs. 189000

Cost of 1 stem cutting = Re. 0.5

Cost of 1 t neem cake = Rs. 25000

Cost of 1 t FYM = Rs. 400

Cost of 1 t CPC = Rs. 8000

Cost of 1 t wood ash = Rs. 2000

Cost of 1 kg PGPR mix 1 = Rs. 70

Cost of 1 kg Urea = Rs. 7.5

Cost of 1 kg Rajphos = Rs. 10

Cost of 1 kg MOP = Rs. 17.5

Price of 1 kg tuber = Rs. 25

Benefit cost ratio showed a decreasing trend with delay in planting with the highest BCR (1.84) for November 15 planting (d_1) and the lowest (1.32) for January 1 planting (d_4).

Modified dose through fertilizers (n_3) recorded the highest BCR of 1.84. The RD through fertilizers (n_1) registered significantly higher BCR (1.58) than the same dose through organic manures (n_2 -1.22).

Regarding interaction effects (Table 14b), all the treatment combinations recorded values above 1. The highest BCR was recorded by d_1n_3, d_2n_3, d_1n_1, d_3n_3, d_2n_1 and d_4n_3 in that order. The treatment combinations d_3n_2 and d_4n_2 (late planting with organic nutrition) registered drastic reduction in BCR.

4.9 CORRELATION STUDIES

Correlation study was conducted between tuber yield and yield components, tuber yield and uptake of nutrients, total dry matter production and uptake of nutrients and tuber yield and total dry matter production obtained due to treatments. Correlations were also worked out between the total rainfall received during the cropping period and the data on yield components, tuber yield, uptake of nutrients and total dry matter production. The correlation coefficients are given in Table 15.

The correlation studies (Table 15) indicated that tuber yield and yield components, tuber yield and uptake of nutrients, total dry matter production and uptake of nutrients and tuber yield and total dry matter production were significantly and positively correlated.

The results in Table 15 also showed that number of marketable tubers per plant, tuber yield per ha and uptake of N and K were significantly and positively correlated with the total rainfall received during the cropping period. Weight of marketable tubers per plant and P uptake were positively correlated with the rainfall data.

Table 15. Simple correlation coefficients

Sl.No.	Characters correlated	Correlation coefficient (r)
1.	Yield x Number of tubers per plant	0.968**
2.	Yield x Number of marketable tubers per plant	0.974**
3.	Yield x Weight of tubers per plant	0.950**
4.	Yield x Weight of marketable tubers per plant	0.975**
5.	Yield x N uptake	0.939**
6.	Yield x P uptake	0.927**
7.	Yield x K uptake	0.957**
8.	Total dry matter production x N uptake	0.973**
9.	Total dry matter production x P uptake	0.948**
10.	Total dry matter production x K uptake	0.979**
11.	Yield x Total dry matter production	0.968**
12.	Number of marketable tubers per plant x Total rainfall	0.975*
13.	Weight of marketable tubers per plant x Total rainfall	0.929
14.	Yield x Total rainfall received during cropping period	0.970*
15.	Total dry matter production x Total rainfall	0.934
16.	N uptake x Total rainfall	0.970*
17.	P uptake x Total rainfall	0.894
18.	K uptake x Total rainfall	0.975*

NS-Non Significant

**Significant at 1 %

*Significant at 5 %

DISCUSSION

5.DISCUSSION

The results of the field experiment conducted to fix the ideal time of planting and nutrient management for off season production of coleus var. Suphala and to work out the economics of cultivation are discussed in this chapter.

5.1 EFFECT OF DATE OF PLANTING

5.1.1 Growth Characters

The results revealed that the different dates of planting significantly influenced the growth characters like plant height, number of branches and leaves per plant and leaf area index at all stages of crop growth (Table 3 to 6). Planting on November 15 recorded the tallest plants at all growth stages except 1 MAP (Fig.3). Early planting on November 15 or December 1 produced significantly more number of branches than late planting on December 15 or January 1 at all growth stages except 4 MAP when the effect was not significant. The highest number of leaves per plant was recorded by November 15 planting followed by December 1 planting at all growth stages except 1 MAP. At 1 MAP, December 1 planting produced taller plants with higher number of leaves compared to November 15 planting. However, a decreasing trend in LAI at all growth stages was observed with delay in planting (Fig. 4). These results indicated that November 15 planting is ideal for better growth of coleus during the off season.

5.1.2 Yield and Yield Components

Date of planting exerted significant influence on the yield components of coleus var. Suphala (Table 7 and 8). November 15 planting registered the highest tuber number and maximum tuber weight per plant followed by December 1 planting (Fig. 5 and 6). December 15 or January 1 planting did not register any difference in these yield components. Number and weight of marketable tubers per plant showed a decreasing trend with delay in planting (Fig. 5 and 6). It could be seen from Table 7 and 8 that the percentage number and weight of marketable tubers per plant was

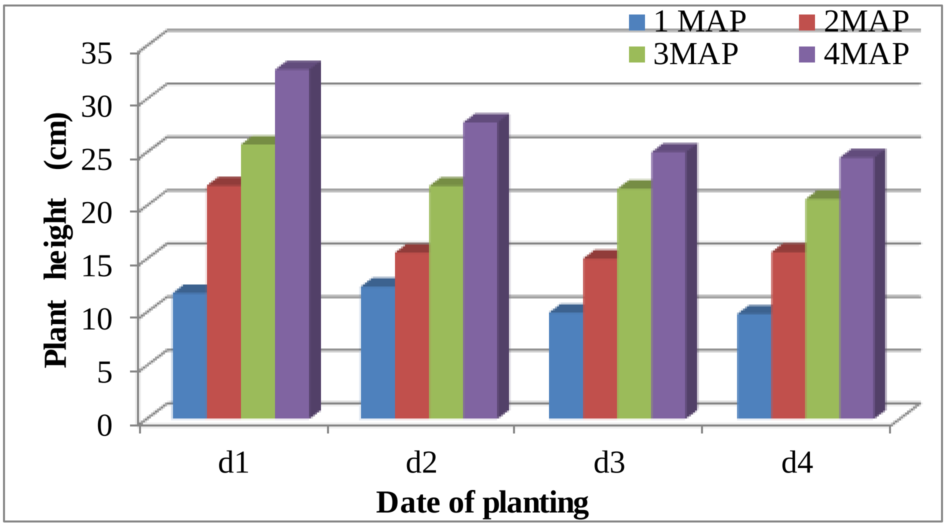

Figure 3. Effect of date of planting on plant height

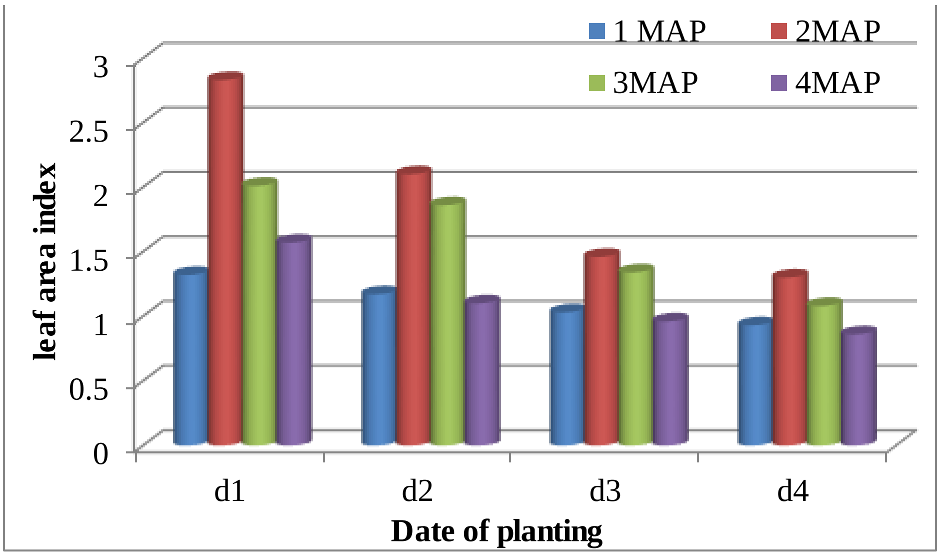

Figure 4. Effect of date of planting on leaf area index

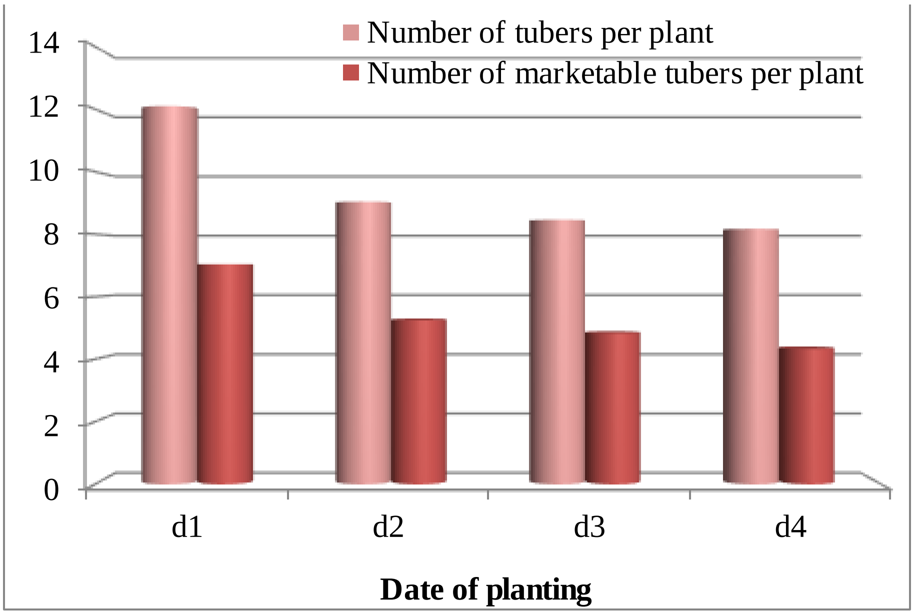

Figure 5. Effect of date of planting on number of tubers and number marketable tubers per plant

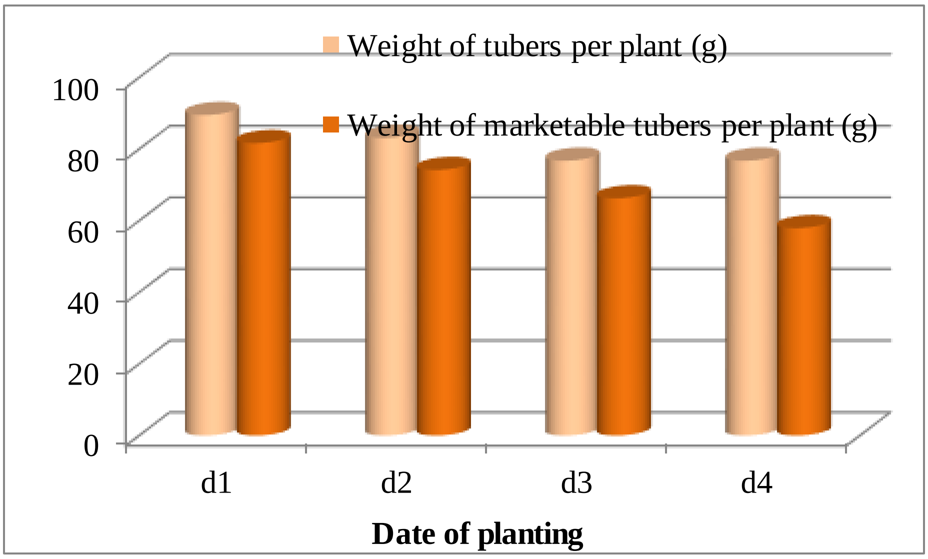

Figure 6. Effect of date of planting on weight of tubers and weight of marketable tubers per plant

almost similar for November 15, December 1 and December 15 planting. But a significant reduction was noticed due to late planting onJanuary 1. The superiority of November 15 planting for better growth of coleus during the off season might have contributed for its superiority in the yield components.

Tuber yield varied significantly with date of planting (Table 9). The tuber yield exhibited a declining trend with delay in planting (Fig.7) with the highest tuber yield of 14.89 t ha^{-1} for November 15 planting and the lowest yield of 10.71 t ha^{-1} for January 1 planting. The decreasing trend in the yield components like number and weight of marketable tubers per plant with delay in planting (Table 7 and 8) was reflected in the tuber yield as depicted in Fig.7. Correlation study also indicated significant and positive correlation between yield components and tuber yield as evident from Table 15. Significant influence of different time of planting on tuber yield has been reported by Singh and Mandal (1976) and KAU (2008) in coleus and Mukhopadhyay *et al.* (1991), Dayal and Sharma (1993) and Nedunchezhiyan and Byju (2005) in sweet potato.

An average yield of 20.99 t ha^{-1} was realized for the var. Suphala during the normal planting season of coleus from July to October (Atul *et al.* 2013). KAU (2007) reported an average yield of 15.93 t ha^{-1} for the var. Suphala. Comparable tuber yield was obtained for November 15 planting in the present study during off season. It was also possible to realize a tuber yield of 10.71 t ha^{-1} during the off season when the crop was planted late on January 1. It is noteworthy that 14.89 to 10.71 t ha^{-1} of tuber yield could be realized during the off season of coleus within an average duration of four months. Hence there is scope for profitable cultivation of coleus var. Suphala in the summer rice fallows.

