PRODUCTION TECHNOLOGY FOR ORGANIC COLEUS

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THESIS

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2012

DEDICATED TO MY FATHER AND MOTHER

DECLARATION

I hereby declare that this thesis entitled **"Production technology for organic coleus"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other university or society.

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Certified that this thesis, entitled **"Production technology for organic coleus"** is a record of research work done independently by **ATUL JAYAPAL (2010-11-141)** 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 him.

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27 .07. 2012

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
BCR	Benefit cost ratio
CD	Critical difference
cm	Centimetre
CPC	Coir pith compost
CTCRI	Central Tuber Crops Research Institute
°C	Degree celsius
DMP	Dry matter production
et al	And others
Fig.	Figure
FYM	Farmyard manure
g	Gram
ha	Hectare
K	Potassium
KAU	Kerala Agricultural University
kg	Kilogram
LAI	Leaf Area Index
m	Metre
MAP	Months after planting
N	Nitrogen
P	Phosphorus
t ha^{-1}	Tonnes per hectare
UI	Utilization index
var.	Variety

INTRODUCTION

1. INTRODUCTION

Coleus (*Solenostemon rotundifolius* (Poir) Morton) is a minor tuber crop grown in the homesteads for its edible tubers. It is commonly known as ‘koorka’ or ‘cheevakizhangu’ in Malayalam or Chinese potato, country potato or Hausa potato in English. It belongs to the family Labiatae. The new scientific name is *Plectranthus rotundifolius*. It is believed to have originated in Central or East Africa. The plant is a small herbaceous bushy annual with succulent stems and aromatic leaves. It grows to a height of 30-60 cm. Leaves are opposite, petiolate and rounded to ovate in shape with serrated margin. It bears a cluster of dark brownish heteromorphous tubers. The tubers are used as vegetable having an aromatic flavour and delicious taste on cooking. The quality of tubers seems to be comparable with that of potato and hence known as poor man's potato. It is a short duration crop of about five months and hence is fitted in multiple cropping programmes. Unlike most other vegetables, coleus tubers possess good keeping quality. The tubers are rich in minerals like calcium and iron and certain vitamins including thiamine, riboflavin, niacin and ascorbic acid. The tubers possess anti-oxidant, anti-cancer and anti-ageing properties. The saponins (2-20%) and alkaloids (15-25%) present in the plant are the primary source of its significant medicinal properties (Palaniswami and Peter, 2008). Being a component of export market of vegetables to Middle East countries, lot of potential exists for its commercial cultivation.

Organic farming is a valid alternate approach for sustained production of crops especially tuber crops ensuring food security and safer environment. Increasing consciousness about environment conservation and health hazards associated with the indiscriminate use of agrochemicals and consumer preference for safe and chemical free food led to growing interest in organic farming. With a sizeable acreage coming naturally under organic by default, India has tremendous potential for raising organic crops. Tuber crops, as they are adapted to marginal environments and low input management with high flexibility in mixed farming systems, have wide potential for organic cultivation. Moreover, there is a premium price for organically produced tubers both nationally and internationally. Like other tuber crops, coleus also responds well to application of organic manures.

Organic manures are known to be effective in the maintenance of adequate supply of organic matter in soils with good improvement in soil physical, chemical and biological properties favouring better crop performance. Farm yard manure (FYM) is the traditional organic manure. Inadequate availability of FYM has led us to think of alternate sources of organic manure. Coirpith which is abundantly available in Kerala as a by-product of coir industry has high C: N ratio and its accumulation leads to environmental pollution. But it can be used as organic manure after narrowing its C: N ratio with *Pleurotus*. Wood ash is the indigenous source of potassium. Neem cake is not only an organic manure, but it also acts as a repellent against insect pests and nematodes. Amending the soil with neem cake @ 1 t ha^{-1} was found effective in reducing the incidence of root knot nematode (*Meloidogyne incognita*) in coleus (Nisha, 2005).Biofertilizer is a promising component of organic production system. Use of biofertilizers enhances the efficiency of native and applied nutrients in the soil.

The recommended time of planting of coleus is between July & October (KAU, 2007). Early or late planting reduces tuber yield. Sree Dhara is a high yielding (25 t ha^{-1}) variety of coleus released from Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram with a duration of 5 months. Recently Kerala Agricultural University (KAU) has released one high yielding (15.93 t ha^{-1}) var. Suphala with a duration of 120-140 days and which is adapted for year round cultivation (KAU, 2007).

Even though coleus has high potential for organic production, especially for export oriented market, the full exploitation is still underway as there is no definite recommendation for the same. It has been necessitated to study the response of coleus to different levels of organic manure with and without biofertilizer. Also there is an urgent need to evaluate the performance of the photo-insensitive early maturing coleus var. Suphala in the southern zone of Kerala. Keeping these views under consideration, the present investigation entitled "Production technology for organic coleus" was undertaken to standardize an organic nutrient package for coleus and work out the economics of cultivation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Even though coleus (*Solenostemon rotundifolius* (Poir) Morton) is used as a vegetable in many parts of the world, organic nutrition of coleus has not been standardized. Traditionally tuber crops are fertilized with organic manures only such as farmyard manure and ash and even today this is followed by subsistence farmers (Mohankumar *et al*., 2000). Since these crops are highly responsive to organic manures and less prone to pests and diseases, there is considerable scope for organic nutrition in tuber crops (Suja and Nayar, 2006 and Suja *et al*., 2006).

The potential organic sources of plant nutrients for tuber crops are FYM, poultry manure, different types of compost, wood ash, crop residues, green manures and oil cakes like neem cake. Biofertilizer is one of the important components of organic nutrition as they are cost effective and renewable source of plant nutrients to supplement chemical fertilizers. In the present study, FYM, coir pith compost (CPC) and wood ash were used as sources of organic manure along with and without the biofertilizer, PGPR mix 1. Hence the relevant literature on the effect of different organic manures and biofertilizer application on tuber crops are reviewed in this chapter.

2.1 Effect of organic manures

2.1.1 Effect of farm yard manure

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

2.1.1.1 Growth characters

Cassava showed better response in growth characters when it was applied with FYM @ 12.5 t ha^{-1} (Asokan and Sreedharan, 1977 and KAU, 2007). Among different organic manure like FYM, poultry manure and CPC tried for cassava, Pamila (2003) reported significantly taller plants with higher number of leaves due to application of FYM.

In sweet potato, vine length was recorded to be maximum due to FYM application at all stages except at 40 DAP compared to the application of poultry manure and CPC (Dhanya, 2011).

Archana and Swadija (2000) reported that FYM as the source of organic manure produced higher dry matter production in coleus.

In a study conducted by Veenavidyadharan (2000) in arrowroot, it was found that application of FYM at the highest level (20 t ha^{-1}) increased the plant height, leaf and sucker numbers per hill and dry matter production.

Wildjajanto and Widodo (1982) reported that increasing rates of FYM increased plant height but had inconsistent effect on the number of main stem per hill in potato. Sahota (1983) found that FYM application increased plant height and leaf number in potato.

2.1.1.2 Yield components and yield

Studies done at CTCRI and KAU revealed increase in yield of cassava due to basal application of FYM @ 12.5 t ha^{-1} (Mohankumar *et al*., 1976; Asokan and Sreedharan, 1977; Pillai *et al*., 1987 and Ravindran and Balanambisan, 1987). When FYM alone was applied to cassava, Mohankumar *et al*. (1976) obtained 17.7% increase in yield and Gaur *et al*. (1984) obtained 11.8% increase over control. Gomes *et al*. (1983) observed higher efficiency of FYM in producing higher yield of cassava compared to castor oil cake and urea.

Gaur *et al*. (1984) reported 30.6% increase in yield of sweet potato due to FYM application, over control. Pillai *et al*., 1987 and Ravindran and Balanambisan, 1987 reported that basal application of 5 t ha^{-1} of FYM to sweet potato increased the yield. According to Ravindran and Balanambisan (1987), application of FYM enhanced tuber yield of sweet potato both in lowland and upland situations.

Application of FYM @ 20 t ha^{-1} produced significantly superior tuber yield in *Dioscorea alata* (CTCRI, 1973). But Mohankumar and Nair (1979) suggested the application of FYM @ 20 t ha^{-1} over lower doses (10-15 t ha^{-1}) was not sufficient to compensate the increased cost of FYM and they recommended 10 t ha^{-1} of FYM for economic returns in *Dioscorea alata*.

Application of FYM alone resulted in enhanced yields in EFY (Patel and Mehta, 1987).

Farmyard manure as the source of organic manure for coleus had positive influence on yield and yield components like number and weight of tubers and weight of marketable tubers per plant, as observed by Archana and Swadija (2000).

The profound influence of farm yard manure on number of rhizomes per plant and yield of arrowroot has been reported by Maheswarappa *et al* (1997) and Veenavidyadharan and Swadija (2000).

2.1.1.3 Quality characters

Kurien *et al*. (1976) observed increase in bitterness and cyanogens content in cassava due to application of cowdung alone. A mixture of cowdung and ash tended to reduce the cyanogens. Mohankumar *et al.* (1976) and Pillai *et al.* (1987) reported enhanced quality of cassava tubers due to application of FYM @ 12.5 t ha^{-1}. Pamila *et al*. (2011) reported that application of FYM for cassava produced significantly lower protein and higher HCN contents of tuber than application of poultry manure.

Ravindran and Balanambisan (1987) found that the quality of sweet potato tubers was not much affected when different doses of FYM were applied.

2.1.2 Effect of coir pith compost

Coir pith compost, 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 and its accumulation leads to environmental pollution. Coir pith can be used as a soil conditioner and as organic manure after composting with *Pleurotus* sp.

Significant increase in tuber yield of cassava was reported by Ayyaswami *et al*. (1996) due to incorporation of coir waste @ 10 t ha^{-1} compared to FYM @ 12.5 t ha^{-1} and coir waste @ 5 t ha^{-1}. The positive effect of coir waste may be because of its higher water holding capacity and better nutrient uptake by the crop. Studies conducted at CTCRI for substituting FYM in cassava with pressmud and CPC showed that there was no conspicuous yield variation among them, suggesting the suitability of CPC or pressmud as an alternative to FYM in cassava (CTCRI, 1998). Pamila *et al.*(2006) reportedno significant difference in the tuber yield of cassava in lowland between FYM and CPC indicating the possibility of substitution of FYM with CPC. Pamila *et al.* (2011) reported no marked variation in the quality characters of cassava due to source of organic manure suggesting the suitability of poultry manure and CPC as alternate sources to FYM.

Archana and Swadija (2000) opined that FYM can be substituted with CPC and neem cake in equal proportions if there is scarcity of FYM and if CPC is easily available.

Maheswarappa *et al*. (1997) observed application of CPC produced lower values of growth characters, yield components and quality parameters of arrowroot.

Suja (2001) reported that application of CPC to white yam increased vine length, number of functional leaves, LAI, biomass production and uptake of N and K. 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.

2.2 Effect of biofertilizers

Sattar and Gaur (1987) observed improvement in plant growth and development by the production of plant growth hormones like IAA, GA and cytokinins by P-solubilizers.

Good responses have been reported in many crops in recent years by the use of biofertilizers like *Azospirillum*, *Azotobacter* and P solubilising bacteria. As a renewable source of energy and cost effective supplement to chemical fertilizers, biofertilizers can help to economize on the high investment recorded for fertilizer use as far as N and P are concerned (Pandey and Kumar, 2002).