A perusal of the weather data during the cropping period (Fig.1 and Appendix I) indicated that there is considerable variation in the total rainfall received by the crop planted on different dates. The crop planted on November 15, December 1, December 15 and January 1 received a total of 394.8, 253.8, 154 and 150 mm of

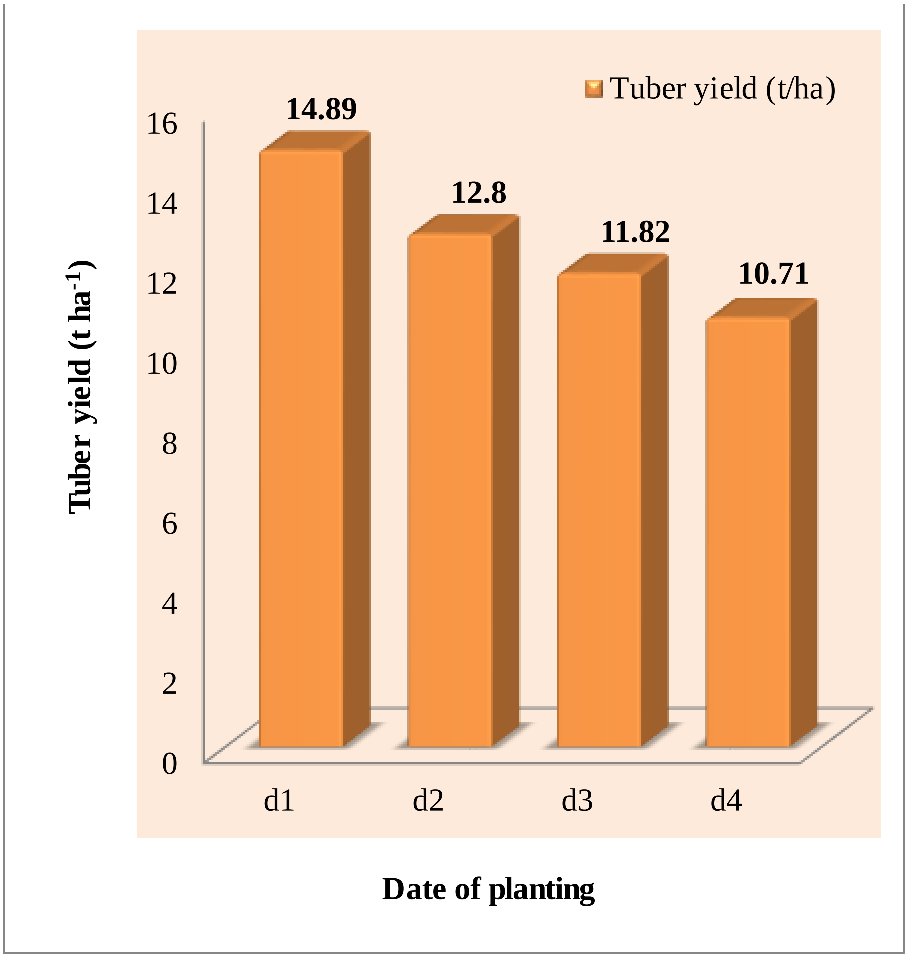

Figure 7. Effect of date of planting on tuber yield

rainfall respectively. When the rainfall data was correlated with yield data, it was observed that number of marketable tubers per plant and tuber yield were significantly and positively correlated with total rainfall during the cropping period (Table 15). Hence the variation in tuber yield might be due to the variation in the total rainfall received by the crop planted on different dates. November 15 planted crop received 2.6 times higher rainfall than January 1 planted crop which might have resulted in 39 % increased yield for November 15 planted crop.

5.1.3 Physiological parameters

Total dry matter production presented in Table 10 also showed a declining trend with delay in planting as in the case of tuber yield, the highest quantity of dry matter being produced by November 15 planting and the lowest by January 1 planting (Fig.8). The favourable effect of November 15 planting on growth characters, yield components and tuber yield was reflected in the dry matter production. The highest dry matter production in sweet potato due to November 30 planting was reported by Mukhopadhyay *et al.* (1991).

The data in Table 11 indicated the significant effect of date of planting on utilization index. The highest UI of 1.39 was obtained for November 15 planting and the lowest UI of 1.28 for January 1 planting (Fig. 9). This might be due to the decreasing trend exhibited in tuber yield and dry matter production with delay in planting beyond November 15.

5.1.4 Quality attributes

The results presented in Table 11 revealed no significant variation in quality attributes of tuber like starch and protein contents due to date of planting. Hence date of planting can be selected for getting higher returns from coleus without sacrificing quality of tubers during the off season.

5.1.5 Uptake of nutrients

Uptake of nutrients like N, P and K (Table 12) exhibited a decreasing trend with delay in planting (Fig.10), the effect of which was reflected in the tuber yield (Table 9) and total dry matter production (Table 10). The correlation study also

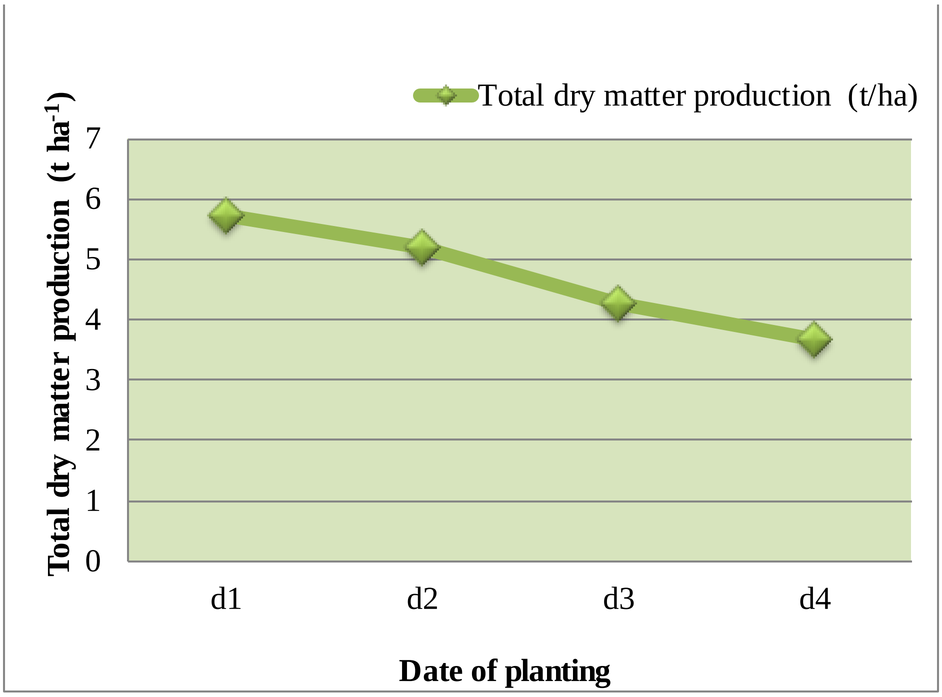

Figure 8. Effect of date of planting on total dry matter production

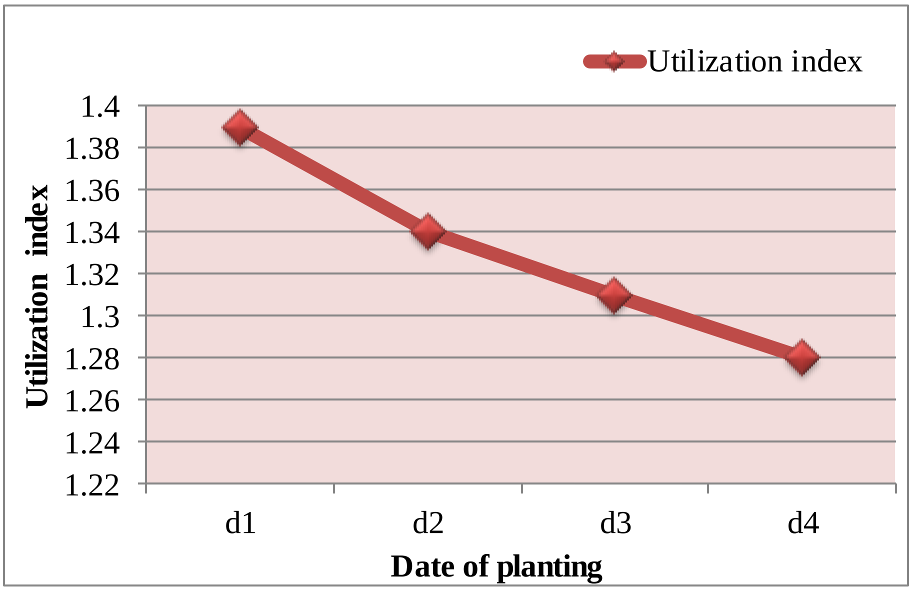

Figure 9. Effect of date of planting on utilization index

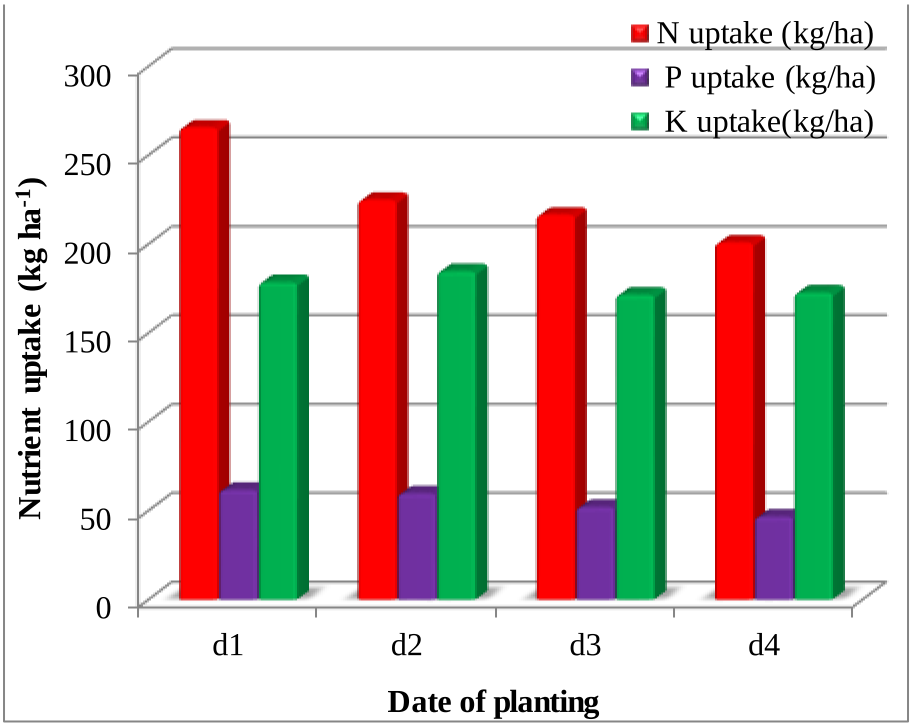

Figure 10. Effect of date of planting on nutrient uptake

revealed that uptake of nutrients was significantly and positively correlated with tuber yield and total dry matter production (Table 15).November 15 planting registered the highest uptake of nutrients (65.4 kg N, 29.7 kg P and 134.92 kg K ha^{-1}) and January 1 planting registered the lowest uptake (31.19 kg N, 14.23 kg P and 67.22 kg K ha^{-1}). Significant and positive correlation between total rainfall received during the cropping period and uptake of nutrients is another observation from this study. Total rainfall received by the crop planted on November 15 was 2.6 times higher than that for January 1 planting which might have resulted in better uptake of nutrients for November 15 planting.

5.1.6 Soil analysis after the experiment

Soil analysis after the experiment (Table 13) indicated higher pH than the initial value before the experiment (Table 1). No significant variation in the soil pH after the experiment was observed due to planting on November 15 or December 1 or December 15 but late planting on January 1 registered a lower pH (Table 13). No depletion of soil nutrient status was noticed after the experiment (Table 1 and 13). The content of organic carbon and available K in the soil after the experiment did not show any significant variation due to date of planting (Table 13). Early planting on November 15 or December 1 resulted in higher available N and P contents in the soil than late planting on December 15 and January 1.

5.1.7 Economics of cultivation

The economics of cultivation was worked out in terms of net income and BCR and is presented in Table 14a. Both net income and BCR showed a decreasing trend with delay in planting (Fig.11 and 12) as in the case of tuber yield. The highest net income of 167525 ha^{-1} and BCR of 1.84 were obtained when the crop was planted on November 15. The results indicated that November 15 is the ideal planting date for off season production of coleus. Although net income and BCR decreased when planted beyond November 15, late planting even on January 1 recorded a net income of Rs.62858 ha^{-1} and BCR of 1.32.

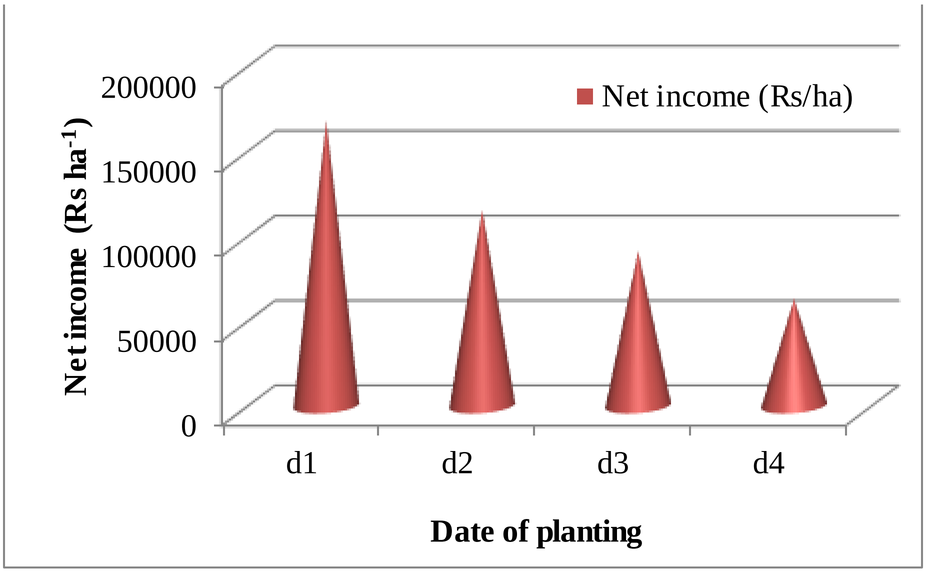

Figure 11. Effect of date of planting on net income

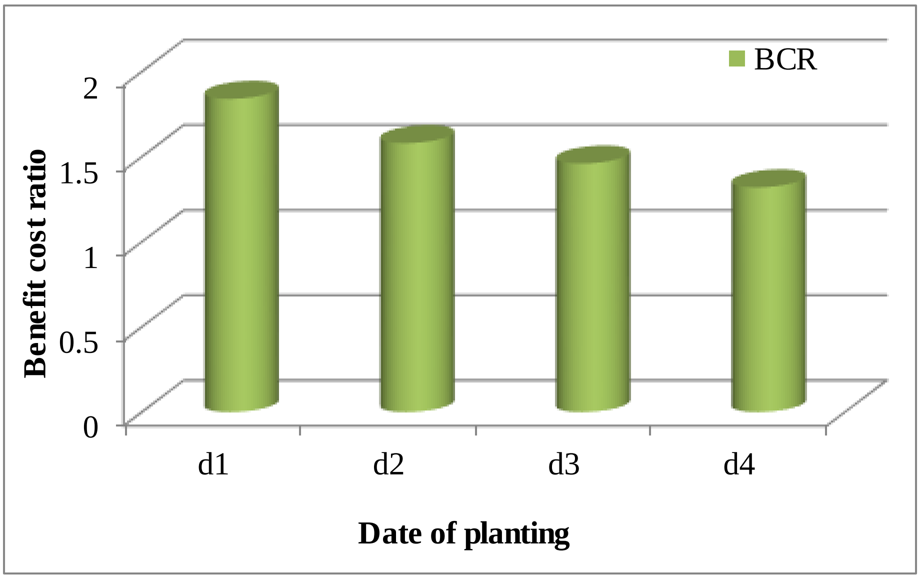

Figure 12. Effect of date of planting on benefit cost ratio

5.2 EFFECT OF NUTRIENT MANAGEMENT

5.2.1 Growth characters

Nutrient management significantly influenced the growth characters at all growth stages (Table 3 to 6). Application of modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers combined with a uniform basal dose of FYM @ 10 t ha^{-1} (integrated nutrient management) produced superior values of growth characters like plant height, number of branches and leaves per plant and LAI at all growth stages (Fig.13 and 14). There was no significant variation in plant height and number of branches per plant when the RD of nutrients (60:60:100 kg NPK ha^{-1}) was applied through fertilizers or organic manures along with the basal dose of FYM @ 10 t ha^{-1}. Similar trend was observed in leaf number during initial stages of growth. But RD through fertilizers recorded higher number of leaves per plant than the same dose through organic manures during later stages of crop growth. However, in the case of LAI, RD through fertilizers was superior to RD through organic manures at all growth stages. Among growth characters, LAI showed significant reduction due to organic nutrition compared to integrated nutrient management practices.

5.2.2. Yield and yield components

The yield components like number and weight of tubers per plant and number and weight of marketable tubers per plant (Table 7 and 8) were significantly influenced by nutrient management practices (Fig.15 and 16). Modified nutrient dose (60:30:120 kg NPK ha^{-1}) through fertilizers produced maximum values of these yield components which might be due to its profound influence on growth characters. The RD (60:60:100 kg NPK ha^{-1}) through fertilizers produced higher values of these yield components than the same dose through organic manures. The sufficiency of 30 kg P_2O_5 ha^{-1} for getting higher values of yield components of coleus was reported by Archana and Swadija (2000). The highest percentage of number and weight of marketable tubers per plant was recorded for the modified nutrient dose through fertilizers while no conspicuous variation in these parameters was noted between RD through fertilizers and RD through organic manures.

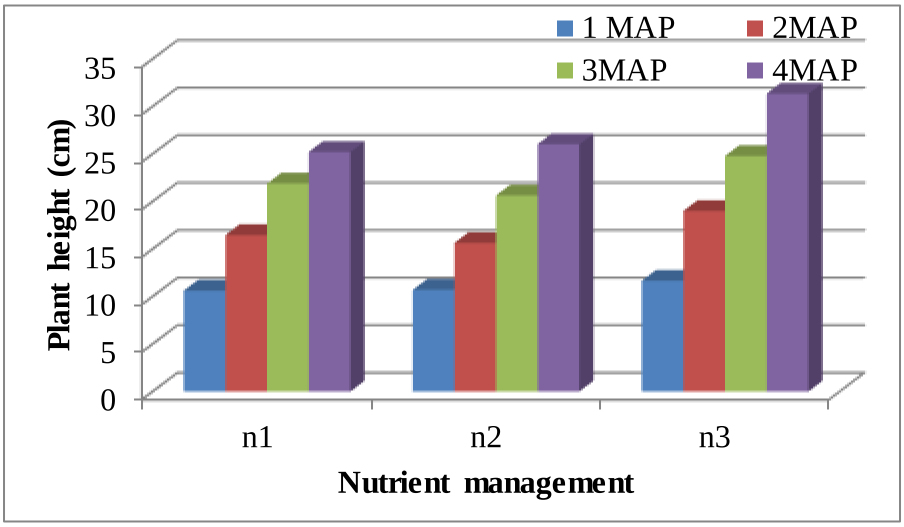

Figure 13. Effect of nutrient management on plant height

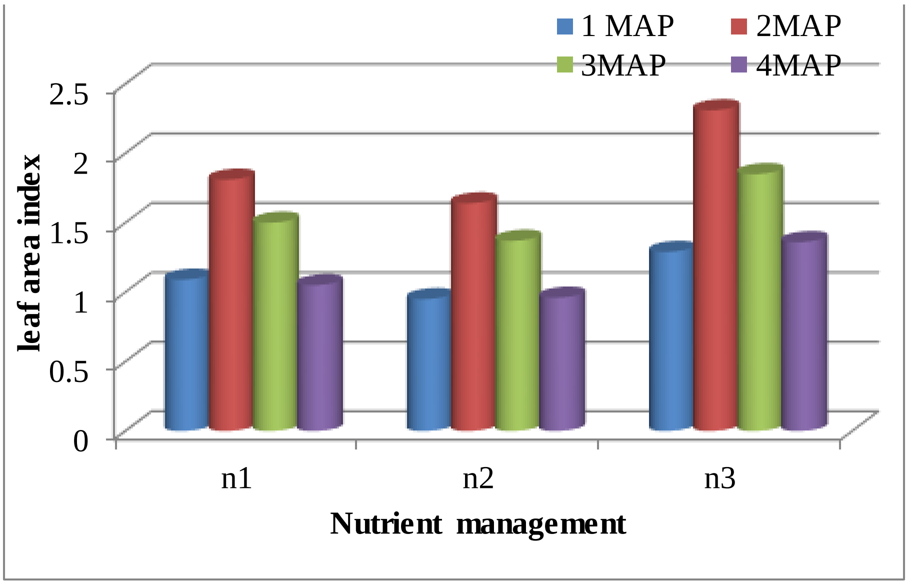

Figure 14. Effect of nutrient management on leaf area index

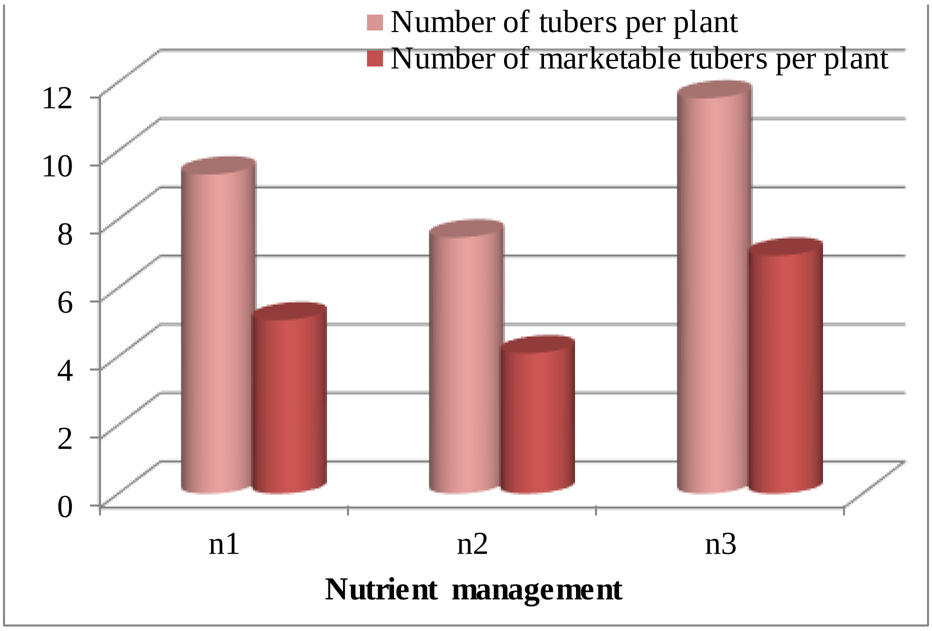

Figure 15. Effect of nutrient management on number of tubers and number of marketable tubers per plant

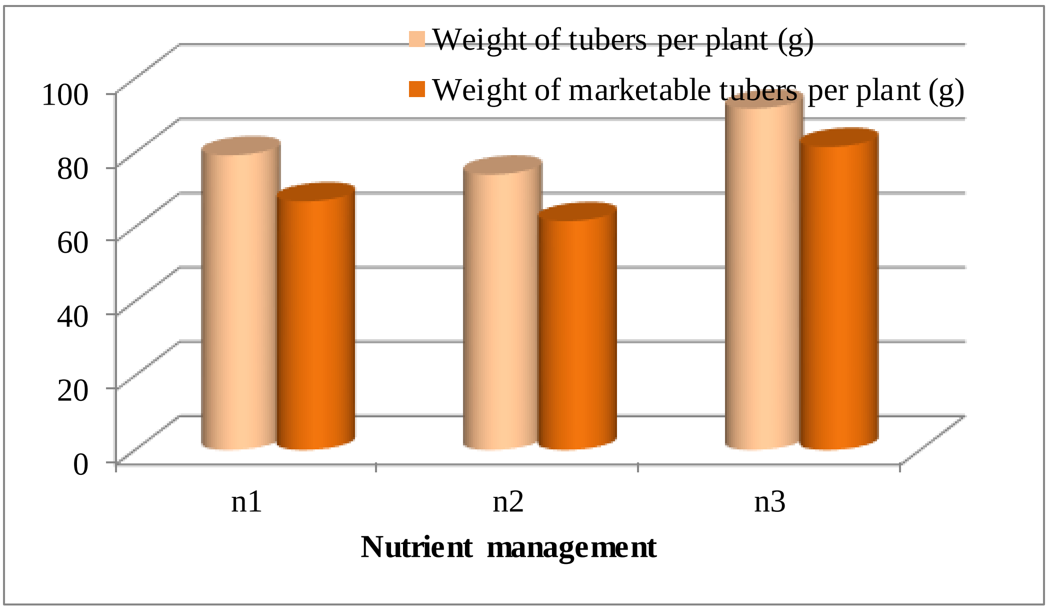

Figure 16. Effect of nutrient management on weight of tubers and weight of marketable tubers per plant

The data in Table 9 also indicated significant influence of nutrient management practices on tuber yield. The profound influence of modified dose of nutrients was reflected in tuber yield. Application of modified nutrient dose (60:30:120 kg NPK ha^{-1}) through fertilizers combined with FYM @ 10 t ha^{-1} recorded significantly higher tuber yield of 14.36 t ha^{-1} (Fig.17) than the RD of nutrients (60:60:100 kg NPK ha^{-1}) through fertilizers. The modified nutrient dose resulted in yield increase of 16 % over the RD of nutrients. The crop response to lower P and higher K levels might be due to high available P and low available K status of the soil (Table 1) which is in agreement with the findings of Geetha (1983) and Archana and Swadija (2000).

The RD of nutrients (60:60:100 kg NPK ha^{-1}) through fertilizers registered significantly higher tuber yield (12.39 t ha^{-1}) than the same dose through organic manures (10.94 t ha^{-1}), both treatments combined with a uniform dose of FYM @ 10 t ha^{-1}. The integrated nutrient management practice resulted in 16% yield increase over organic nutrition. The significant effect of integrated nutrient management practice on LAI, uptake of nutrients and yield components might have culminated in its significant effect on tuber yield. The superiority of integrated nutrient management practice over organic nutrition on crop growth and tuber yield of elephant foot yam, as in the present study in coleus, was reported by Kolambe *et al.* (2013).