Conjoint use of biofertilizers like *Azospirillum* and phosphobacteria can reduce 50% of N and P fertilizer dose for cassava as reported by Geetha *et al*. (2001) and Suja *et al*. (2005).

Nair *et al*. (2001) found that inoculation of *Azospirillum* in the rhizosphere of sweet potato is helpful in substituting 25-50 % N applied to the crop. Saikia and Borah (2007) observed that inoculation of *Azospirillum* could save 1/3rd of RD of N and P in sweet potato and could give higher net returns and BCR from sweet potato cultivation. However, the effect of mixing organic manure with microbial consortium of *Azospirillum, Azotobacter* and P solubilising bacteria @ 1% failed to produce any significant effect on the growth and yield of sweet potato (Dhanya, 2011).

Swadija *et al*. (2011) reported that application of biofertlizers (*Azospirillum* and phosphobacteria) along with different doses of FYM increased the rhizome yield of arrow root over respective treatments without biofertilizers.

2.3 Combined effect of organic manures and biofertilizers

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 Suja *et al*., 2008). The organic farming technology package standardized for elephant foot yam includes the application of farm yard manure @ 36 t ha^{-1}, green manuring with cowpea to generate 20-25 t ha^{-1} of green matter in 45-60 days, neem cake @ 1 t ha^{-1} and ash @ 3 t ha^{-1}. On farm trials revealed the superiority of organic farming practised over farmer's practice and conventional practice (POP- FYM @ 25 t ha^{-1} + NPK @ 100:50:150 kg ha^{-1}) as reported by Suja *et al*., 2010. Organic farming practice produced significantly higher corm yield and higher net income and BCR at all locations. Dry matter content of the corms was significantly higher and oxalate content was significantly lower.

According to Suja *et al*. (2009), FYM application @ 12.5 t ha^{-1} along with wood ash @ 3 t ha^{-1} favoured growth, biomass partitioning and yield attributes contributing to higher yield of tannia. Combined application of FYM @ 12.5 t ha^{-1} mycorrhiza @ 5 kg ha^{-1}, *Azospirillum* @ 3 kg ha^{-1} and phosphobacteria 2.5 kg ha^{-1} produced yield of tannia on par with that produced by the farmer's practice of application of FYM @ 25 t ha^{-1} + ash @ 2 t ha^{-1}. Results of 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. The organic farming technology package developed from the study comprised of FYM @ 20 t ha^{-1}, green manuring with cowpea to generate 15-20 t ha^{-1} of green matter in 45-60 days, neemcake @ 1 t ha^{-1} and ash @ 2 t ha^{-1} (Suja *et al*., 2009).

The study conducted by Dhanya (2011) revealed that nutrient sources tested namely farm yard manure, poultry manure and coir pith compost were equally effective on the growth and yield of sweet potato. The full recommended dose of nutrients through organic manures was required for expressing the yield potential of the crop. Regarding the quality of tubers, plants treated with FYM recorded higher starch content on par with CPC treated plants and significantly superior to poultry manure but sugar content of tuber was not affected by the source of organic manure. Full RD on NPK through organic manure recorded significantly higher starch and sugar contents. Considering the economics, organic production system was found economically feasible. Poultry manure @ 100% RD was the best treatment followed by FYM @ 100% RD with BCR of 2.03 and 1.81 respectively.

Swadija *et al*. (2011) reported that organic nutrition had significant influence on rhizome yield of arrow root intercropped in the homesteads. The yield data indicated sufficiency of FYM @ 15 t ha^{-1} along with biofertilizers (*Azospirillum* and phosphobacteria) for realising the higher rhizome yield of arrow root intercropped in the homesteads. The highest net return of Rs.74, 450 and BCR of 1.99 were recorded by the treatment FYM @ 15 t ha^{-1} + biofertilizers.

A scan of literature indicates the feasibility of organic nutrition in tuber crops. Hence the present study is undertaken to study the organic nutrient package for coleus. Archana and Swadija (2000) found FYM as the best source of organic manure for coleus. But it can be substituted half with neem cake and half with CPC wherever CPC is easily available. Suja (2001) and Suja and Nayar (2006) suggested CPC as an alternative to FYM for white yam production. Pamila *et al*., 2006 opined that CPC can be used as an alternate source of manure provided it is made cost effective. Hence in the present study, half the RD of nutrients was applied through FYM and half through CPC. Use of biofertilizer along with organic manure may reduce the dose of organic manure. So three levels of organic manure (to supply 100%, 75% and 50% of RD of NPK) with and without the biofertilizer, PGPR mix 1 were tried in the present study. It is also further envisaged to study where there is varietal variation in response to organic nutrition by including two high yielding varieties namely Sree Dhara and Suphala in the present study.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was carried out at College of Agriculture, Vellayani to standardize an organic nutrient package for coleus and 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 the College of Agriculture, Vellayani situated at 8.5° North latitude and 76.9° East longitude and 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 5.8. It was high in organic carbon and available P, low in available N and medium in available K contents.

3.1.3 Cropping history of the field

The experimental area was lying fallow for six months prior to this experiment.

3.1.4 Season

The investigation was conducted during August to December 2011.

3.1.5 Weather conditions

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

3.1.6 Planting material

Coleus varieties Sree Dhara released from CTCRI, Sreekariyam, Thiruvananthapuram and Suphala, released from KAU, Vellanikkara, Thrissur were used for the experiment. Sree Dhara is a high yielding (25 t ha^{-1}) variety of coleus with a duration of five months.

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

Sl.no	Parameter	Content	Method
A. Mechanical composition			
1.	Coarse sand (%)	52.6	International pipette method (Piper, 1966)
2.	Fine sand (%)	15.2	
3.	Silt (%)	7.9	
4.	Clay (%)	25.3	
	Texture - Sandy clay loam		
B. Chemical composition			
1.	pH	5.8	pH meter with glass electrode (Jackson, 1973)
2.	Organic carbon (%)	1.46	Wet oxidation method (Walkely and Black, 1934)
3.	Available N (kg ha^{-1})	188.16	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
4.	Available P (kg ha^{-1})	48.16	Bray colorimeter method (Jackson, 1973)
5.	Available K (kg ha^{-1})	125.89	Neutral normal ammonium acetate method (Jackson, 1973)

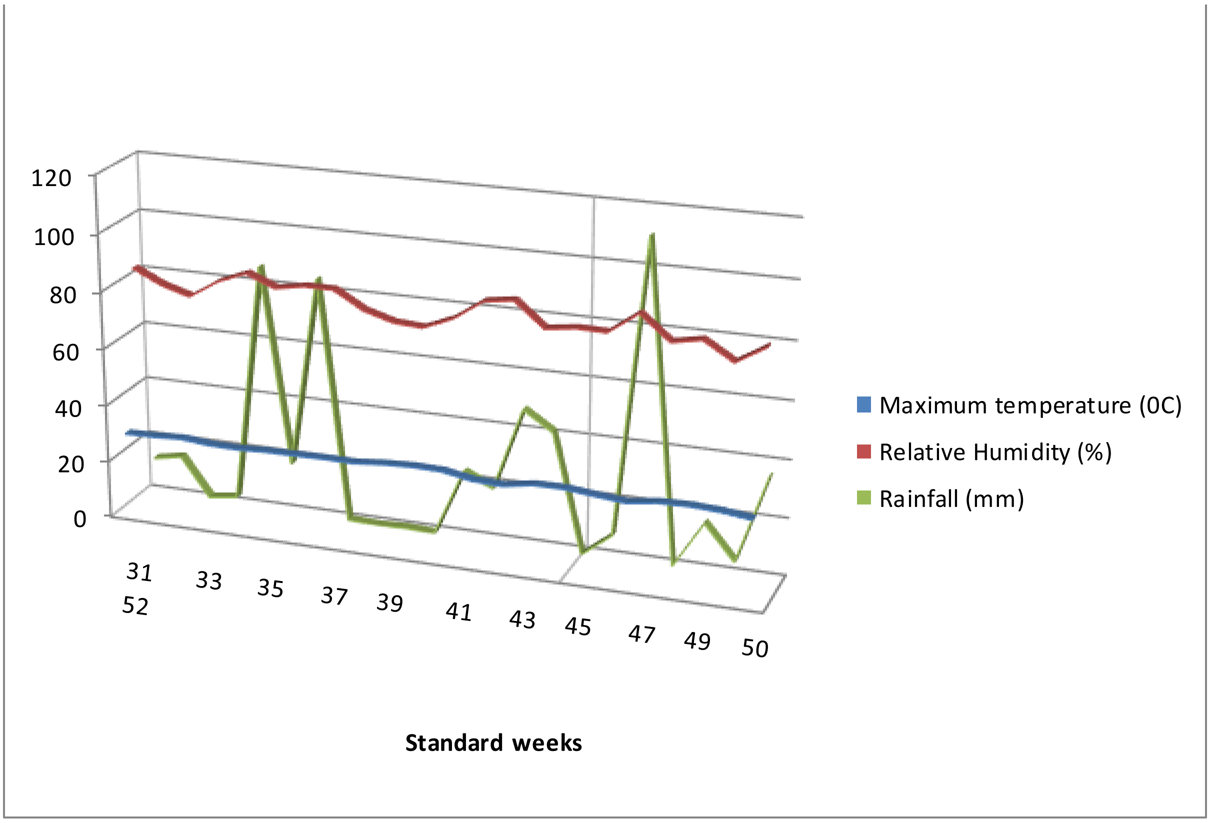


Fig. 1 Weather data during the cropping period

Suphala is a high yielding (15.93 t ha^{-1}), photo-insensitive variety which is adapted for year round cultivation with a duration of 120-140 days (KAU, 2007).

3.1.7 Organic Manures

Organic manures used in the experiment were FYM analysing 0.5 % N, 0.3% P_2O_5, 0.2% K_2O, CPC containing 1 % N, 0.12 % P_2O_5, 1 % K_2O and wood ash containing 0.52 % N, 1.04 %P_2O_5 and 2.2 % K_2O.

3.2 Methods

3.2.1 Details of treatments

The treatments consisted of factorial combinations of three levels of organic manure with and without biofertilizer and two varieties.

i) Levels of organic manure (M)

(Half the dose as FYM + Half the dose as CPC)

m_1-to supply 100% recommended dose (RD) of 60:60:100 kg NPKha^{-1}(KAU, 2007)

m_2-to supply 75% RD of NPK

m_3-to supply 50% RD of NPK

The dose of FYM and CPC were fixed on N equivalent basis and additional requirement of K was supplied through wood ash.

ii) Biofertilizer (B)

b_1- with PGPR mix 1

b_2- without biofertilizer

iii) Varieties (V)

v_1- Sree Dhara

v_2- Suphala

Treatment combinations

T_1- $m_1b_1v_1$	T_5- $m_2b_1v_1$	T_9- $m_3b_1v_1$
T_2- $m_1b_1v_2$	T_6- $m_2b_1v_2$	T_{10}- $m_3b_1v_2$
T_3- $m_1b_2v_1$	T_7- $m_2b_2v_1$	T_{11}- $m_3b_2v_1$
T_4- $m_1b_2v_2$	T_8- $m_2b_2v_2$	T_{12}- $m_3b_2v_2$

3.2.2 Experimental design and layout

The experiment was laid out as a 3x2x2 asymmetrical factorial RBD. The layout plan is given in Fig. 2.