5.2.3 Physiological parameters

Nutrient management practices had significant effect on the physiological parameters (Table 10). Modified nutrient dose through fertilizers recorded the highest dry matter production followed by RD through fertilizers and the lowest by RD through organic manures (Fig.18). The effect of nutrient management practices on total dry matter production is indicative of its cumulative favourable effect on growth characters, yield components and tuber yield. The necessity of application of higher K dose for higher dry matter production in coleus has been reported by Geetha

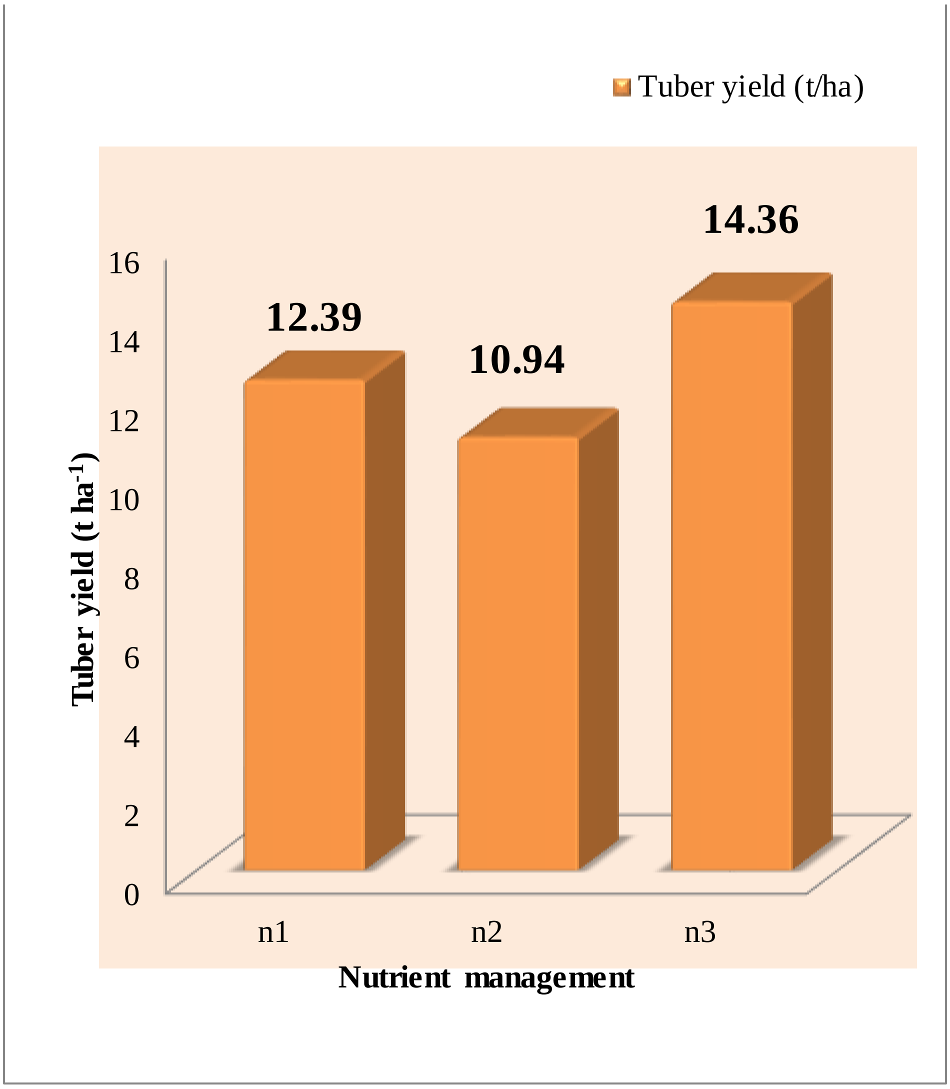

Figure 17. Effect of nutrient management on tuber yield

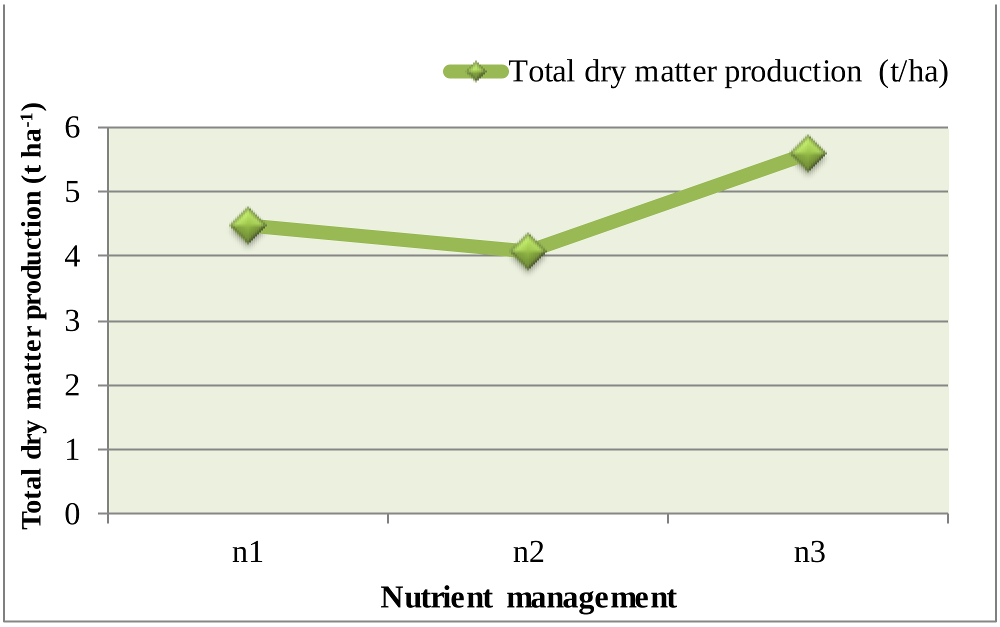

Figure 18. Effect of nutrient management on total dry matter production

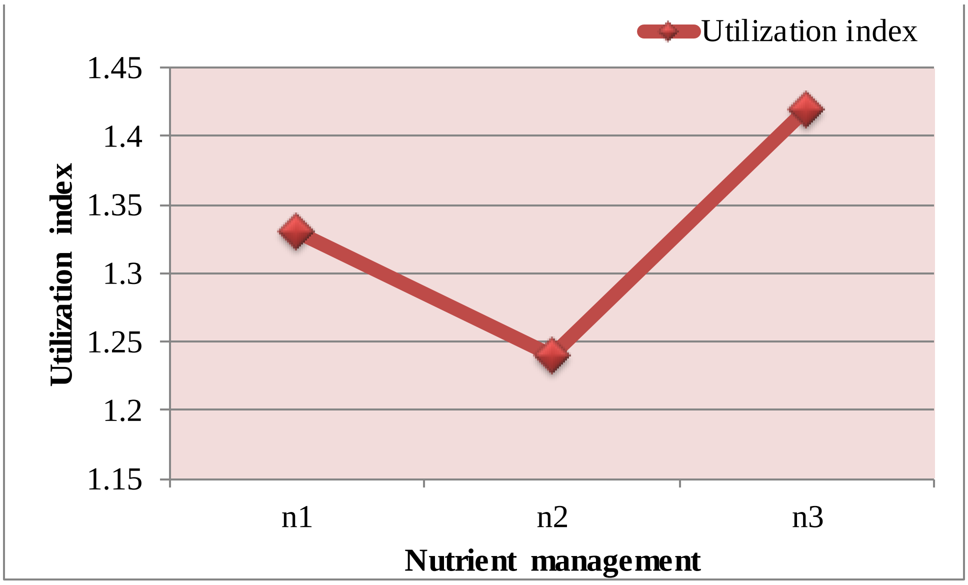

Figure 19. Effect of nutrient management on utilization index

(1983). The sufficiency of a lower dose of P for coleus has been reported by Geetha (1983) and Archana and Swadija (2000).

The effect of nutrient management practices on UI (Table 10) showed the same trend as that on tuber yield and dry matter production. The highest UI of 1.42 could be obtained for the modified nutrient dose through fertilizers (Fig. 19). Geetha (1983) suggested application of lower dose of P and higher dose of K (as included in the modified nutrient dose in the present study) for producing higher UI in coleus. The RD through fertilizers registered a higher UI (1.33) than the same dose through organic manures. This might be due to lower values of LAI, tuber yield and dry matter production registered by organic nutrition compared to integrated nutrient management practices.

5.2.4 Quality attributes

Among quality attributes, starch content of the tuber varied significantly with nutrient management practices (Table 11). Modified nutrient dose (60:30:120 kg NPK ha^{-1}) through fertilizers produced the highest starch content, which might be due to its higher K dose, followed by RD (60:60:100 kg NPK ha^{-1}) through fertilizers. Adequate supply of K is necessary for the synthesis and translocation of starch. Significant influence of K levels on starch content of tuber of coleus has been reported by Geetha (1983) and non significant influence of P levels has been reported by Archana and Swadija (2000) and Oomen (1989) in sweet potato. The protein content of the tuber did not vary significantly with organic and integrated nutrient management practices which was in conformity with the findings of Kolambe *et al.* (2013) in elephant foot yam.

5.2.5 Uptake of nutrients

Application of modified nutrient dose (60:30:120 kg NPK ha^{-1}) through fertilizers resulted in the highest uptake of N, P and K (57.09 kg N, 26.28 kg P and 120.68 kg K ha^{-1}) than RD (60:60:100 kg NPK ha^{-1}) through fertilizers (44.22 kg N, 23 kg P and 92.01 kg K ha^{-1}) as evident from Fig.20. It is to be noted that the uptake of N, P and K were in the same proportion in which the nutrients were supplied

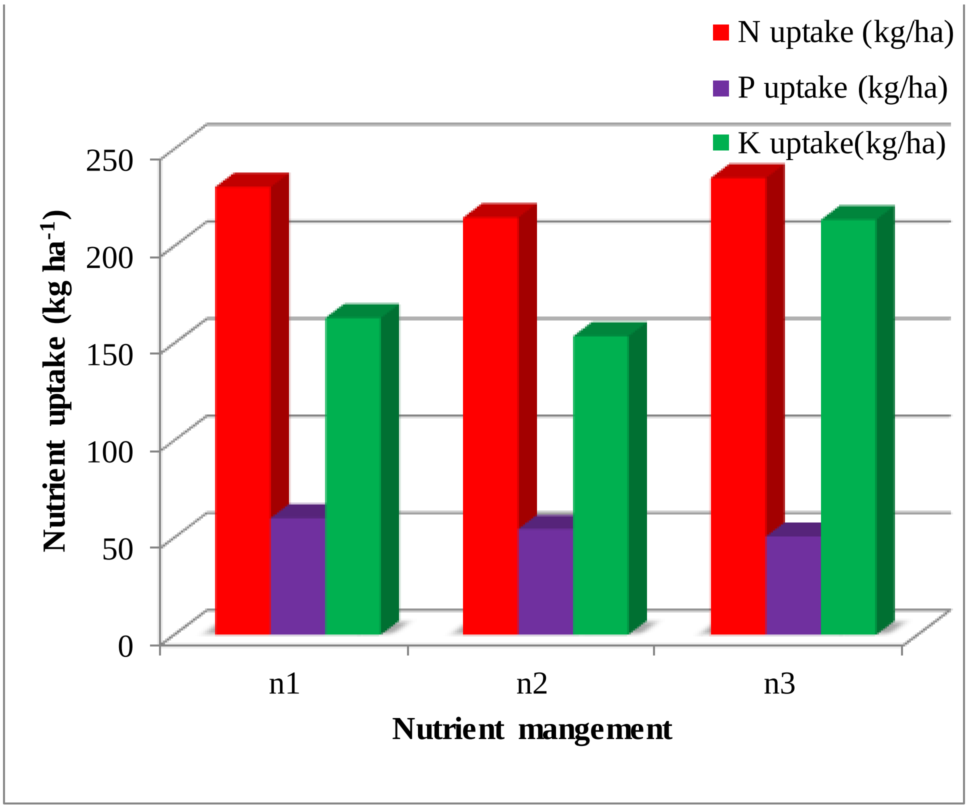

Figure 20. Effect of nutrient management on nutrient uptake

through modified nutrient dose (2:1:4). Lower P uptake compared to N and K uptake by coleus has been observed by Kabeerathumma *et al.* (1987). Organic nutrition resulted in comparatively lower uptake of nutrients which might be due to the slow availability of the nutrients from the organic manures.

5.2.6 Soil analysis after the experiment

There was no significant variation in soil pH by the application of RD or modified nutrient dose through fertilizers, but registered significantly lower pH compared to organic nutrition (Table 13). Increase in soil pH observed in fertilizer applied plots did not vary considerably than the initial soil pH (Table 1) which might be due to the integrated application of FYM and neem cake in those plots. Organic nutrition resulted in an increase in the soil pH which is in agreement with the findings of Maheswarappa *et al.* (1999), Ramesh *et al.* (2010) and Suja *et al.* (2012).

Modified nutrient dose through fertilizers recorded significantly higher content of organic carbon than RD through fertilizers but these treatments did not produce significant variation in the soil available N content (Table 13). Significantly lower content of soil available P and higher content of soil available K were observed with modified nutrient dose compared to RD through fertilizers which might be due to lower P and higher K doses in the modified nutrient dose than in the recommended nutrient dose. Significant increase in available P in the soil with increase in P dose applied for sweet potato was reported by Oomen (1989) and increased availability of K in the soil with higher levels of K applied for sweet potato was observed by Oomen (1989) and Devi (1990). Compared to integrated nutrient management, organic nutrition resulted in higher organic carbon and available P content and lower contents of available N and K in the soil after the experiment. But soil nutrient status improved than the initial status (Table 1). Maheswarappa *et al.* (1999), Gopimony *et al.* (2001), Ramesh *et al.* (2010), Suja *et al.* (2012) and Kolambe *et al.* (2013) have reported build up of organic carbon in the soil due to organic nutrition.