The details of the layout are given below:

Design	- RBD
Treatment combinations	- 12
Replication	- 3
Total number of plots	- 36
Plot size	- 3 m x 3 m
Spacing	- 30 cm x 15 cm

3.2.3 Details of cultivation

3.2.3.1 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. Vine cuttings of length of 10-15cm of two varieties of coleus were planted at a spacing of 30 cm x 15 cm during the first week of July 2011. Healthy and vigorous cuttings of length of 10-15 cm from the apical portions were taken for planting in the main field.

Plate 1. General view of nursery

3.2.3.2 Preparation of main field

The experimental area was cleared, ploughed 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.

3.2.3.2 Application of manures and biofertilizer

Neem cake @ 1 t ha^{-1} and FYM @ 10 t ha^{-1} were applied uniformly to all the plots. The required quantities of FYM and CPC as per the treatments were applied to the plots and well incorporated into the soil.Wood ash was applied six weeks after planting in appropriate quantities as per the treatments and mixed with soil.

The biofertilizer, PGPR mix I, received from the department of Microbiology, College of Agriculture, Vellayani is a combination of N fixing and P and K solubilizing bacteria. It was applied @ 2% along with basal dose of organic manures.

3.2.3.3 Planting

Coleus cuttings taken from the nursery were planted in the main field during the first week of August 2011, at a spacing of 30 cm x 15cm. Shade was provided immediately after planting and uniform irrigation was given.

3.2.3.4 After cultivation

Gap filling was done a week after planting to have uniform stand of the crop. The first intercultural operation, weeding and earthing up were done three weeks after planting. Second weeding, application of wood ash and earthing up were done six weeks after planting. A portion of the vine was covered with soil to promote tuber formation.

3.2.3.5 Harvest

The crop was harvested by the third week of December 2011. Harvesting was done by digging out tubers carefully and tubers were separated from shoot portion. The border rows and observational plants were harvested separately from each plot.

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.

N

R I	R II	R III
$m_3b_1v_2$	$m_3b_2v_1$	$m_2b_1v_1$
$m_3b_1v_1$	$m_1b_1v_1$	$m_2b_1v_2$
$m_2b_2v_2$	$m_1b_2v_2$	$m_1b_1v_1$
$m_1b_2v_1$	$m_1b_1v_2$	$m_1b_2v_2$
$m_2b_2v_1$	$m_3b_1v_1$	$m_1b_2v_1$
$m_2b_1v_1$	$m_2b_1v_2$	$m_3b_1v_2$
$m_1b_1v_1$	$m_2b_1v_1$	$m_2b_2v_2$
$m_1b_2v_2$	$m_3b_1v_2$	$m_3b_2v_1$
$m_1b_1v_2$	$m_2b_2v_2$	$m_3b_1v_1$
$m_2b_1v_2$	$m_2b_2v_1$	$m_1b_1v_2$
$m_3b_2v_1$	$m_3b_2v_2$	$m_2b_2v_1$
$m_3b_2v_2$	$m_1b_2v_1$	$m_3b_2v_2$

Fig.2. Layout plan of the experiment

Plate 2. General view of experimental field

3.3.1 Growth characters

Growth characters were recorded from the five observational plants at monthly intervals from planting upto harvest and the 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 Branches per plant

Numbers of branches per plant were counted and recorded.

3.3.1.3 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 Tuber number per plant

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

3.3.2.2 Marketable tuber number per plant

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

3.3.2.3 Percentage number of marketable tubers per plant

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

3.3.2.4 Tuber weight per plant

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

3.3.2.5 Marketable tuber weight 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

3.3.2.7Tuber 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 $70 \pm 5\ ^{O}C$ 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 characters of tuber

3.3.4.1. Starch content

Starch content of tuber was estimated by using potassium ferri cyanide 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 % of N in tuber with the factor 6.25 (Simmpson *et al.*, 1965)

3.3.4.3 Shelf life

Samples of tubers weighing 100g each taken from all the treatments were arranged over newspaper spread on floor under ambient conditions and observed for shelf life of tubers. Every day the tubers were observed for sprouting and decay. The weight of samples was recorded once in three days to calculate physiological loss in weight (PLW) using the formula as given below.

$$PLW\ (\%) = \frac{(\text{Initial weight- Final weight})}{\text{Initial weight}} \times 100$$

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 was analysed for mechanical composition and physico - chemical properties. After the experiment, compositesamples were collected from each plot, air dried, powdered and passed through a 2 mm sieve and analysed for available NPK 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 NPK at harvest. The tubers and shoot portions 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 nutrient contents.

3.4.2.1 N uptake

The N content in plant samples was estimated by the modified micro kjeldhal method (Jackson, 1973) and uptake of N was calculated by multiplying the N content of plant sample with the total dry weight of plants. 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 in plant sample with total dry weight of plants. The uptake was 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 with total dry weight of plants. 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 crop period. Soil samples were analysed for nematode population during the cropping period at (3 MAP).

3.6 Economics of cultivation

The economics of cultivation of the crop in terms of net income and benefit cost ratio (BCR) was worked out as follows.

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

BCR = Gross income ÷ Cost of cultivation.

3.7 Statistical analysis

The experimental data was analysed statistically by applying the technique of analysis of variance (ANOVA) for 3 x 2 x 2 factorial RBD 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.

RESULTS

4. RESULTS

The field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from August to December 2011 to standardise an organic nutrient package for coleus and work out the economics of cultivation. The experiment was laid out in asymmetrical factorial RBD with 12 treatments and three replications. The experimental data was statistically analysed and the results are presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Plant height

The effect of levels of organic manure (M), biofertilizer (B) and variety (V) on plant height of coleus plant at monthly intervals starting from 1MAP is given in Table 2a.

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

There was no significant difference in plant height due to application of different levels of organic manure at any stage of the growth.

The use of biofertilizer also had no significant influence on plant height at any growth stage.

The two varieties tested had no significant influence in plant height at 1MAP and 2 MAP. However, var. Sree Dhara (v_1) showed a significant increase in plant height over var. Suphala (v_2) at 3 MAP and 4 MAP. The var. Sree Dhara recorded plant height of 36.35 cm while var. Suphala recorded 25.44 cm at 3 MAP. At 4 MAP, var. Sree Dhara recorded a height of 39.03 cm while var. Suphala recorded 28.90 cm.

Regarding the interaction effect (Table 2b), significant interaction between M, B and V was observed at 1 MAP. The treatment combination $m_1b_1v_1$ registered the highest value but was on par with $m_1b_2v_2$, $m_3b_1v_2$, $m_2b_1v_1$, $m_2b_1v_2$ and $m_3b_2v_1$. The lowest value was recorded by $m_3b_2v_2$.

4.1.2 Branch number per plant

The influence of levels of organic manure, biofertilizer and varieties on number of branches per plant at monthly intervals is presented in Table 3.

Table 2a.Effect of levels of organic manure, biofertilizer and varieties on plant height (cm)

Treatment	Plant height (cm)			
	1 MAP	2 MAP	3 MAP	4 MAP
Levels of organic manure				
m_1 (100% RD)	20.97	25.69	31.86	35.99
m_2 (75% RD)	19.11	23.91	30.69	33.47
m_3(50% RD)	19.22	22.83	30.14	32.43
SE	0.76	1.31	1.91	1.72
CD (0.05)	NS	NS	NS	NS
Biofertilizer				
b_1(With PGPR mix 1)	20.16	24.61	31.92	35.05
b_2(Without PGPR mix 1)	19.37	23.68	29.87	32.88
SE	0.62	1.07	1.56	1.40
CD (0.05)	NS	NS	NS	NS
Varieties				
v_1 (Sree Dhara)	19.68	25.53	36.35	39.03
v_2 (Suphala)	19.85	22.76	25.44	28.90
SE	0.62	1.07	1.56	1.40
CD (0.05)	NS	NS	4.567	4.119

NS – Non Significant

Table 2b. Interaction effect of levels of organic manure, biofertilizer and varieties on plant height(cm)

Treatments	Height (cm) at 1 MAP
$m_1b_1v_1$	23.55
$m_1b_1v_2$	18.66
$m_1b_2v_1$	18.66
$m_1b_2v_2$	22.99
$m_2b_1v_1$	19.66
$m_2b_1v_2$	19.66
$m_2b_2v_1$	18.11
$m_2b_2v_2$	18.99
$m_3b_1v_1$	18.66
$m_3b_1v_2$	20.77
$m_3b_2v_1$	19.44
$m_3b_2v_2$	18.00
SE	1.523
CD	4.468

Table 3.Effect of levels of organic manure, biofertilizer and varieties on branch number per plant

Treatment	1 MAP	2 MAP	3 MAP	4 MAP
Levels of organic manure				
m_1 (100% RD)	17.00	11.80	9.75	7.64
m_2 (75% RD)	14.81	12.19	9.41	7.29
m_3 (50% RD)	13.86	11.78	9.91	7.19
SE	0.77	0.48	0.40	0.41
CD (0.05)	2.266	NS	NS	NS
Biofertilizer				
b_1 (With PGPR mix 1)	15.92	12.48	10.13	7.42
b_2 (Without PGPR mix 1)	14.52	11.37	9.26	7.33
SE	0.63	0.39	0.33	0.33
CD (0.05)	NS	NS	NS	NS
Varieties				
v_1 (Sree Dhara)	14.92	12.50	10.54	7.94
v_2 (Suphala)	15.52	11.35	8.85	6.81
SE	0.63	0.39	0.33	0.33
CD (0.05)	NS	NS	0.957	0.972

NS – Non Significant

Number of branches per plant showed a decreasing trend with increasing age of the plants. The levels of organic manure had significant influence at 1 MAP, but at later stages, the effect turned non significant. At 1 MAP, m_1 (100% level) produced 17 branches per plant which was on par with m_2 (75% level) but was superior to m_3 (50% level).

Application of biofertilizer produced no significant difference in number of branches per plant throughout the crop period.

No significant difference in number of branches per plant between varieties was observed at earlier stages of the crop, but significant difference was seen at 3 MAP and 4MAP. At both stages, the var. Sree Dhara recorded a higher number of branches (10.54 and 7.94) than the var. Suphala (8.85 and 6.81 respectively).

4.1.3 Leaf number per plant

The data on the effect of levels of organic manure, biofertilizer and varieties on leaf number per plant at monthly intervals are shown in Table 4a.

Leaf number per plant showed a decreasing trend with increase inthe age of the crop.

The levels of organic manure had significant effect at 1 MAP and 3MAP only. At 1 MAP, the plots which were given full RD (m_1) produced more number of leaves (123.17) which was on par with m_2 but was superior to m_3. At the same time, the levels m_2 and m_3 were on par in their effects. At 3 MAP, m_1 level recorded the highest number of leaves (67.30) which was significant over m_2 (57.66) and m_3 (53.22) which were on par.

Biofertilizer had significant effect at 1 MAP, but did not show any significant influence at other stages of the crop. At 1 MAP, leaf number per plant increased due to biofertilizer application.

There was significant varietal difference in leaf production at all stages of the crop. The var. Suphala produced more leaves at 1 MAP, but the var. Sree Dhara recorded more leaves at other stages.

With respect to interaction effects (Table 4b), only the interaction M x V was significant at 4 MAP. The treatment combinations involving v_1 recorded higher values than with v_2. The treatment combination $m_3v_1$recorded the highest number of leaves but was on par with m_2v_1 while the treatment combination m_2v_2 was superior to m_1v_2 and m_3v_2.