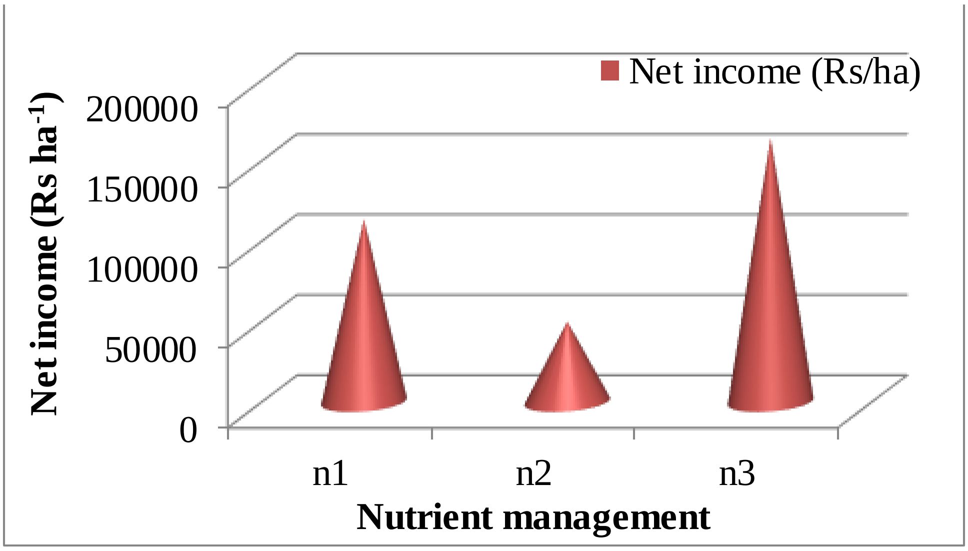

Figure 21. Effect of nutrient management on net income

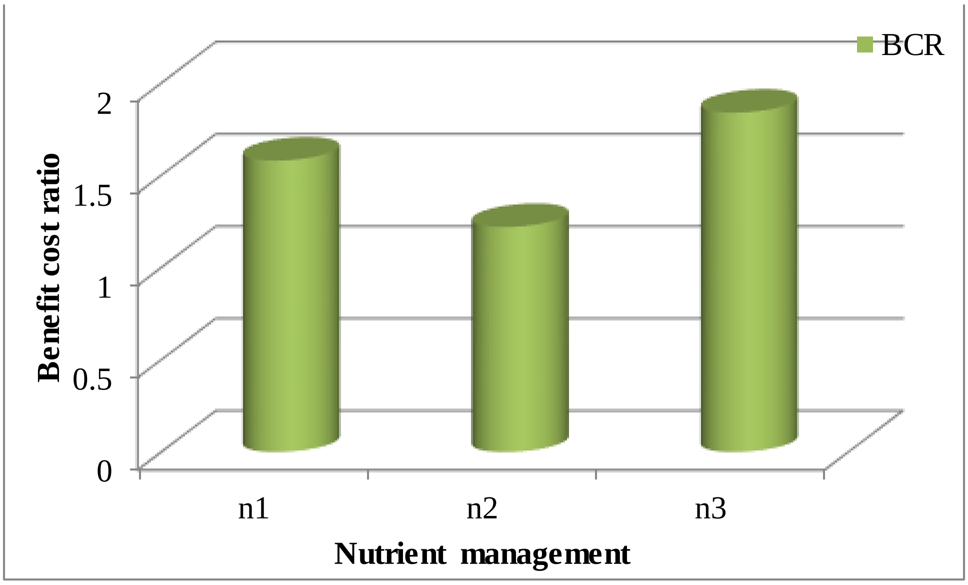

Figure 22. Effect of nutrient management on benefit cost ratio

5.2.7 Economics of cultivation

The effect of nutrient management practices on net income and BCR (Table 14a) followed the same trend as that on tuber yield (Table 9). Application of modified nutrient dose through fertilizers resulted in the highest net income of Rs.163900 ha^{-1} and BCR of 1.84 (Fig.21 and 22) followed by RD through fertilizers. Among nutrient management practices tried, the highest yield was realized through modified nutrient dose (Table 9), the cost of treatment of which was only Rs.5975 ha^{-1}. Application of RD through organic manures resulted in lower net income (Rs.49875 ha^{-1}) and lower BCR (1.22) compared to the application of the same dose through fertilizers. This was due to lower tuber yield (Table 9) and higher cost of treatment in organically manured plots. The cost of RD through fertilizers was only Rs.6950 ha^{-1} whereas the cost of RD through organic manures was Rs. 34500 ha^{-1}. In spite of higher cost involved, organic nutrition was found economical for off season production of coleus as revealed from the data on net income and BCR (Table 14a). In the present calculation, tubers produced under organic and integrated nutrient management practices were given a uniform price of Rs. 25 kg^{-1}. If organic tubers were sold at premium price, net income and BCR under organic nutrition would have further increased.

5.3 INTERACTION EFFECT OF DATE OF PLANTING AND NUTRIENT MANAGEMENT

5.3.1 Growth Characters

Significant interaction effects on growth characters were noticed for plant height at 4 MAP and LAI at all growth stages except 2 MAP (Table 3 and 6) November 15 planting with modified nutrient dose through fertilizers (d_1n_3) produced the tallest plants with the highest LAI followed by the treatment combinations d_1n_1 and d_2n_3 (Fig.23 and 24). The trend observed in the main effects of the treatments was reflected in the interaction effects.

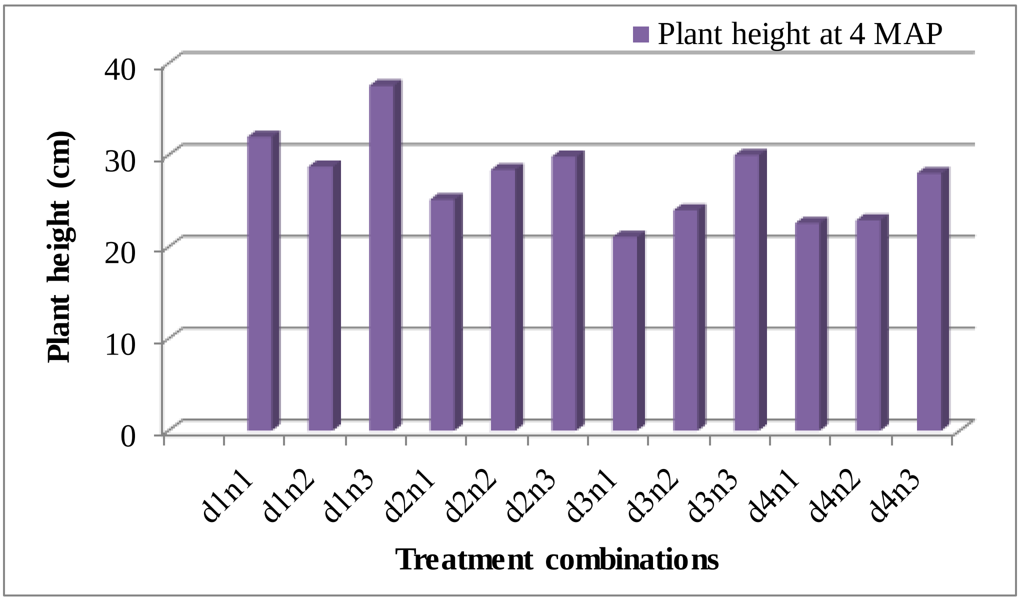

Figure 23. Interaction effect of date of planting and nutrient management on plant height at 4 MAP

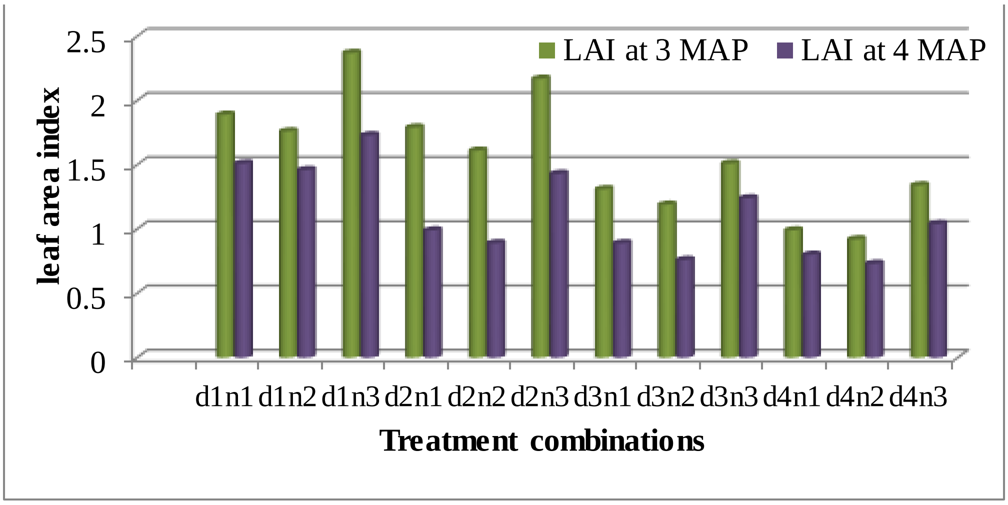

Figure 24. Interaction effect of date of planting and nutrient management on leaf area index at 3 MAP and 4 MAP

5.3.2 Yield and yield components

The D x N interaction was significant on number of marketable tubers per plant (Table 8). On each date of planting, modified nutrient dose recorded significantly higher number of marketable tubers per plant (Fig.25). Organically manured plots registered lower number of marketable tubers per plant on all dates of planting.

Although the interaction effects were not significant, modified nutrient dose recorded higher tuber yield on each date of planting (Table 9 and Fig.26) which reflected the main effects of date of planting and nutrient management on tuber yield. The highest tuber yield of 16.9 t ha^{-1} could be realized by planting coleus var. Suphala on November 15 with the application of modified nutrient dose through fertilizers (d_1n_3) followed by November 15 planting with RD of nutrients (d_1n_1) and December 1 planting with modified nutrient dose (d_2n_3). The effect of treatments on the yield components was reflected in their effects on tuber yield as indicated by the significant and positive correlation between yield components and tuber yield (Table 15).

5.3.3 Uptake of nutrients

Significant effect of modified nutrient dose on the uptake of nutrients was observed on all dates of planting as evident from their interaction effects presented in Table 11 and Fig.27. November 15 planting with modified nutrient dose (d_1n_3) registered the highest uptake of nutrients followed by December 1 planting with modified nutrient dose (d_2n_3). Reduction in uptake of nutrients was observed with delay in planting whatever be the nutrient management practice.

5.3.4 Soil analysis after the experiment

The D x N interaction registered significant effect on soil pH and organic carbon and available K contents in the soil after the experiment (Table 13). Organic nutrition on all dates of planting resulted in higher pH and organic carbon status of the soil. Modified nutrient dose through fertilizers on each date of planting recorded higher available K status of the soil which might be due to its higher K dose

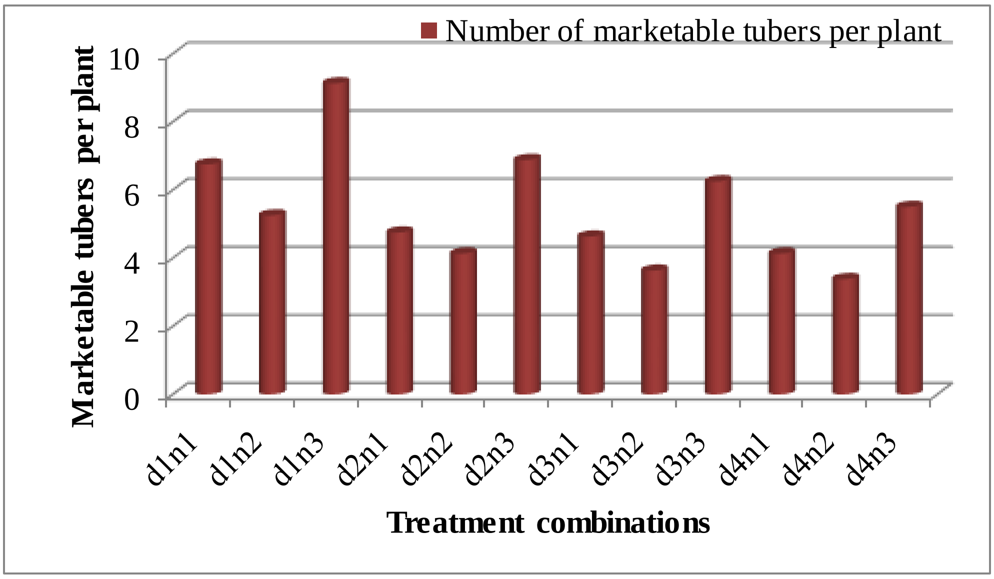

Figure 25. Interaction effect of date of planting and nutrient management on number of marketable tubers per plant

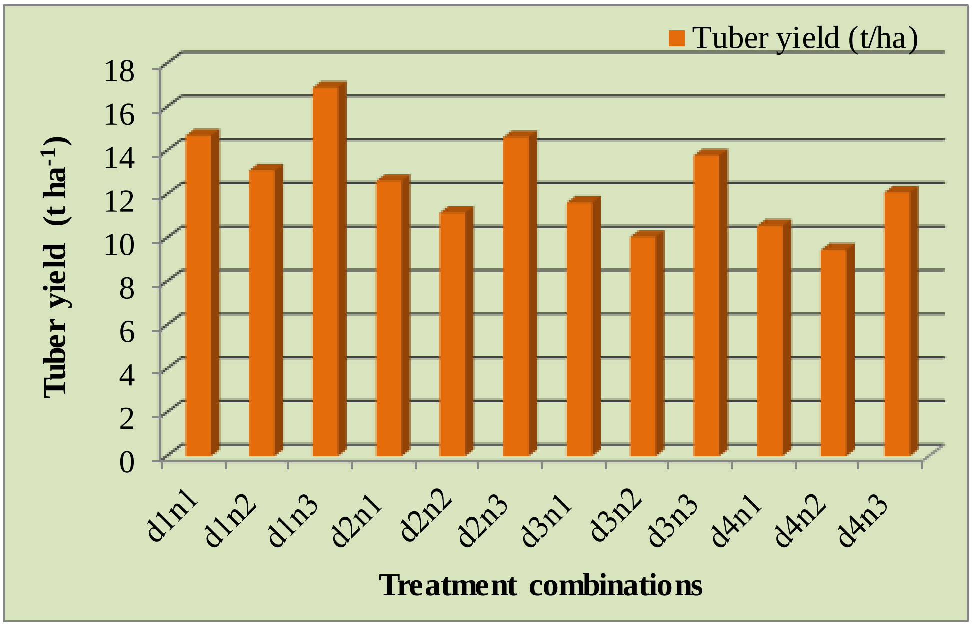

Figure 26. Interaction effect of date of planting and nutrient management on tuber yield

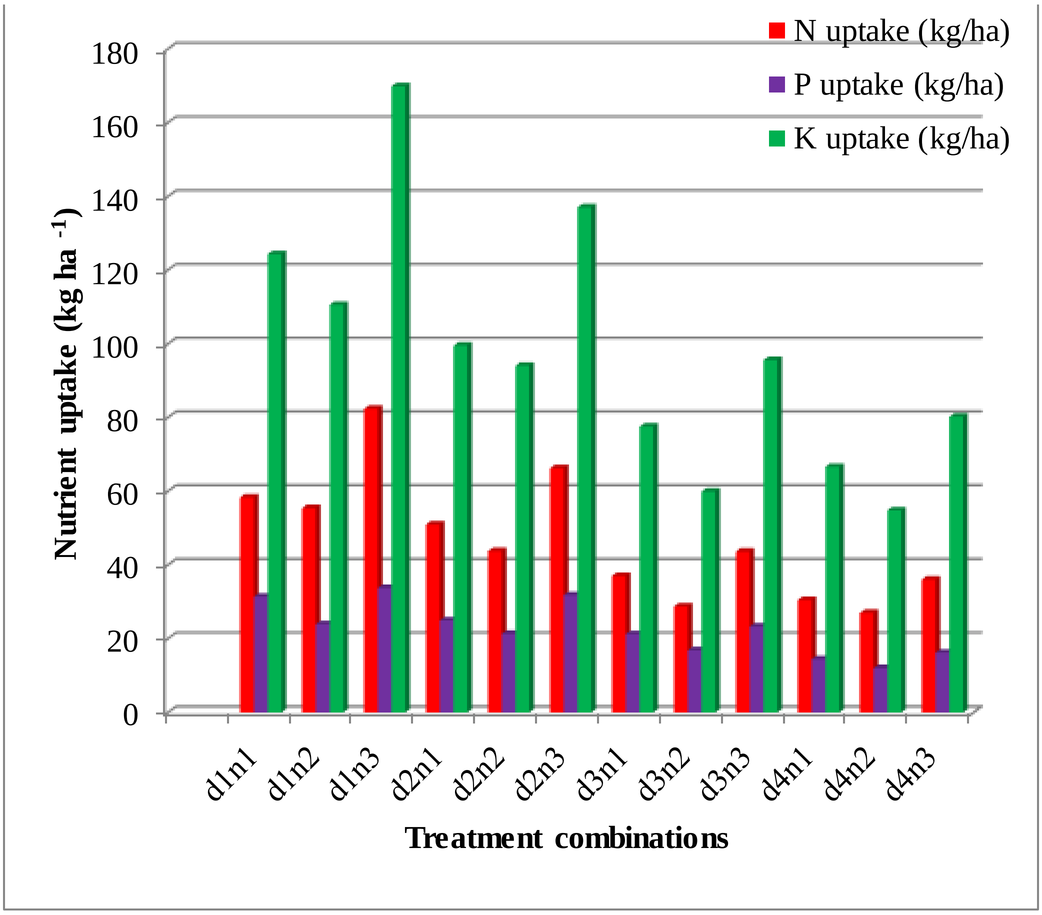

Figure 27. Interaction effect of date of planting and nutrient management on nutrient uptake

compared to other treatments. Soil reaction and nutrient status varied with the nutrient management practices than with date of planting.

5.3.5 Economics of cultivation

The results in Table 14b indicated the profitability of integrated nutrient management practices irrespective of the date of planting. Higher net income and BCR were obtained by the modified nutrient dose through fertilizers on all dates of planting (Fig. 28 and 29). Organic nutrition was also found to be profitable as revealed from the net income obtained ranging from Rs.13000 to 103375 ha^{-1} depending upon the date of planting. Compared to integrated nutrient management practices, organic nutrition on all dates of planting resulted in lower net income and BCR which was due to high cost of purchased inputs and lower tuber yield obtained. The profitability of organic nutrition can be further enhanced through the use of on- farm generated organic manures and sale of organic tubers at premium price. November 15 planted crop with modified nutrient dose (d_1n_3) recorded the highest net income and BCR followed by November 15 planted crop with RD of nutrients through fertilizers (d_1n_1) and December 1 planted crop with modified nutrient dose (d_2n_3) in that order reflecting the effects of these interactions on tuber yield.

5.4 INCIDENCE OF PEST AND DISEASE

Attack of leaf roller was noticed by the end of January 2014 and mealy bug during the third week of March 2014 which were controlled immediately by giving uniform spray of neem based pesticide and *Verticillium* respectively. No disease incidence was noticed.

Coleus is usually attacked by root knot nematode (*Meloidogyne incognita* Chitwood) which reduces tuber yield considerably (Mohandas, 1994). But in the present study, there was no symptom of nematode attack in the crop. As a prophylactic measure, neem cake @ 1 t ha^{-1} was applied uniformly in the experimental field at the time of land preparation (Nisha, 2005). Analysis of soil samples collected from the field during the cropping period did not show the presence of the nematode.

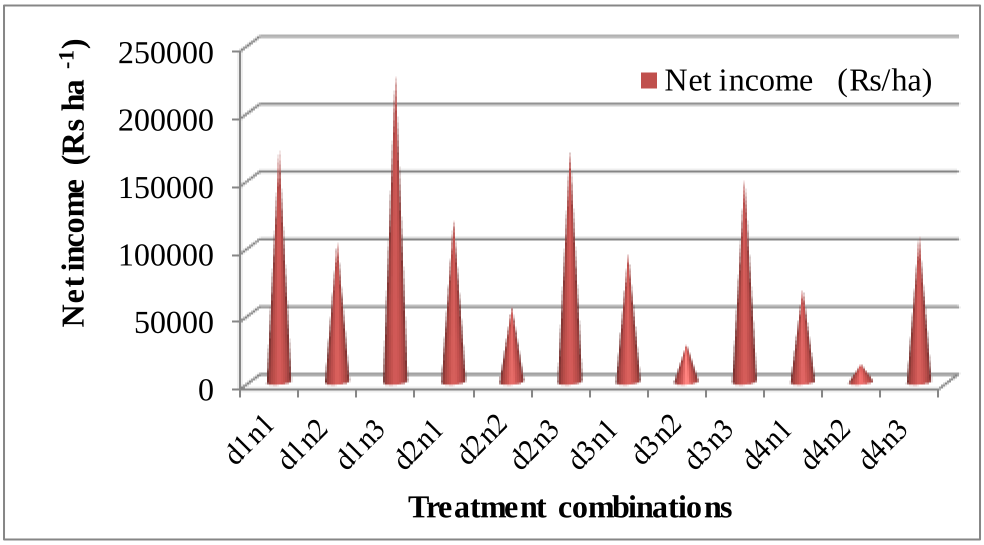

Figure 28. Interaction effect of date of planting and nutrient management on net income

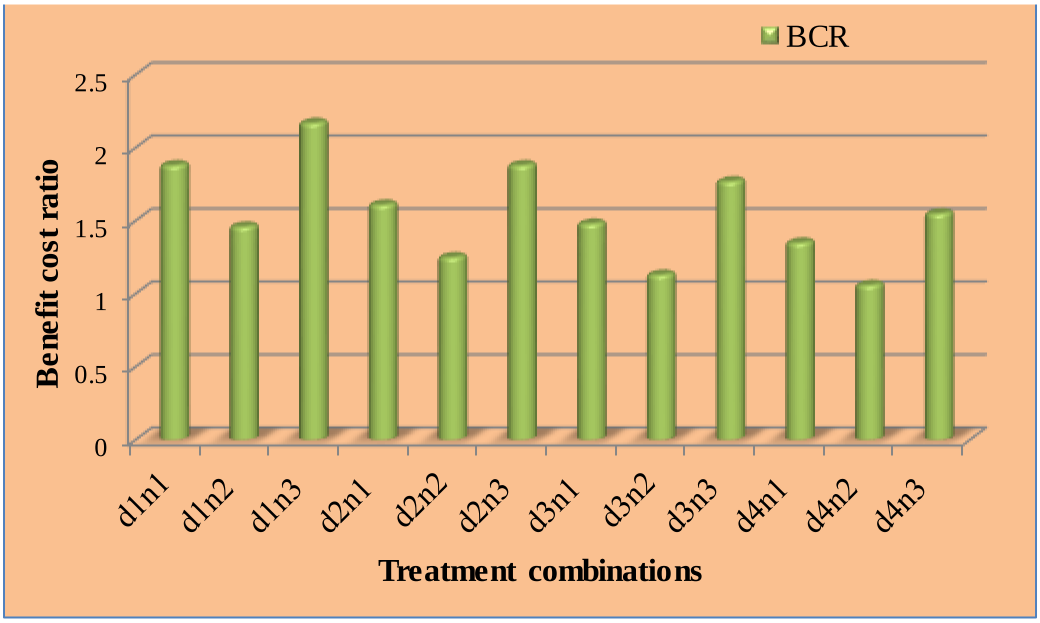

Figure 29. Interaction effect of date of planting and nutrient management on benefit cost ratio

The study revealed that for off season production of coleus var. Suphala in the southern zone of Kerala, the ideal time of planting is November 15 which recorded higher tuber yield, net income and benefit cost ratio. Modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers + 10 t ha^{-1} of FYM + 1 t ha^{-1} of neem cake can be recommended for the crop for getting higher tuber yield, net income and benefit cost ratio.

FUTURE LINE OF WORK

Studies can be conducted to evaluate the performance of coleus var. Suphala throughout the year at fortnightly interval along with other released varieties. The effect of integrated nutrient management practices including the modified nutrient dose on the var. Suphala and other released varieties of coleus may be studied during the normal planting season. Different sources of organic manure to substitute the present recommended dose and the modified nutrient dose adopted in the present study may be tried. It is necessitated to fix the optimum dose and to evolve efficient method of application of PGPR mix I for coleus.

SUMMARY

1. SUMMARY

The field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from November 2013 to May 2014 to fix the ideal time of planting and nutrient management for off season production of coleus var. Suphala and to work out the economics of cultivation. The treatments consisted of four dates of planting (d_1 - November 15; d_2 - December 1; d_3 - December 15 and d_4 - January 1) and three nutrient management practices (n_1 - Recommended dose - 60:60:100 kg NPK ha $^{-1}$ through fertilizers; n_2 - RD through organic manures - 6 t FYM + 3 t CPC + 3 t wood ash ha^{-1}+ PGPR mix1 and n_3 - Modified nutrient dose - 60:30:120 kg NPK ha $^{-1}$ through fertilizers). The experiment was laid out in split plot design with dates of planting in main plots and nutrient management practices in sub plots with four replications. A uniform dose of FYM @ 10 t ha^{-1} and neem cake @ 1 t ha^{-1} of was applied to all plots. The results of the study are summarized below.

Planting on November 15 recorded the tallest plants at all stages of crop growth except 1 MAP. At 1 MAP, the effects of planting on November 15 or on December 1 were on par. Modified nutrient dose through fertilizers registered taller plants than RD through fertilizers or organic manures at all growth stages. The interaction effects were significant only at 4 MAP, when November 15 planting with modified nutrient dose through fertilizers recorded the tallest plants.

Planting on November 15 or on December 1 registered more number of branches per plant at all growth stages than late planting. At all stages, modified nutrient dose through fertilizers produced significantly more number of branches per plant than RD through fertilizers or organic manures.

The highest number of leaves per plant at all growth stages was observed when the crop was planted on November 15. The modified nutrient dose through fertilizers recorded the highest number of leaves per plant at all growth stages.

Leaf area index showed a decreasing trend at all growth stages with delay in planting with the highest LAI for November 15 planting and the lowest for January 1 planting. At each growth stage, modified nutrient dose recorded the highest LAI. Regarding D x N interaction, November 15 planting with modified nutrient dose recorded significantly higher LAI at all growth stages.

Planting on November 15 recorded the highest number and weight of tubers per plant. Modified nutrient dose through fertilizers was found superior in these yield components.

Number and weight of marketable tubers per plant decreased with delay in planting, higher values being recorded by November 15 planting. Modified nutrient dose through fertilizers recorded higher values of these yield components. Regarding interaction, November 15 planting with modified nutrient dose recorded the highest number of marketable tubers per plant.

No significant variation in percentage of number and weight of marketable tubers per plant was noted by planting on November 15 or December 1 or December 15. Late planting on January 1 recorded significantly lower values. Significantly higher percentage of number and weight of marketable tubers per plant was noted for the modified nutrient dose.

Tuber yield per ha showed a declining trend with delay in planting with the highest yield being recorded when planted on November 15 and the lowest when planted on January 1. Significant and positive correlation was observed between tuber yield and total rainfall received during the cropping period. Modified nutrient dose through fertilizers was found superior to RD through fertilizers or organic manures.

Total dry matter production exhibited a decreasing trend with delay in planting, the highest value being recorded by November 15 planting. Modified nutrient dose registered the highest dry matter production.

Among dates of planting, UI was the highest for November 15 planting. Regarding nutrient management, the highest UI was registered by the modified nutrient dose through fertilizers.

The starch content of the tuber varied significantly only with nutrient management practices. Modified nutrient dose through fertilizers recorded the highest starch content of tuber. No significant variation in protein content of tuber was noticed due to treatments.

A declining trend in the uptake of N, P and K was observed with delay in planting with the highest values being recorded by November 15 planting. Modified nutrient dose through fertilizers resulted in the highest uptake of nutrients. With regard to interaction effects, November 15 planting with modified nutrient dose recorded higher uptake of nutrients.