Table 4a.Effect of levels of organic manure, biofertilizer and varieties on leaf number per plant

Treatment	1 MAP	2 MAP	3 MAP	4 MAP
Levels of organic manure				
m_1 (100% RD)	123.17	92.38	67.30	30.11
m_2 (75% RD)	110.44	92.27	57.66	33.94
m_3 (50% RD)	106.33	92.08	53.22	32.98
SE	4.69	4.49	2.71	1.43
CD (0.05)	13.745	NS	7.952	NS
Biofertilizer				
b_1 (With PGPR mix 1)	119.63	92.90	60.37	33.98
b_2 (Without PGPR mix 1)	107.00	91.59	58.42	30.71
SE	3.83	3.67	2.21	1.17
CD (0.05)	11.223	NS	NS	NS
Varieties				
v_1 (Sree Dhara)	106.11	100.72	75.85	43.94
v_2 (Suphala)	120.51	83.77	42.94	20.75
SE	3.83	3.67	2.21	1.17
CD (0.05)	11.223	10.763	6.493	3.426

NS – Non Significant

Table 4b. Interaction effect of levels of organic manure, biofertilizer and varieties on number of leaves per plant

Treatments	Leaf number at 4 MAP
m_1b_1	33.81
m_1b_2	26.42
m_2b_1	33.58
m_2b_2	34.30
m_3b_1	34.55
m_3b_2	31.42
SE	2.022
CD	NS
m_1v_1	41.55
m_1v_2	18.67
m_2v_1	42.55
m_2v_2	25.33
m_3v_1	47.72
m_3v_2	18.25
SE	2.022
CD	5.933
b_1v_1	44.85
b_1v_2	23.11
b_2v_1	43.03
b_2v_2	18.39
SE	1.651
CD	NS

NS – Non Significant

4.1.4 Leaf area index

The effect of treatments on LAI is presented in Table 5a.

The levels of organic manure had significant influence on LAI at 1 MAP and 4 MAP. At 1 MAP, m_1 showed maximum LAI (4.08) and was on par with m_2 (3.66), but the effects of m_2 and m_3 were on par. At 4 MAP, LAI significantly increased with increase in the level of organic manure with the $m_1$level recording the highest value (0.86).

The effect of biofertilizer was significant effects at 1 MAP and 4 MAP only. At both stages, biofertilizer treated plots produced higher LAI (4.03 and 0.64 respectively) than plots without biofertilizer.

There was significant difference in LAI between varieties at all stages except at 2 MAP. At 1 MAP, the var. Suphala recorded LAI of 3.93 than the var. Sree Dhara (3.32). But the significance got levelled off at 2 MAP. At 3 MAP and 4 MAP, the var. Sree Dhara recorded higher LAI than the var. Suphala.

Regarding interactions (Table 5b), only M x V had significant influence on LAI at 4 MAP. At m_1 and m_2 levels the variety v_1 produced significantly higher LAI than the variety v_2. But both varieties were found on par at m_3 level. The variety v_1 showed significant decrease in LAI with decrease in the level of organic manure. But the variety v_2 produced significantly higher LAI at m_1 level than m_2 and m_3 levels which were on par. The effect of higher order interaction M x B x V was significant at 1MAP and 4 MAP (Table 5c). At 1 MAP, the treatment combinations $m_1b_1v_1$ registered the highest LAI but was on par with $m_1b_1v_2$, $m_2b_1v_2$, $m_3b_1v_2$. At 4 MAP, the highest LAI was recorded by $m_1b_2v_1$ which was on par with $m_1b_1v_1$ and $m_2b_1v_1$.

4.2 YIELD AND YIELD COMPONENTS

The results pertaining to the effect of levels of organic manure, biofertilizer and varieties on yield and yield components at harvest are presented in Table 6 and 7.

4.2.1 Tuber number per plant

It can be seen from Table 6 that the effect of levels of organic manure, biofertilizer and varieties recorded significant influence on tuber number per plant.

Table 5a.Effect of levels of organic manure, biofertilizer and varieties on LAI

Treatment	1 MAP	2 MAP	3 MAP	4 MAP
Levels of organic manure				
m_1 (100% RD)	4.08	3.40	2.37	0.86
m_2 (75% RD)	3.66	3.37	2.21	0.60
m_3 (50% RD)	3.15	2.93	2.45	0.29
SE	0.23	0.25	0.16	0.03
CD (0.05)	0.683	NS	NS	0.100
Biofertilizer				
b_1 (With PGPR mix 1)	4.03	3.32	2.36	0.64
b_2 (Without PGPR mix 1)	3.22	3.14	2.34	0.52
SE	0.19	0.21	0.13	0.03
CD (0.05)	0.558	NS	NS	0.082
Varieties				
v_1 (Sree Dhara)	3.32	3.24	3.11	0.81
v_2 (Suphala)	3.93	3.23	1.59	0.35
SE	0.19	0.21	0.13	0.03
CD (0.05)	0.558	NS	0.380	0.082

NS – Non Significant

Table 5b. Interaction effect of levels of organic manure, biofertilizer and varieties on LAI

TREATMENTS	LAI at 4 MAP
m_1b_1	0.92
m_1b_2	0.80
m_2b_1	0.72
m_2b_2	0.49
m_3b_1	0.28
m_3b_2	0.29
SE	0.048
CD	NS
m_1v_1	1.21
m_1v_2	0.51
m_2v_1	0.92
m_2v_2	0.29
m_3v_1	0.32
m_3v_2	0.25
SE	0.048
CD	0.142
b_1v_1	0.85
b_1v_2	0.43
b_2v_1	0.78
b_2v_2	0.27
SE	0.039
CD	NS

NS – Non Significant

Table 5c. Higher order interaction effect of levels of organic manure, biofertilizer and varieties on LAI

Treatments	LAI at 1 MAP	LAI at 4 MAP
$m_1b_1v_1$	5.31	1.18
$m_1b_1v_2$	4.01	0.65
$m_1b_2v_1$	3.07	1.23
$m_1b_2v_2$	3.91	0.36
$m_2b_1v_1$	3.48	1.08
$m_2b_1v_2$	4.69	0.36
$m_2b_2v_1$	2.84	0.75
$m_2b_2v_2$	3.62	0.22
$m_3b_1v_1$	2.49	0.29
$m_3b_1v_2$	4.22	0.27
$m_3b_2v_1$	2.76	0.35
$m_3b_2v_2$	3.12	0.23
SE	0.466	0.068
CD	1.37	0.200

Regarding the levels of organic manure, the effect of m_1 (100%) and m_2 (75%) levels were on par but were superior to m_3(50%) level.

Application of the biofertilizer PGPR mix 1 (b_1) registered significantly higher number of tubers per plant.

The var. Sree Dhara (v_1) recorded significantly higher number of tubers per plant (34.06) than the var. Suphala (v_2).

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

4.2.2 Marketable tuber number per plant

As in the case of total tuber number per plant, the levels of organic manure, biofertilizer and varieties had significant influence on number of marketable tubers per plant (Table 6).

The effect of m_1 (100%) and m_2 (75%) levels were on par but superior to m_3 (50%) level.

Biofertilizer treated plants showed significantly higher number of tubers (12.47) per plant.

The var. Sree Dhara produced significantly higher number of marketable tubers (12.61) per plant.

Interaction effects were not significant with respect to this parameter.

4.2.3 Percentage number of marketable tubers per plant

The data in Table 6 revealed no significant effect of levels of organic manure and biofertilizer on percentage number of marketable tubers per plant.

There was significant difference in percentage number of marketable tubers per plant between the varieties. The var. Suphala (v_2) recorded significantly higher percentage number of marketable tubers per plant.

None of the interactions were significant in their effects on this parameter.

Table 6.Effect of levels of organic manure, biofertilizer and varieties on tuber number per plant

Treatment	Tuber number/plant	Marketable tuber number/plant	Percentage number of marketable tubers/ plant
Levels of organic manure			
m_1 (100% RD)	29.88	12.58	44.26
m_2 (75% RD)	28.08	12.25	46.91
m_3 (50% RD)	22.58	9.67	46.75
SE	0.94	0.43	2.671
CD (0.05)	2.757	1.262	NS
Biofertilizer			
b_1 (With PGPR mix 1)	29.17	12.47	44.94
b_2 (Without PGPR mix 1)	24.53	10.53	47.01
SE	0.77	0.35	2.181
CD (0.05)	2.251	1.030	NS
Varieties			
v_1 (Sree Dhara)	34.06	12.61	37.21
v_2 (Suphala)	19.64	10.39	54.73
SE	0.77	0.35	3.084
CD (0.05)	2.251	1.030	6.400

NS – Non Significant

4.2.4 Tuber weight per plant

Similar to tuber number per plant, tuber weight per plant was also significantly influenced by levels of organic manure, biofertilizer and varieties (Table 7).

The tuber weight per plant significantly increased with increase in the level of organic manure from 50% to 100%with the highest value of 146.56 g recorded by m_1 level.

Significant increase in tuber weight per plant was observed due to application of PGPR mix 1.

The var. Sree Dhara (v_1) was found superior to the var. Suphala (v_2) in producing higher tuber weight per plant(105.96 and 97.01 respectively).

The interaction effects were not significant.

4.2.5 Marketable tuber weight per plant

The weight of marketable tubers per plant was significantly influenced by the level of organic manure, biofertilizer and varieties (Table 7).

The weight of marketable tubers per plant significantly increased with increase in the level of organic manure as in the case of tuber weight per plant. The highest value of 97.71 g was shown by m_1 level.

Application of biofertilizer (b_1) significantly increased the weight of marketable tubers per plant from 77.43 g (without biofertilizer) to 92.72 g.

The var. Sree Dhara (v_1) produced significantly higher weight of marketable tubers per plant (88.21 g) than the var. Suphala (v_2).

The interactions failed to produce significant effects.

4.2.6 Percentage weight of marketable tubers per plant

The data in Table 7 showed an increase in the percentage weight of marketable tubers per plant with increase in the level of organic manure, but the effect was not significant.

Table 7. Effect of levels of organic manure, biofertilizer and varieties on tuber weight per plant

Treatment	Tuber weight/ plant (g)	Marketable tuber weight/ plant (g)	Percentage weight of marketable tubers/ plant
Levels of organic manure			
m_1 (100% RD)	114.56	97.71	85.14
m_2 (75% RD)	104.31	86.88	83.33
m_3 (50% RD)	85.58	70.65	82.69
SE	2.10	1.45	1.22
CD (0.05)	6.160	4.265	NS
Biofertilizer			
b_1 (With PGPR mix 1)	107.58	92.72	86.14
b_2 (Without PGPR mix 1)	95.39	77.43	81.30
SE	1.71	1.19	0.99
CD (0.05)	5.030	3.483	2.918
Varieties			
v_1 (Sree Dhara)	105.96	88.21	82.83
v_2 (Suphala)	97.01	81.94	84.60
SE	1.71	1.19	0.99
CD (0.05)	5.030	3.483	NS

NS – Non Significant

There was significant difference in percentage weight of marketable tubers per plant due to application of biofertilizer (b_1). PGPR treated plants recorded on an average 86.14% of marketable tubers per plant while plants without biofertilizer recorded an average value of 81.30%.

Although there was no significant varietal difference in the percentage weight of marketable tubers per plant, the var. Suphala (v_2) registered higher value of 84.6% as against 82.83% for the var. Sree Dhara (v_1).