Soil analysis after the experiment recorded higher pH and organic carbon status and increased availability of nutrients than the initial status. Availability of N and P decreased with delay in planting. Modified nutrient dose through fertilizers resulted in the highest content of available N and K while RD through fertilizers recorded significantly higher available P in the soil after the experiment. Organic nutrition resulted in significantly higher pH and the higher organic carbon content of the soil irrespective of date of planting.

Attack of leaf roller and mealy bug was noticed which were immediately controlled by spraying organic pesticides. No incidence of disease or nematode attack was noticed in the crop. No nematode could be detected in the soil samples collected during the cropping period.

Economics of cultivation worked out in terms of net income and BCR exhibited a declining trend with delay in planting. Planting on November 15 resulted in the highest net income and benefit cost ratio. Modified nutrient dose through fertilizers was found superior to RD through fertilizers or organic manures. The highest net income and BCR were obtained when the crop was planted on November

15 with modified nutrient dose.

The study revealed that for off season production of coleus var. Suphala in the southern zone of Kerala, the ideal time of planting is November 15 which recorded higher tuber yield, net income and benefit cost ratio. Modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers + FYM @ 10 t ha^{-1} + neem cake @ 1 t ha^{-1} can be recommended for the crop for getting higher tuber yield, net income and benefit cost ratio.

FUTURE LINE OF WORK

Studies can be conducted to evaluate the performance of coleus var. Suphala throughout the year at fortnightly interval along with other released varieties. The effect of integrated nutrient management practices including the modified nutrient dose on the var. Suphala and other released varieties of coleus may be studied during the normal planting season. Different sources of organic manure to substitute the present recommended dose and the modified nutrient dose adopted in the present study may be tried. It is necessitated to fix the optimum dose and to evolve efficient method of application of PGPR mix I for coleus.

REFERENCES

REFERENCES

Archana, B. and Swadija, O.K. 2000. Influence of different organic manures, P level and biofertilizer on the growth and yield of coleus. *J. Root Crops* 26(2): 78-81.

Archana, B. 2001. Integrated nutrient management for coleus (*Solenostemon rotundifolius* (Poir) Morton. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 100p.

Atul, J. 2012. Production technology for organic coleus. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 59p.

Atul, J., Swadija, O.K., and Vijayaraghavakumar. 2013. Effect of organic management on growth and yield of Chinese potato (*Plectranthus rotundifolius*). *J. Root Crops* 39(1): 103-106.

Bourke, R.M. 1985. Influence of nitrogen and potassium on growth of sweet potato in Papua New Guinea. *Field Crop. Res*. 12: 363-375.

Bray, R.H. and Kurtz, L.T. 1964. Determination of total organic and available forms of phosphorus in soils. *Soil Sci*. 59: 39-45.

Cochran, W.G. and Cox, G.M. 1965. *Experimental Designs*. Wiley Publication in applied statistics, New York, 204p.

CTCRI [Central Tuber Crops Research Institute]. 2006. *Tuber Crop Varieties Released by Central Tuber Crops Research Institute*. Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, 64p.

Das, R.C. and Behera, S. 1989. A note on the uptake and quality of root tubers of sweet potato. (*Ipomoea batatas* Lam.) as affected by potash application. *Orissa J. Hortic*. 17(1 & 2): 96-99.

Dayal, T.R. and Sharma, R.P. 1993. Response of sweet potato (*Ipomoea batatas*) to fertilizer, method and time of planting and spacing. *Indian J. Agron*. 38(3): 431-435.

Devi, K.C.S. 1990. Standardisation of agro techniques for sweet potato variety Sree Nandini. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 88p.

Dhanya, T. 2011. Production technology for organic sweet potato. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 82p.

Elizabeth K. S. and Kunju, U.M. 1989. Response of sweet potato (*Ipomoea batatas* L.) to NPK in the reclaimed alluvial soils of Kuttanad, Kerala. *J. Root Crops* 15(2): 91-96.

Gaur, A.C., Neelakantan, S., and Dargan, K.S. 1984. *Organic Manures*. ICAR, New Delhi, 159p.

Geetha, K. 1983. Nutritional management in coleus (*Coleus parviflorus* Benth). M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 118p.

Geetha, K. and Nair, K.P.M. 1993. Effect of N and K on coleus. *J. Trop. Agric.* 31(2): 198-203.

Gopimony, R., Varghese, T., and Kamalam, N. 2001. Nutrient dynamics of bhendi and cassava production under organic farming. *J. Root Crops* 27(1): 231-234.

Hegde, M., Gowda, J., and Kumar, D.P. 1986. Effect of nitrogen and potassium on growth and yield of sweet potato. *South Indian Hort*. 34(5): 310-313.

Hrishi, N. and Mohankumar, C.R. 1976. Coleus for homestead garden. *Indian Farming* 26(3): 33-35.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India. Pvt. Ltd., NewDelhi, 498p.

Kabeerathumma, S., Mohankumar, B., and Nair, P.G. 1987. *Nutrient Uptake and Their Utilization by Yams, Aroids and Coleus*. CTCRI Technical Bulletn Series No. 10, Central Tuber Crops Research Institute, Thiruvananthapuram, India.32p.

KAU[Kerala Agricultural University]. 2007. *Package of Practices Recommendations: Crops-2007* (13th Ed.). Kerala Agricultural University, Thrissur, 334p.

KAU[Kerala Agricultural University]. 2008. *Research Report 2004-2006*. Kerala Agricultural University, Thrissur, 251p.

KAU[Kerala Agricultural University]. 2009. *Package of Practices Recommendations (Adhoc) for Organic Farming: Crops*. Kerala Agricultural University, Thrissur, 200p.

KAU[Kerala Agricultural University]. 2011. *Package of Practices Recommendations: Crops* (14th Ed.). Kerala Agricultural University, Thrissur, 360p.

Kolambe, B.N., Patel, K.G., Kaswala, A.R., Patel, V.S., and Desai, K.C. 2013. Organic management affects growth, yield, quality and soil properties in elephant foot yam. *J. Root Crops* 39(1): 62-66.

Kushwah, S.S., Dwivedi, Y.C., and Jain, P.K. 2011. Effect of time of planting on growth, yield and economics of sweet potato under rainfed conditions . *J. Root Crops* 37(2): 189-191.

Maheswarappa, H. P., Nanjapppa, 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., Nanjapppa, 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(3): 318-323.

Mareen, A. 2002. Assessment and induction of variability for higher yield and photoinsensitivity in coleus (*Coleus parviflorus* Benth). Ph.D. thesis, Kerala Agricultural University, Thrissur, 144p.

Mareen, A. and Radhakrishnan, V.V. 2004. Assessment and induction of variability in Chinese potato (*Solenostemon rotundifolius* Poir.). *J. Root Crops* 30(2): 143-150.

Mohandas, C. 1994. Nematodes in Tuber Crops. In**:** Chadha, K.L. and Nayar, G.G. (eds), *Advances in Horticulture-8.Tuber Crops.* Malhotra Publishing House, New Delhi, pp.523-533.

Mohankumar, C. R., Nair, G. M., George, J., Ravindran, C. S., and Ravi, V. 2000, *Production Technology of Tuber crops.* Central Tuber Crops Research Institute, Thiruvananthapuram. 174p.

Mukhopadhyay, S.K., Sen, H., and Jana, P.K. 1991. Effect of time of planting on growth, yield parameters and tuber yield of sweet potato. *J. Root Crops* 17(1): 19-25.

Mukhopadhyay, S.K., Sen, H., and Jana, P.K. 1992. Effect of potassium on growth and yield of sweet potato. *J. Root Crops* 18(1): 10-14.

Mukhopadhyay, S.K., Sen, H., and Jana, P.K. 1993. Dry matter accumulation, starch and nutrient concentration in sweet potato as influenced by potassium nutrition. *J. Root Crops*. 19: 21-28.

Nair, P.G., Mohankumar, B., Prabhakar, M., and Kabeerathumma, S. 1988. Response of cassava to graded doses of phosphorus in acid laterite soils of high and low P status. *J. Root Crops* 14(2): 1-9.

Nair, D.B. and Nair, V.M. 1992. Nutritional status studies in sweet potato. *J. Root Crops* 18(1): 53-57

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, 230p.

Navarro, A.A. and Padda, D.S. 1983. Effects of sulphur, phosphorus and nitrogen application on the growth and yield of sweet potatoes grown on clay loam. *J. Agric. Univ. Puerto Rico* 67(2): 108-111.

Nedunchezhiyan, M. and Byju, G. 2005. Effect of planting season on growth and yield of sweet potato (*Ipomoea batatas* L) varieties. *J. Root Crops* 31(2): 111-114.

Nedunchezhiyan, M. and Reddy, S. 2006. Effect of planting and varieties on growth and yield of sweet potato (*Ipomoea batatas* L) under rainfed conditions. In: Naskar, S.K., Nedunchezhiyan, M., Rajasekhara Rao, K., Sivakumar, P.S., Ray, R.C., Misra, R.S. and Mukherjee, A. (eds), *Root And Tuber Crops in Nutrition, Food Security and Sustainable Environment* . Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar, pp.123-127.

Nisha, M.S. 2005. Integrated management of root-knot nematode *Meloidogyne incognita* (Kofoid and White) Chitwood in coleus (*Solenostemon rotundifolius* (Poir) Morton) Ph.D. thesis, Kerala Agricultural University, Thrissur, 233p.

Nicholaides, J.J., Chaney, H.F., Mascaghi, H.J., Wilson, L.G., and Eaddy, D.W. 1985. Sweet potato- Response to K and P fertilization. *Agron. J.* 77(3): 466-470.

Oomen, M. 1989. Cultural, manorial and water requirement for sweet potato (*Ipomoea batatas* (L) Lam.) Ph.D. thesis, Kerala Agricultural University, Thrissur, 253p.

Pamila, V., Swadija, O.K., and Pushpakumari, R. 2006. Performance of short duration varieties of cassava in lowlands as influenced by different organic manures and nitrogen levels. *J. Root Crops* 32(2): 171-174.

Pamila, V., Swadija, O.K., and Padmanabhan, V.B. 2011. Influence of different organic manures and nitrogen levels on quality characters of cassava in lowlands. In: Sajeev, M. S., Anantharaman, M., Padmaja, G., Unnikrishnan, M., Ravi, V., Suja, G., and Vinayaka Hegde (eds.), *Climate Change and Food Security: Challenges and Opportunities for Tuber Crops.* Proceedings of an international conference, Thiruvananthapuram, Kerala. Central Tuber Crops Research Institute , Thiruvananthapuram, Kerala, pp.307-311.

Panda, S.C. 2011. *Soil Management and Organic Farming*. Agrobios (India), Jodhpur. 462p.

Panday, V. and Kumar, D. 2002. Biofertilizers for sustainable agriculture. *Agric. Today* 5: 44-47.

Patil, Y.B., Patil, A.A., Bharati Chimmad., and Hulamani, N.C. 1990. Influence of levels of fertilizers and spacing on the cooking quality and nutrient composition of sweet potato (*Ipomoea batatas* (L.) Poir) . *J. Root Crops* 16(1): 22-27.

Patil, Y.B., Patil, A.A., Madalageri, B.B., and Patil, V.S. 1992. Effect of levels of N, K and inter row spacing on growth and yield of sweet potato. *J. Root Crops* 18(1): 58-61.

Piper, C.S. 1966. *Soil and Plant Analysis* . University of Adelaide, Australia, 368p.

Prasad, M. and Rao, M.V.L. 1986. Effect of nitrogen, phosphorus and potassium on sweet potato yield. *J. Root Crops* 12: 111-112.

Ramesh, P., Panwar, N.R., Singh, A.B., Ramana, S., Yadav, S.K., Shrivastava, R., and Rao, A.S. 2010. Status of organic farming in India. *Curr. Sci.* 98(9): 1190-1194.

Ravindran, C.S. and Nair, P.G. 1994. Agrotechniques and nutritional requirements of sweet potato. In: Chadha, K.L. and Nayar, G.G. (eds), *Advances in Horticulture-8. Tuber Crops.* Malhotra Publishing House, New Delhi, pp.234-251.

Ravi, V., Suja, G., and Ravindran, C.S. 2011. Method for leaf area determination in chinese potato (*Plectranthus rotundifolius*). *J. Root Crops* 37(1): 37-40.

Sattar, M. A. and Gaur, A. C. 1987. Production of auxins and gibberllins by phosphate dissolving microorganisms. *Zentralblatt fur Microbiologei*, 142: 393-395.

Simpson, J.F., Adair, C.R., Kohler, G.O., Dawson, E.H., Debald, H.A., Kaestar, E.B., and Klick, J.T. 1965. *Quality Evaluation Studies of Foreign and Domestic Races.* Technical Bulletin 1331 Service. United States Department of Agriculture, 180p.

Singh, K.D and Mandal, R.C. 1976.Performance of coleus and sweet potato in relation to seasonal variation (time of planting). *J. Root Crops* 2(2): 17-22.

Singh, S.J., Singh, R.L., Mishra, S.S., and Mishra, S. 1986. Effect of planting pattern and nitrogen on the growth and yield of sweet potato (*Ipomoea batatas* (L.) Lam). *Indian J. Agron*. 31(4):423-25.

Subbiah, B. V. and Asija, G. L. 1956. Rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25: 259-260.

Suja, G. 2001. Resource management for intercropping white yam (*Dioscorea rotundata* Poir) in coconut garden. Ph.D. thesis, Kerala Agricultural University, Thrissur, 195 p.

Suja, G., Nayar, T. V. R., Potty, V. P., and Sundaresan, S. 2006. Organic farming: An alternative option for tuber crop production. *CTCRI News* 23(1): 4-5.