The interaction effects were not significant.

4.2.7 Tuber yield per hectare

The results pertaining to tuber yield (t ha^{-1}) is presented in Table 8.

It is observed that the tuber yield significantly increased with increase in the level of organic manure. The m_1 level recorded the highest tuber yield of 23.49 t ha^{-1} while m_2 recorded 22.42 t ha^{-1}. The lowest yield of 19.88 t ha^{-1} was recorded by $m_3$level.

Application of biofertilizer significantly increased the tuber yield from 20.78 t ha^{-1} (without biofertilizer) to 23.07 t ha^{-1}.

There was significant varietal difference in tuber yield. The var. Sree Dhara (v_1) produced higher tuber yield of 22.86 t ha^{-1}than the var. Suphala (v_2) which produced 20.99 t ha^{-1}.

The interactions effects on tuber yield were not significant.

4.3 PHYSIOLOGICAL PARAMETERS

The mean values of total dry matter production at harvest and utilization index are given in Table 9.

4.3.1 Dry matter production

The data in Table 9 revealed significant effect of levels of organic manure on dry matter production. Dry matter production significantly increased with increase in the level of organic manure. The level m_1 (100% RD) recorded the highest quantity of dry matter(7.03 t ha^{-1}) and the level m_3 (50% RD) registered the lowest quantity of dry matter (5.68 t ha^{-1}).

Table 8. Effect of levels of organic manure, biofertilizer and varieties on tuber yield (t ha^{-1})

Treatment	Tuber yield (t ha^{-1})
Levels of organic manure	
m_1 (100% RD)	23.49
m_2 (75% RD)	22.42
m_3 (50% RD)	19.88
SE	0.33
CD (0.05)	0.979
Biofertilizer	
b_1 (With PGPR mix 1)	23.07
b_2 (Without PGPR mix 1)	20.78
SE	0.27
CD (0.05)	0.799
Varieties	
v_1 (Sree Dhara)	22.86
v_2 (Suphala)	20.99
SE	0.27
CD (0.05)	0.799

NS – Non Significant

Biofertilizer application significantly enhanced dry matter production.

The var. Sree Dhara (v_1) recorded significantly higher dry matter (6.69 t ha^{-1}) than the var. Suphala (v_2 - 5.99 t ha^{-1}).

None of the interaction effects were significant with regard to dry matter production.

4.3.2 Utilization index

It can be seen from Table 9 that the levels of organic manure varied significantly in their effects on utilization index.The levels m_1 (100%) and m_2 (75%) were on par but superior to m_3 (50%) level in their effects in utilization index.

The biofertilizer treated plants registered significantly higher UI of 2.35.

There was no significant difference in utilization index between varieties.

The interactions registered no significant effect on utilization index.

4.4 Quality characters of tuber

The results of the effect of levels of organic manure, biofertilizer and varieties on quality characters of tuber are presented in Table 10a and 10b.

4.4.1 Starch content

The mean values given in Table 10a showed no significant difference in starch content of tuber due to different levels of organic manure or due to biofertilizer application.

There was no significant difference between varieties in their starch content of tuber. However, var. Sree Dhara produced a higher starch content of 72.45 % than the var. Suphala which produced 70.69% starch.

4.4.2 Protein content

There was no significant difference in protein content of tuber due to levels of organic manure or biofertilizer application (Table 10a). But $m_1$level of organic manure produced the highest content of protein.

Varieties also did not register significant difference in protein content but the var. Sree Dhara registered higher protein content (7.58 %) than the var. Suphala (6.81 %).

Table 9. Effect of levels of organic manure, biofertilizer and varieties on total dry matter production (t ha^{-1}) and utilization index

Treatment	Total dry matter production (t ha^{-1})	Utilization index
Levels of organic manure		
m_1 (100% RD)	7.03	2.44
m_2 (75% RD)	6.36	2.31
m_3 (50% RD)	5.68	2.06
SE	0.08	0.07
CD (0.05)	0.231	0.201
Biofertilizer		
b_1 (With PGPR mix 1)	6.73	2.35
b_2 (Without PGPR mix 1)	5.99	2.18
SE	0.06	0.06
CD (0.05)	0.189	0.164
Varieties		
v_1 (Sree Dhara)	6.69	2.25
v_2 (Suphala)	6.02	2.28
SE	0.06	0.06
CD (0.05)	0.189	NS

NS – Non Significant

4.4.3 Shelf life

Sprouting of tubers started one month after storage. At the end of two months, sprouting of all the tubers was observed in all the samples.

No decay of tubers due to microbial attack was observed even when the tubers were stored for two months.

The physiological loss in weight (PLW) at the end of one month and two months of storage of tubers was calculated and given in Table 10a and 10b.

It can be seen from Table 10a that PLW at the end of one month of storage was significantly influenced by levels of organic manure, biofertilizer and varieties. The PLW increased with the increase in the level of organic manure with the highest loss (14.83%) recorded by m_1 and the lowest by m_3 (9.54%) level.Higher PLW was observed due to biofertilizer application. The var. Suphala showed significantly lower PLW (8.69%) than the var. SreeDhara (15.47%). None of the interactions were found significant.

At the end of two months of storage, varieties alone showed significant variation in PLW (Table 10a) and the var. Suphala registered a lower value of 14.03 %. The interaction B x V (Table 10b) produced significant effects on PLW of tubers. Higher PLW was recorded by b_2v_1 and b_1v_1 which were on par at both stages of observation.But at the end of one month of storage, the effect of b_1v_2 was significantly higher than that of b_2v_2. After two months of storage the effects of b_1v_2 and b_2v_2 were found to be on par.

4.5 UPTAKE OF NUTRIENTS

The data on the effect of levels of organic manure, biofertilizer and varieties on the uptake of nutrients at harvest are presented in Table 11.

4.5.1 N uptake

It is observed from Table 11 that the effect of levels of organic manure was non-significant with respect to N uptake, although N uptake increased with increasing levels of organic manure.

Biofertilizer application significantly increased the N uptake. Application of biofertilizer recorded higher N uptake (70.71 kg ha^{-1}) than plots not treated with biofertilizer (54.69 kg ha^{-1}).

Table 10a. Effect of levels of organic manure, biofertilizer and varieties on quality characters

Treatment	Starch (%)	Protein (%)	PLW % after 1 month of storage	PLW % after 2 months of storage
Levels of organic manure				
m_1 (100% RD)	71.89	7.58	14.83	19.00
m_2 (75% RD)	71.81	7.44	11.88	17.38
m_3 (50% RD)	71.00	6.56	9.54	16.63
SE	0.95	0.46	0.65	0.87
CD (0.05)	NS	NS	1.892	NS
Biofertilizer				
b_1 (With PGPR mix 1)	71.78	7.29	13.14	17.86
b_2 (Without PGPR mix 1)	71.35	7.10	11.03	17.47
SE	0.78	0.38	0.53	0.71
CD (0.05)	NS	NS	1.545	NS
Varieties				
v_1 (Sree Dhara)	72.45	7.58	15.47	21.31
v_2 (Suphala)	70.69	6.81	8.69	14.03
SE	0.78	0.38	0.53	0.71
CD (0.05)	NS	NS	1.545	2.074

NS – Non Significant

Table 10b. Interaction effect of levels of organic manure, biofertilizer and varieties on quality characters

TREATMENTS	PLW % after 1 month of storage	PLW % after 2 months of storage
m_1b_1	16.83	19.75
m_1b_2	12.83	18.25
m_2b_1	12.33	17.33
m_2b_2	11.42	17.42
m_3b_1	10.25	16.50
m_3b_2	8.83	16.75
SE	0.91	1.22
CD	NS	NS
m_1v_1	19.58	23.17
m_1v_2	10.08	14.83
m_2v_1	14.75	20.08
m_2v_2	9.00	14.67
m_3v_1	12.08	20.67
m_3v_2	7.00	12.58
SE	0.91	1.22
CD	NS	NS
b_1v_1	15.22	20.39
b_1v_2	11.06	15.33
b_2v_1	15.72	22.22
b_2v_2	6.33	12.86
SE	0.744	1.00
CD	2.185	2.933

NS – Non Significant

The var. Sree Dhara registered significantly higher N uptake (67.81 kg ha^{-1}) than the var. Suphala (57.58 kg ha^{-1}).

4.5.2 P uptake

The levels of organic manure, biofertilizer and varieties produced significant effect on P uptake (Table 11).

Uptake of P significantly increased with increasing levels of organic manure with the 100% level registeringthe highest value of 26.45 kg ha^{-1}.

Application of biofertilizer significantly influenced P uptake.Biofertilizer treated plants recorded P uptake of 24.42 kg ha^{-1} while the plants not treated with biofertilizer recorded P uptake of 20.87 kg ha^{-1}.

The var. Sree Dhara showed significantly higher P uptake (24.53 kg ha^{-1}) than the var. Suphala (20.77 kg ha^{-1}).

4.5.3 K uptake

The data presented in Table 11 revealed significant effects of levels of organic manure, biofertilizer and varietieson K uptake.

Uptake of K significantly increased with incremental doses of organic manure and 100% level recorded the highest uptake of 145.57 kg ha^{-1}.

Biofertilizer treated plots registered significantly higher uptake of K of 137.09 kg ha^{-1} over the plots not treated with biofertilizer (114.79 kg ha^{-1}).

The var. Sree Dhara registered significantly higher K uptake (131.9 kg ha^{-1}) than the var. Suphala (119.97 kg ha^{-1}).

4.6 SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

The data on soil nutrient status after the experiment are summarised in Table 12a and 12b.

4.6.1 Organic carbon

The results furnished in Table 12a revealed significant effects of levels of organic manure on the organic carbon content in the soil after the experiment.

Table 11. Effect of levels of organic manure, biofertilizer and varieties on nutrient uptake ($kgha^{-1}$)

Treatment	N uptake ($kgha^{-1}$)	P uptake ($kgha^{-1}$)	K uptake ($kgha^{-1}$)
Levels of organic manure			
m_1 (100% RD)	68.10	26.45	145.57
m_2 (75% RD)	62.65	22.82	126.21
m_3 (50% RD)	57.34	18.67	106.03
SE	3.82	0.53	3.57
CD (0.05)	NS	1.5646	10.48
Biofertilizer			
b_1 (With PGPR mix 1)	70.71	24.42	137.09
b_2 (Without PGPR mix 1)	54.69	20.87	114.79
SE	3.12	0.44	2.92
CD (0.05)	12.93	1.28	8.55
Varieties			
v_1 (Sree Dhara)	67.81	24.53	131.90
v_2 (Suphala)	57.58	20.77	119.97
SE	3.12	0.44	2.92
CD (0.05)	12.93	1.28	8.55

NS – Non Significant

The level m_1 (100% RD) recorded higher organic carbon content which was superior to m_2 and m_3 levels. The effect of levels m_2 and m_3 were on par.

The organic carbon content was not influenced by biofertilizer application or varieties.

4.6.2 Available nitrogen

Available N content in the soil after the experiment was not influenced by the treatments (Table 12a).

4.6.3 Available phosphorus

It can be seen from Table 12a that the levels of organic manure significantly influenced the available P content in the soil. The level m_1 (100%) recorded the highest content which was on par with m_2 but superior to m_3 level. But the effect of levels m_2 and m_3 were on par.

Application of biofertilizer significantly influenced the available P content in soil after the experiment.

No significant difference in the available P content in the soil was observed due to varieties.