Suja, G., Potty, V. P. and Sunderesan, S. 2008. Organic farming of aroids and yams: A feasible alternative farming strategy. In: *Proceedings of the Twentieth Kerala Science Congress*, 28-31 January, 2008, Thiruvananthapuram. *Kerala State Committee on Science, Technology and Environment, Government of Kerala*, pp.87-89.

Suja, G., Susan John, K., and Sundaresan, S. 2009. Potential of tannia (*Xanthosoma sagittifolium*) for organic production. *J. Root Crops* 35(1): 36-40.

Suja, G., Susan, J. K., Ravindran C. S., Prathapan K., and Sunderesan, S. 2010. On farm validation of organic farming technology in elephant foot yam. *J. Root Crops* 36(1): 59-64.

Suja, G., Sundaresan, S., Susan John, K., Sreekumar, J., and Misra, R.S. 2012. Higher yield, profit and soil quality from organic farming of elephant foot yam. *Agron. Sustain. Dev*. 32: 755-764.

Swadija, O.K., Padmanabhan, V.B., Pushpakumari, R., Vijayaraghavakumar. 2011. Organic nutrition for arrowroot (*Maranta arundinacea* L.) in the homesteads of Kerala. In: Sajeev, M. S., Anantharaman, M., Padmaja, G., Unnikrishnan, M., Ravi, V., Suja, G., and Vinayaka Hegde (eds.), *Climate Change and Food Security: Challenges and Opportunities for Tuber Crops*. Proceedings of an international conference, Thiruvananthapuram, Kerala. Central Tuber Crops Research Institute , Thiruvananthapuram, Kerala, pp.267-272.

Thyagarajan, V. 1969. Studies on the response of koorka (*Coleus parviflorus* Benth) to graded doses of fertilizer application. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur,65p.

Vasudevan, K. and Jos, J.S. 1989. *Gamma Ray Induced Day Length Tolerant Mutants in Coleus*. Mutation Breeding Newsletter, No.32, p.5.

Veenavidyadharan and Swadija, O.K. 2000. Effect of varying levels of farmyard manure, nitrogen and potassium on the yield of arrowroot under partial shade. *J. Root Crops* 26(2): 84-86.

Vimala, B. 1994. Genetic resources and varietal improvement in minor tuber crops In: Chadha, K.L. and Nayar, G.G. (eds), *Advances in Horticulture-8. Tuber Crops* Malhotra Publishing House, New Delhi, pp.139-152.

Walkely, A. and Black, J.A. 1934. An examination of the Degtijareff method for determining soil organic matter and a proposed modification of the chromic acid filteration method. *Soil Sci*. 37: 93-101.

Ward and Pigman, 1970. *Analytical Methods for Carbohydrates - The carbohydrates Vol. II B*. Academic press, New York and London. 763p.

Watson, D.J. 1947. The physiological basis of variation in yield. *Adv. Agron*. 4: 101-105.

APPENDIX

APPENDIX- I

Weather data during the cropping period (November 2013- May 2014)

Standard weeks	Temperature (°C)		Relative humidity (%)		Total Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
45.	30.91	23.71	97	76.87	3.2
46.	30.3	23.4	97.7	78.3	138.8
47.	30.6	23.7	97.3	78.1	58.1
48.	30.8	23.0	97.3	75.9	49.8
49.	30.9	22.8	98.6	69.9	1.4
50.	30.3	22.6	96.7	69.6	26
51.	31.2	21.7	97.7	72.0	47
52.	31	20.2	96.6	59.1	0
1.	30.9	21.5	94.9	77.6	0
2.	29	22.3	94.4	77.4	28
3.	31	21.8	94.1	76.1	0
4.	31.3	20.7	90.4	69.9	0.5
5.	31.4	21.9	92.3	68.6	0
6.	30.7	20.2	95.1	68.9	0
7.	31.4	22.8	92	72	3
8.	31.5	23.8	90.6	70.6	18
9.	31.9	23.1	92.3	68.6	25
10.	31.9	23.4	90.4	66.9	0
11.	32.4	21.4	93	63.4	0
12.	33	24.1	93.7	69.1	6.5
13.	33	22.2	89.1	64	0
14.	32.4	24.5	89.9	75.3	19
15.	32	24.2	91	69.6	32
16.	32	25	90.7	73.3	18
17.	32.8	24.4	94	76.6	45.5
18.	32.2	23.8	93.1	83.3	51.5

Strategies for Off Season Production of Coleus in the Southern Zone of Kerala

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Abstract of the
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for the degree of

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2014

ABSTRACT

A field experiment entitled "Strategies for off season production of coleus in the southern zone of Kerala" was undertaken at Instructional Farm, College of Agriculture, Vellayani from November 2013 to May 2014. The objectives of the study were to fix the ideal time of planting and nutrient management for off season production of coleus var. Suphala and to work out the economics of cultivation.

The treatments consisted of four dates of planting (d_1-November 15; d_2-December 1; d_3-December 15 and d_4-January 1) and three nutrient management practices (n_1-Recommended dose - 60:60:100 kg NPK ha^{-1} through fertilizers; n_2-RD through organic manures -6 t farmyard manure + 3 t coir pith compost + 3 t wood ash per ha+ PGPR mix1 and n_3-Modified nutrient dose -60:30:120 kg NPK ha^{-1} through fertilizers). The experiment was laid out in split plot design assigning dates of planting in main plots and nutrient management practices in sub plots with four replications. A uniform dose of FYM @ 10 t ha^{-1} of and of neem cake @ 1 t ha^{-1} was applied to all plots.

Among four dates of planting tried, planting on November 15 (d_1) recorded taller plants, higher number of branches and leaves per plant and higher leaf area index. Yield components like number and weight of tubers per plant were maximum when planted on November 15 (d_1) followed by planting on December 1 (d_2). Number and weight of marketable tubers per plant showed a decreasing trend when planting was delayed beyond November. The tuber yield also exhibited a similar trend recording the highest tuber yield of 14.89 t ha^{-1} for November 15 planting and the lowest tuber yield of 10.71 t ha^{-1} for January 1 planting. The tuber yield was significantly and positively correlated with the total rainfall received during the cropping period. Planting on November 15 recorded the highest utilization index. Total dry matter production and uptake of N, P and K were maximum when the crop was planted on November 15 and it showed a declining trend due to late planting.

But quality attributes of tuber were not significantly influenced by date of planting. The highest net income (Rs.167525 ha $^{-1}$) and BCR (1.84) were obtained by planting on November 15, which decreased with delay in planting.

Modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers (n_3) significantly promoted all the growth characters. Higher number and weight of tubers as well as marketable tubers per plant were recorded by the same treatment which resulted in the highest tuber yield of 14.36 t ha $^{-1}$. The same trend was noticed in the case of total dry matter production, utilization index, uptake of nutrients and starch content of the tuber. Significantly higher net income (Rs.163900 ha $^{-1}$) and BCR (1.84) were recorded by the modified nutrient dose (n_3) followed by recommended dose of nutrients through fertilizers (n_1).

Regarding interaction effects, November 15 planting with modified nutrient dose recorded significantly taller plants with higher leaf area index during later stages of crop growth. Similarly, the same interaction produced the highest number of marketable tubers per plant and tuber yield. November 15 planted crop with modified nutrient dose registered the highest net income and benefit cost ratio.

Soil analysis after the experiment indicated higher pH and organic carbon contents and lower available N, P and K contents in organically manured plots than fertilizer applied plots.

The study revealed that for off season production of coleus var. Suphala in the southern zone of Kerala, the ideal time of planting is November 15 which recorded higher tuber yield, net income and benefit cost ratio. Modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers + FYM @ 10 t ha^{-1} + neem cake @ 1 t ha^{-1} can be recommended for the crop for getting higher tuber yield, net income and benefit cost ratio.

സംഗ്രഹം

കേരളത്തിൽ കൃഷി ചെയ്തുവരുന്ന കുർക്ക ഇനങ്ങളുടെ വളർച്ചയും വിളവെടുപ്പും സൂര്യപ്രകാശത്തെ ആശ്രയിച്ചിരിക്കുന്നതിനാൽ സാധാരണയായി ജുലായ് - ഒക്ടോബർ മാസങ്ങളിലാണ് കുർക്ക വള്ളികൾ നടുന്നത്. എന്നാൽ കേരള കാർഷിക സർവ്വകലാശാല പുറത്തിറക്കിയ സുഫല എന്ന കൂർക്കയിനം കാലഭേദമന്യേ കൃഷി ചെയ്യാവുന്നതാണ്. കേരളത്തിന്റെ തെക്കൻ മേഖലയിൽ കാലഭേദമന്യേ കൂർക്ക ഉത്പാദനത്തിനുള്ള കൃഷി രീതികളെക്കുറിച്ച് വെള്ളായണി കാർഷിക കോളേജിൽ 2013 നവംബർ മുതൽ 2014 മെയ് വരെ ഗവേഷണം നടത്തുകയുണ്ടായി.സുഫല എന്ന കൂർക്കയിനം ഒക്ടോബറിന് ശേഷം കൃഷി ചെയ്യുന്നതിന് അന്യോജ്യമായ നടീൽ സമയം, പോഷക പരിപാലനം, കൃഷിയുടെ സാമ്പത്തിക വശം എന്നിവ പഠിക്കുകയായിരുന്നു ഈ ഗവേഷണത്തിന്റെ ഉദ്ദേശ്യങ്ങൾ. ഇതിനായി നാല് നടീൽ ദിവസങ്ങളും (നവംബർ 15, ഡിസംബർ 1, ഡിസംബർ 15, ജനുവരി 1) മൂന്നു പോഷകപരിപാലന രീതികളും (കേരള കാർഷിക സർവ്വകലാശാല ശുപാർശ ചെയ്തിട്ടുള്ള അളവിൽ പോഷകമൂലകങ്ങൾ ഹെക്ടറൊന്നിന് 60:60:100 കിലോഗ്രാം എൻ. പി. കെ. രാസവളങ്ങളിലൂടെ; മേൽ പറഞ്ഞ അളവിൽ പോഷകമൂലകങ്ങൾ ജൈവവളങ്ങളിലൂടെ അതായത് 6 ടൺ കാലിവളം+ 3 ടൺ ചകിരിചോർ കമ്പോസ്റ്റ് + 3 ടൺ ചാരം + പി. ജി. പി. ആർ മിക്സ് 1; വ്യത്യാസപ്പെടുത്തിയ അളവിൽ പോഷകമൂലകങ്ങൾ 60:30:120 കിലോഗ്രാം എൻ. പി. കെ. രാസവളങ്ങളിലൂടെ) സ്പ്ലിറ്റ് പ്ലോട്ട് ഡിസൈൻ എന്ന പരീക്ഷണ രീതി അവലംബിച്ച് പഠനവിധേയമാക്കി. എല്ലാ പ്ലോട്ടുകളിലും ഒരു ടൺ വേപ്പിൻ പിണ്ണാക്കും 10 ടൺ കാലിവളവും നൽകിയിരുന്നു.

നാലു നടീൽദിവസങ്ങളിൽ നവംബർ15 -ന് നട്ട ചെടികൾ നല്ല വളർച്ചയും വിളവും രേഖപ്പെടുത്തി. നവംബർ 15 - ന് നട്ടപ്പോൾ ഏറ്റവും കൂടുതൽ വിളവും (ഹെക്ടറൊന്നിന് 14.89 ടൺ) അറ്റാദായവും(ഹെക്ടറൊന്നിന് 1,67,525 രൂപ) വരവ് ചിലവ് അനുപാതവും (1:84) രേഖപ്പെടുത്തി; നടീൽ വൈകുന്നതനുസരിച്ച് ഇവ കുറയുകയും ചെയ്തു. കിഴങ്ങിന്റെ വിളവും വിളകാലത്ത് ലഭിച്ച മഴയുടെ അളവും തമ്മിൽ കാര്യമായ അനുകൂല ബന്ധം കണ്ടു. ശുപാർശ ചെയ്യപ്പെട്ട അളവിൽ നിന്നും വ്യത്യാസപ്പെടുത്തിയ അളവിൽ പോഷകമൂലകങ്ങൾ 60:30:120 കിലോഗ്രാം എൻ. പി.കെ. രാസവളങ്ങളിലൂടെ നൽകിയപ്പോൾ ചെടികൾക്ക് നല്ല വളർച്ചയും ഏറ്റവും കൂടുതൽ വിളവും (ഹെക്ടറൊന്നിന് 14.36 ടൺ) ലഭിച്ചു. കൂടാതെ ഈ പോഷകപരിപാലന രീതി ഏറ്റവും കൂടുതൽ അറ്റാദായവും (ഹെക്ടറൊന്നിന് 163900 രൂപ) വരവ് ചിലവ് അനുപാതവും (1.84) രേഖപ്പെടുത്തി.

സാധാരണ നടീൽ കാലമായ ജൂലായ് - ഒക്ടോബർ ഒഴിച്ചുള്ള സമയത്ത് കേരളത്തിന്റെ തെക്കൻ മേഖലയിൽ സുഫല എന്ന കൂർക്ക ഇനം നടുന്നതിന് ഏറ്റവും യോജിച്ച സമയം നവംബർ 15 ആണെന്ന് ഈ പഠനം തെളിയിച്ചു. ഈ സമയത്ത് ഏറ്റവും കൂടുതൽ വിളവും ആദായവും ലഭിക്കുന്നതിന് ഹെക്ടറൊന്നിന് 10 ടൺ കാലിവളവും ഒരു ടൺ വേപ്പിൻപിണ്ണാക്കും 60:30:120 കിലോഗ്രാം എന്ന അളവിൽ എൻ. പി. കെ.രാസവളങ്ങളിലൂടെ നൽകിയാൽ ഏറ്റവും കൂടുതൽ വിളവും ആദായവും ലഭിക്കുമെന്ന് ഈ പഠനം വ്യക്തമാക്കി.