4.6.4 Available potassium

The results in Table 12a indicated significant influence of levels of organic manure on available K content in the soil. The content of available K in the soil after the experiment increased with the level of organic manure applied.

Biofertilizer application significantly influenced the available K content in the soil after the experiment.

Available K content in the soil was not significantly influenced by the varieties.

Among the interactions only M x V produced significant effect on soil available K content (Table 12b). The treatment combinations m_1v_1 and m_2v_2 registered higher contents of soil available K, but were on par in their effects. Similarly m_3v_1 and m_3v_2 registered lower contents of soil available K, which were on par in their effects. But the effect of m_2v_1 was superior to m_2v_2.

Table 12a. Effect of levels of organic manure, biofertilizer and varieties on soil nutrient status after the experiment

Treatment	Organic carbon %	Available N (kgha^{-1})	Available P(kgha^{-1})	Available K (kgha^{-1})
Levels of organic manure				
m_1 (100% RD)	1.57	207.36	61.10	130.31
m_2 (75% RD)	1.44	190.93	59.37	116.89
m_3 (50% RD)	1.42	203.84	53.61	97.61
SE	0.04	11.11	2.09	2.47
CD (0.05)	0.104	NS	6.140	7.230
Biofertilizer				
b_1 (With PGPR mix 1)	1.49	210.02	61.10	118.21
b_2 (Without PGPR mix 1)	1.46	191.40	54.95	111.66
SE	0.03	9.07	1.71	2.01
CD (0.05)	NS	NS	5.013	5.903
Varieties				
v_1 (Sree Dhara)	1.49	203.05	58.75	115.83
v_2 (Suphala)	1.46	198.37	57.30	114.04
SE	0.03	9.07	1.71	2.01
CD (0.05)	NS	NS	NS	NS

NS – Non Significant

Table 12b. Interaction effects of levels of organic manure, biofertilizer and varieties on soil available K

TREATMENTS	Available K (kgha^{-1})
m_1b_1	130.89
m_1b_2	129.73
m_2b_1	121.86
m_2b_2	111.93
m_3b_1	101.88
m_3b_2	93.33
SE	3.49
CD	NS
m_1v_1	125.96
m_1v_2	134.66
m_2v_1	123.98
m_2v_2	109.80
m_3v_1	97.55
m_3v_2	97.66
SE	3.49
CD	10.224
b_1v_1	119.14
b_1v_2	117.28
b_2v_1	112.52
b_2v_2	110.80
SE	2.85
CD	NS

NS – Non Significant

4.7 INCIDENCE OF PEST AND DISEASE

Attack of leaf roller was found in some plots about 1½ MAP and attack of tingid (*Monanthia globulifera*) was observed in some plots at 3 MAP for which a uniform spray of neem based pesticide was given at respective periods. There was no nematode in the soil sample analysed at 3 MAP.

4.8 ECONOMICS OF CULTIVATION

The results on economics of cultivation are presented in Table 13a and 13b.

4.8.1 Net income

The data in Table 13a revealed significant effect of levels of organic manure on net income. The level m_1 (100%) recorded the highest net income of Rs. 2,31,738 ha^{-1} but was on par with m_2 (75%) level (Rs. 2,21,571ha^{-1}). The lowest level of organic manure (m_3 - 50%) registered the lowest net income of Rs. 18, 9203 ha^{-1}.

Application of biofertilizer showedsignificant effect on net income registering Rs.2,25,025 ha^{-1}

The var. Sree Dhara recorded significantly higher net income per hectare of Rs. 2,28,191 than the var. Suphala (Rs. 2,00,250 ha^{-1}).

Although the interaction effects were not significant (Table 13b), higher net income of Rs. 2,65,838 ha^{-1} was recorded by the treatment combination $m_1b_1v_1$ followed by $m_2b_1v_1$ (Rs. 2,40,558 ha^{-1}). For the var. Suphala (v_2), the treatment combination $m_1b_1v_2$ recorded the highest net income (Rs. 2,21,388 ha^{-1})followed by $m_2b_1v_2$ (Rs. 2,17,208 ha^{-1}). At all levels of organic manure with or without biofertilizer, the var. Sree Dhara (v_1) registered higher net income than the respective treatments with the var. Suphala (v_2).

4.8.2 Benefit cost ratio

The levels of organic manure exerted significant influence on BCR (Table 13a). The effects of the levels m_1 (2.92) and m_2 (2.93) were found on par but superior to m_3 level (2.73).

Biofertilizer application failed to produce significant effect on BCR.

Table.13a Effect of levels of organic manure, biofertilizer and varieties on economics of cultivation

Treatment	Net Income (Rs ha^{-1})	BCR
Levels of organic manure		
m_1 (100% RD)	231738	2.92
m_2 (75% RD)	221571	2.93
m_3 (50% RD)	189203	2.73
SE	5000	0.04
CD (0.05)	14690	0.130
Biofertilizer		
b_1 (With PGPR mix 1)	225025	2.86
b_2 (Without PGPR mix 1)	203316	2.87
SE	4100	0.04
CD (0.05)	11994	NS
Varieties		
v_1 (Sree Dhara)	228191	2.99
v_2 (Suphala)	200250	2.74
SE	4100	0.04
CD (0.05)	11994	0.106

NS – Non Significant

Table 13b. Interaction effect of levels of organic manure, biofertilizer and varieties on economics of cultivation

Treatments	Cost of cultivation (Rsha^{-1})	Gross Income (Rsha^{-1})	Net Income (Rs ha^{-1})	BCR
$m_1b_1v_1$	126862	392700	2,65,838	3.10
$m_1b_1v_2$	126862	348250	2,21,388	2.74
$m_1b_2v_1$	114262	347750	2,33,488	3.04
$m_1b_2v_2$	114262	320500	2,06,238	2.81
$m_2b_1v_1$	121042	361600	2,40,558	2.99
$m_2b_1v_2$	121042	338250	2,17,208	2.80
$m_2b_2v_1$	108442	334350	2,25,908	3.08
$m_2b_2v_2$	108442	311050	2,02,608	2.87
$m_3b_1v_1$	115222	320050	2,04,828	2.78
$m_3b_1v_2$	115222	315550	2,00,328	2.74
$m_3b_2v_1$	102622	300550	1,97,928	2.93
$m_3b_2v_2$	102622	256350	1,53,728	2.50
SE	-	-	10,000	0.09
CD	-	-	NS	NS

Cost of cultivation per ha

excluding the treatments = Rs. 90,982

Cost of 1 kg seed tuber = Rs. 15

Cost of 1 t FYM = Rs. 380

Cost of 1 t CPC = Rs. 5000

Cost of 1 t wood ash = Rs. 2000

Cost of 1 t neem cake = Rs. 17500

Cost of 1 kg PGPR mix 1 = Rs. 70

Price of 1 kg tuber = Rs. 15

The var. Sree Dhara recorded significantly higher BCR (2.99) than the var. Suphala (2.74).

The interaction effects were not significant with respect to BCR (Table 13b). But the highest BCR of 3.10 was registered by $m_1b_1v_1$followed by $m_2b_2v_1$(3.08) and $m_1b_2v_1$ (3.04).In the case of var. Suphala (v_2) the treatment combination $m_2b_2v_2$ recorded the highest BCR of 2.87 closely followed by $m_1b_2v_2$ (2.81) and $m_2b_1v_2$ (2.80). The var. Sree Dhara (v_1) recorded higher BCR than the var. Suphala (v_2) at all levels of organic manure with or without biofertilizer.

DISCUSSION

5. DISCUSSION

The results of the experiment conducted to standardise an organic nutrient package for coleus and work out the economics of cultivation are discussed in this chapter.

5.1 Growth characters

The results indicated that the different levels of organic manure did not significantly influence the growth characters like plant height at any stage of the crop (Table 2a) and number of branches at any stage except at 1MAP (Table 3). At 1 MAP, no significant difference in number of branches was noticed due to 100% or 75% level of organic manure. Application of the biofertilizer, PGPR mix 1 also failed to produce significant effect on plant height and number of branches (Table 2a and 3). This result is in agreement with the findings of Dhanya (2011) who reported non significant effect of levels of organic manure and biofertilizer on vine length and number of branches of sweet potato.

Levels of organic manure produced significant effect on leaf number per plant and LAI during early and later stages of crop growth (Table 4a and 5a). At 1MAP, the 100% and 75% levels of organic manure were on par in their effects on leaf number and LAI, but superior to 50% level. At 3MAP, 100% level of organic manure produced significantly higher number of leaves than 75% and 50% levels. The same trend was noticed on LAI at 4MAP. It is seen that application of 100% RD of NPK through organic manures is necessary for higher production of leaves and for getting higher LAI. Significant effect of PGPR mix 1 on leaf number was seen only at 1MAP and on LAI at 1MAP and 4MAP (Table 4a and 5a). It is seen that biofertilizer application is beneficial for retaining more number of leaves and higher LAI during later stage of the crop.

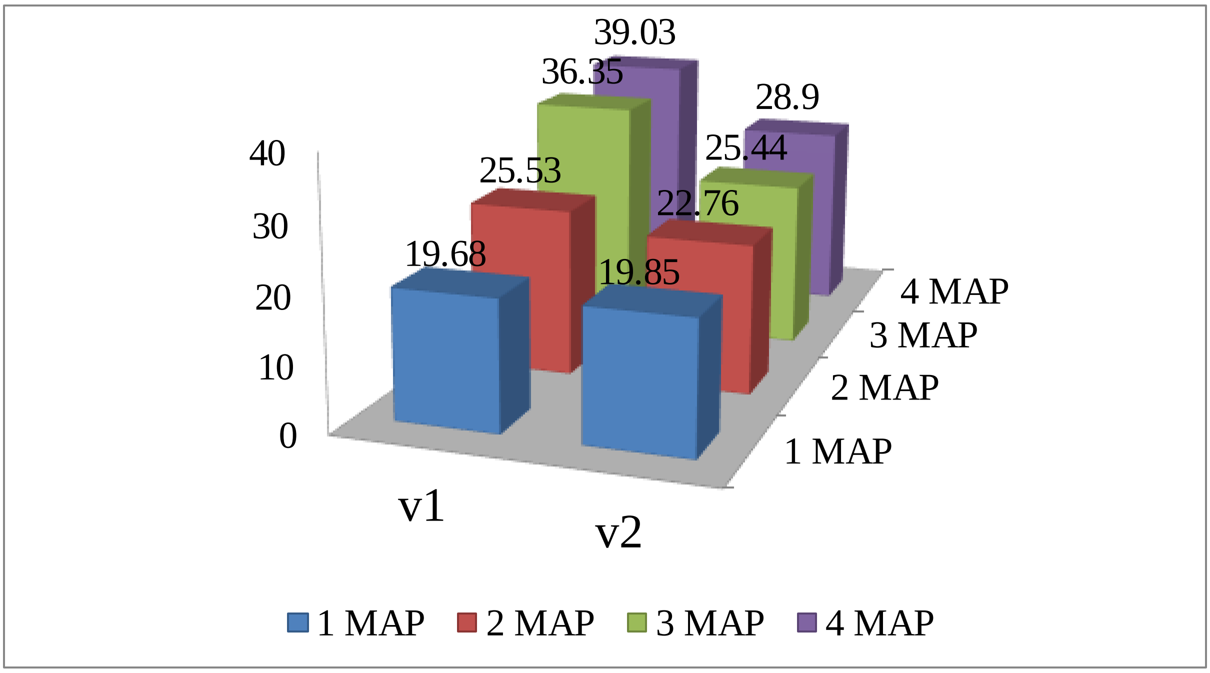
Significant varietal difference was observed in plant height and number of branches per plant during later stages of crop growth (Table 2a and 3). The var. Sree Dhara was found superior at 3MAP and 4MAP in these characters. But there was significant difference between varieties in leaf production at all stages of growth and in LAI at all stages except at 2 MAP (Table 4a and 5a). During the initial stage, the var. Suphala recorded higher leaf number and LAI but during the later stages of the crop, the var. Sree Dhara dominated over the var. Suphala. Significant interaction effects of M x V and M x B x V on leaf number and LAI at 4 MAP clearly revealed the dominance of the var. Sree Dhara at all levels of organic manure. It can be seen from Fig.3 that the var. Suphala was taller with more number of branches and leaves per plant and higher LAI at 1MAP compared to the var. Sree Dhara indicating the early initial growth of the var. Suphala.There was drastic reduction in leaf number and LAI of the var. Suphala at 3MAP and 4MAP indicating the early maturing character of the variety (KAU, 2011).

5.2 Yield and yield components

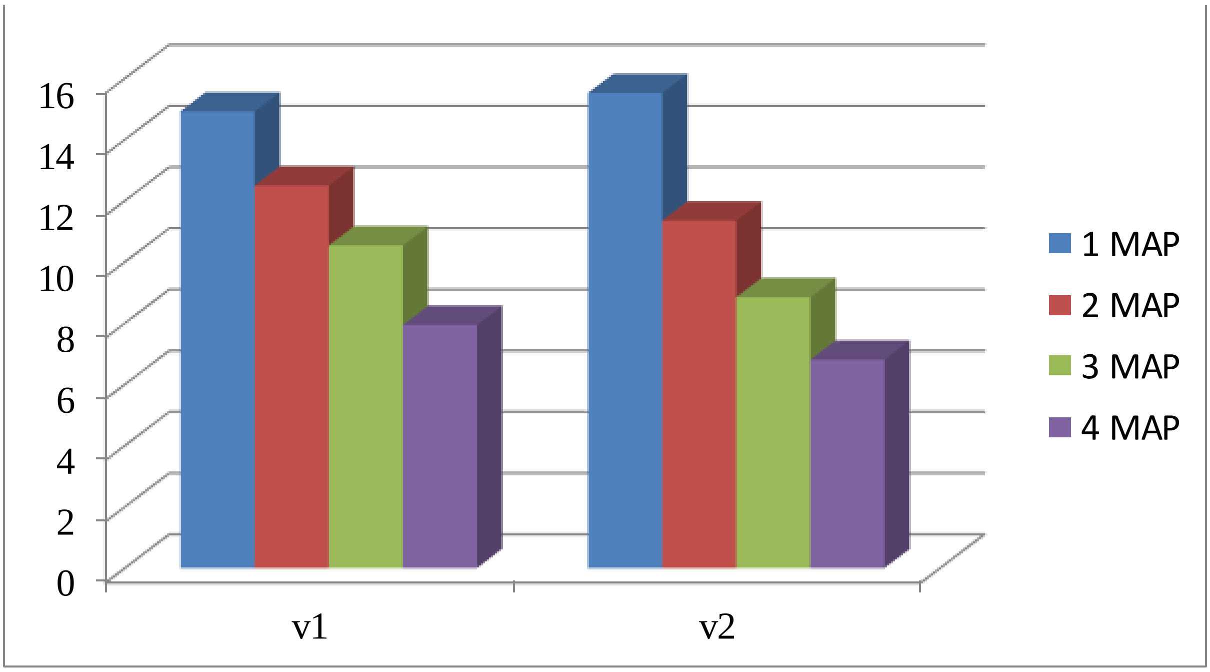
The treatments exerted profound influence on yield components (Table 6 and 7). With respect to number of tubers and number of marketable tubers per plant (Fig. 4), the effect of 100% and 75% levels of organic manure were found on par. Application of PGPR mix 1significantly increased the number of tubers and number of marketable tubers per plant. The var. Sree Dhara produced higher number of tubers and marketable tubers per plant. But the var. Suphala recorded significantly higher percentage number of marketable tubers per plant than the var. Sree Dhara.It is due to the fact that the var. Suphala produced bigger sized tubers than the var. Sree Dhara (Plate 3).

Weight of total tubers and marketable tubers per plant increased with increase in the level of organic manure as shown in Fig. 5. But no significant difference in percentage weight of marketable tubers per plant was observed due to levels of organic manure. Application of PGPR mix 1 significantly increased the weight of total tubers and marketable tubers per plant. The var. Sree Dhara was found superior in producing higher weight of tubers and marketable tubers per plant. But there was no significant varietal difference in the percentage weight of marketable tubers per plant.

Tuber yield was significantly influenced by levels of organic manure, biofertilizer and varieties as evident from Table 8. Tuber yield increased with increasing levels of organic manure as depicted in Fig 6. The highest tuber yield of 23.49 t ha^{-1} was recorded by 100% level closely followed by 75% level (22.42 t ha^{-1}). The increasing trend shown by weight of tubers as well as weight of marketable tubers per plant with incremental levels of organic manure was reflected in the tuber yield. Increasing the level of organic manure from 75% to 100% could produce an yield increase of only 1.07 t ha^{-1} which may be due to the non significant increase in tuber number per plant when the level of organic manure was increased from 75% to 100% level. The result revealed the necessity for the application of full RD of NPK through organic manure (half the dose as FYM + half the dose as CPC) for getting higher yields of coleus.

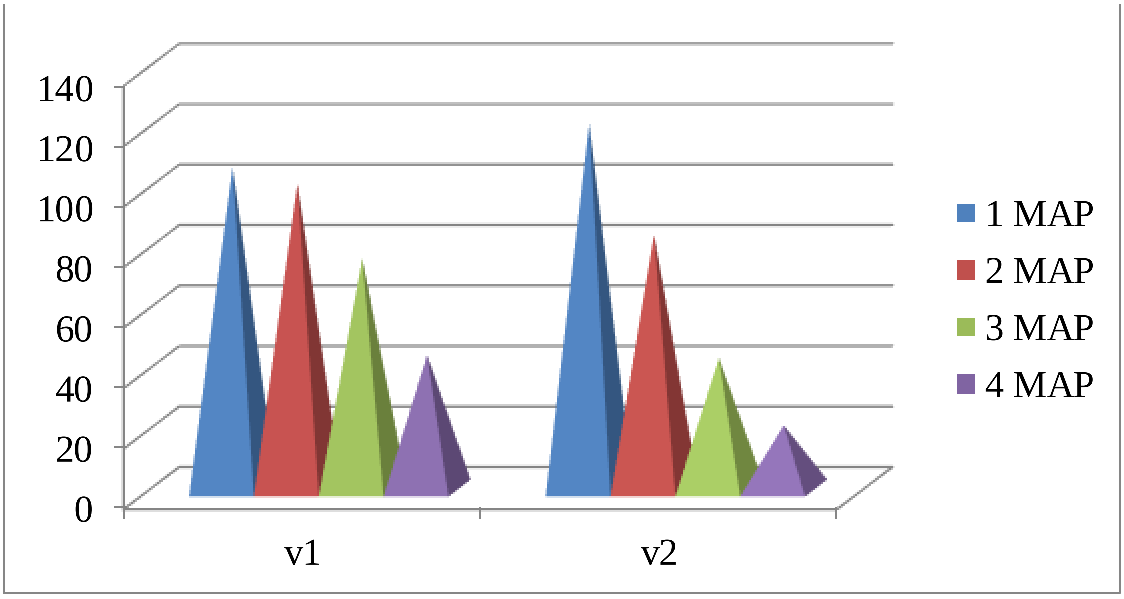


Plant height (cm)

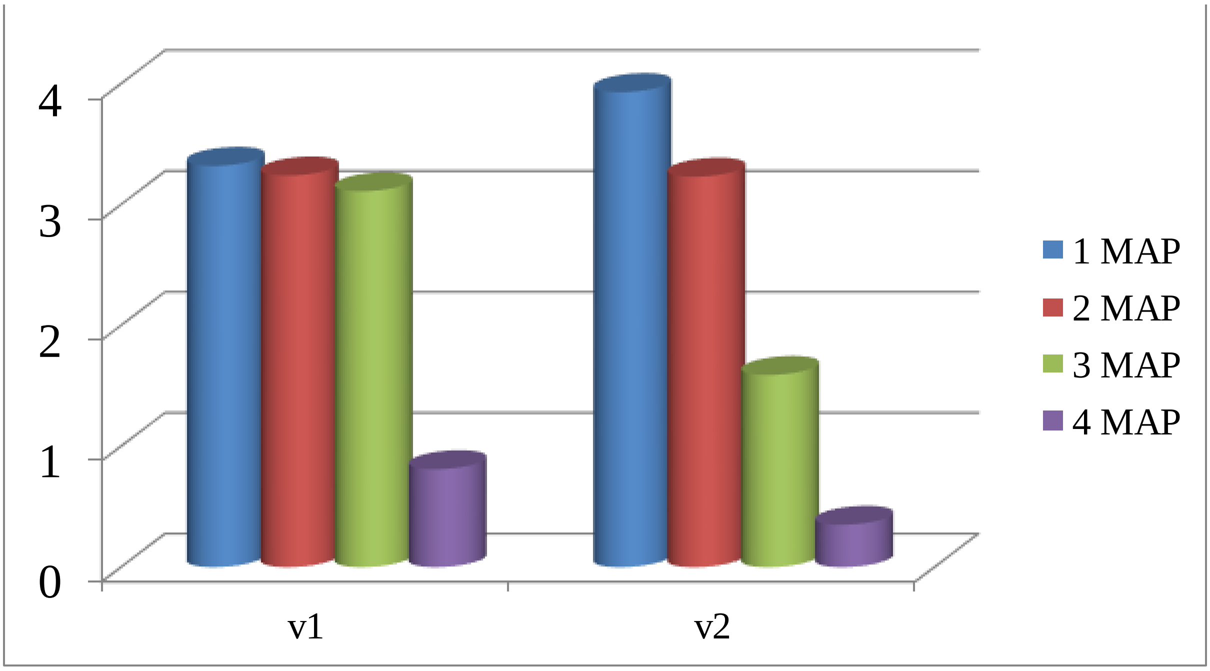


Number of branches per plant

Fig. 3. Phenotypic comparison of coleus var. Sree Dhara (V_1) and var. Suphala (V_2) as influenced by treatments



Number of leaves per plant



Leaf area index

Fig. 3 Phenotypic comparison of coleus var. Sree Dhara (V_1) and var. Suphala (V_2) as influenced by treatments (continued...)

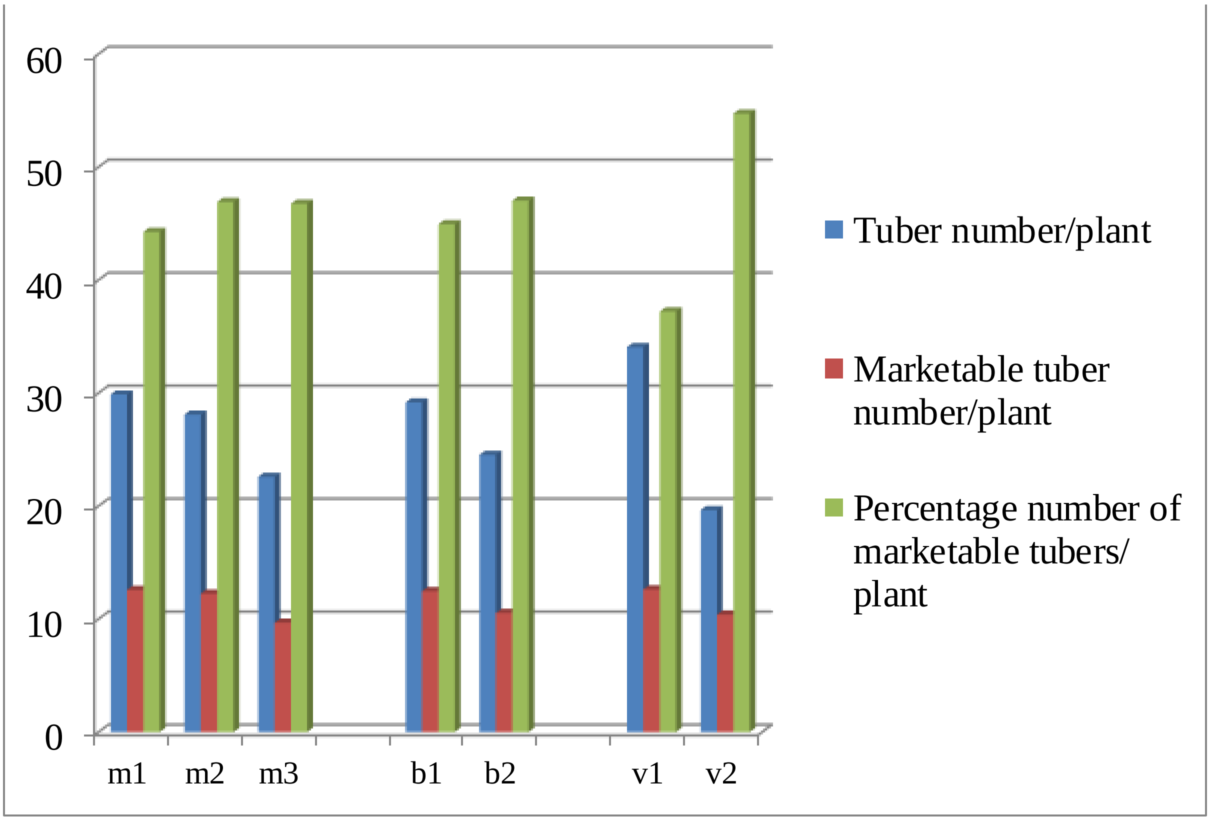


Fig 4. Effect of levels of organic manure, biofertilizer and varieties on tuber number per plant

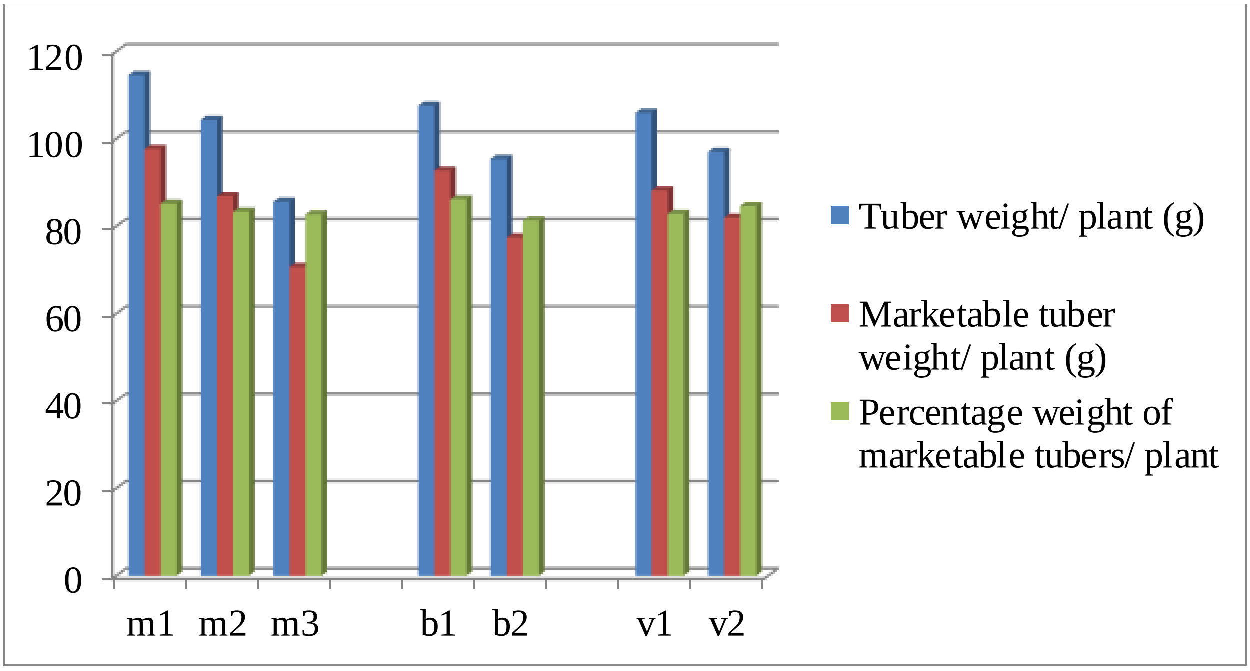


Fig 5. Effect of levels of organic manure, biofertilizer and varieties on tuber weight per plant

Plate 3. Coleus tubers

This is in conformity with the findings of Dhanya (2011) who reported that the full RD of nutrients through organic manure was required for expressing the yield potential of sweet potato. The higher yields realised due to organic nutrition of coleus emphasised the fact that coleus is suited for organic production.

Biofertilizer treatment with PGPR mix 1 significantly increased the average tuber yield from 20.78 t ha^{-1} (produced without biofertilizer) to 23.07 t ha^{-1} (Table 8). Dhanya (2011) failed to get positive effect of PGPR mix 1 on tuber yield of sweet potato which is reported to be due to the insufficient dose (@ 1% of organic manure) of the biofertilizer. Hence PGPR mix 1 was applied @ 2% along with organic manures in the present investigation. Significant improvement in yield components especially in the number and weight of tubers per plant due to application of PGPR mix 1 might have resulted in its significant effect on tuber yield. The increase in tuber yield of elephant foot yam and tannia due to biofertilizer application along with FYM than due to conjoint use of FYM and chemical fertilizers has been reported by Suja *et al*., 2008 and Suja *et al*., 2009.

The varieties differed significantly in their yield potential (Fig. 6). The var. Sree Dhara recorded an average yield of 22.86 t ha^{-1} while the var. Suphala recorded an average yield of 20.99 t ha^{-1} as shown in Table 8. This might be due to the significant varietal difference exhibited in yield components with the var. Sree Dhara dominating over the var. Suphala. The potential yield reported for the var. Sree Dhara is 25 t ha^{-1} and for the var. Suphala is 15.93 t ha^{-1} (KAU, 2007). Hence, this yield variation is as expected. But the var. Suphala is found to be early maturing and is recommended for year round cultivation whereas the var. Sree Dhara with a duration of five months is recommended for normal planting season of July to September.

5.3 Physiological parameters

It can be seen from Table 9 and Fig. 7 that the quantity of dry matter increased with incremental levels of organic manure with 100% level recording the highest quantity of dry matter (7.03 t ha^{-1}), closely followed by 75% level (6.36 t ha^{-1}). The lowest quantity of dry matter of 5.68 t ha^{-1} was registered by 50% level of organic manure. This might be due to the significant increase in tuber yield with increasing levels of organic manure and their significant effects on leaf number and LAI during later stages of growth. As in the case of tuber yield the results indicated that application of 100% RD of NPK through organic manure (half as FYM and half as CPC) is necessary for higher dry matter production in coleus.

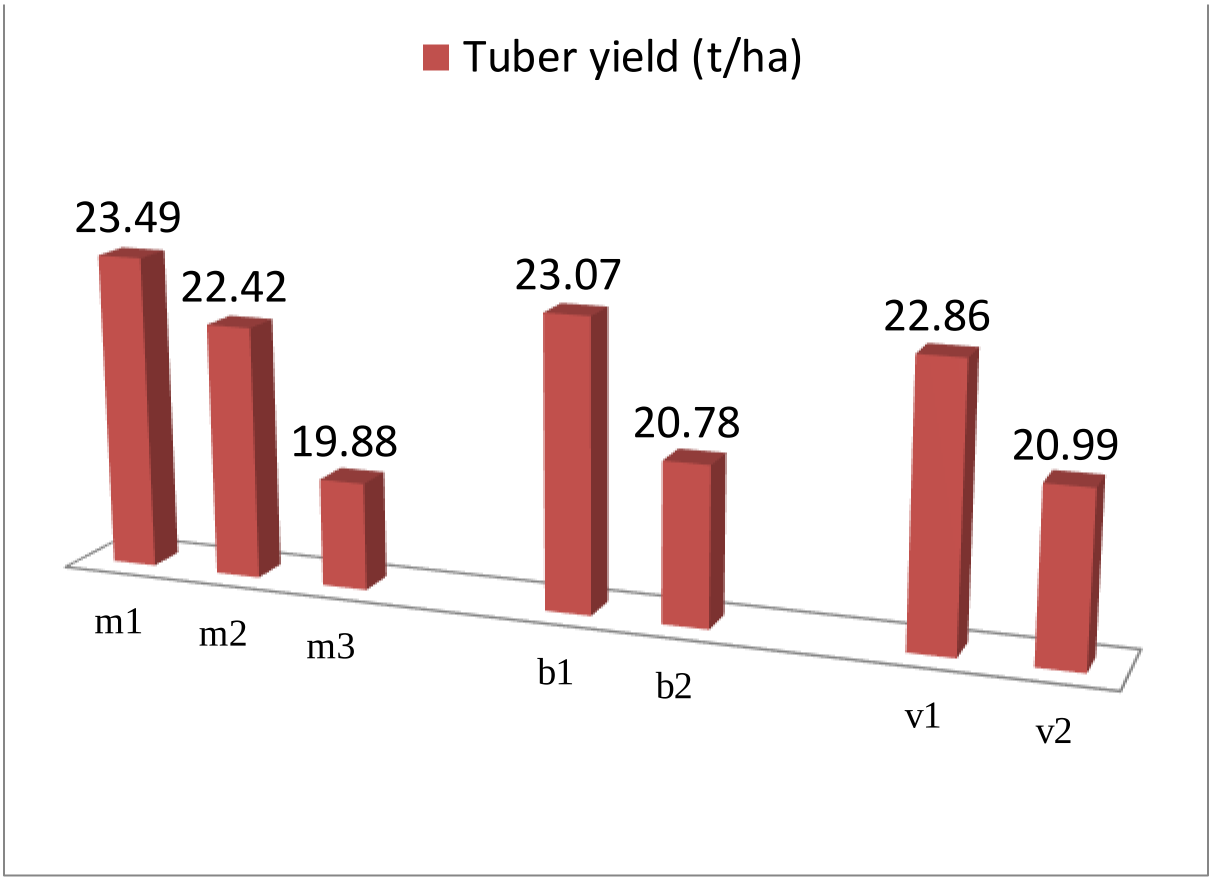


Fig. 6 Effect of levels of organic manure, biofertilizer and varieties on tuber yield

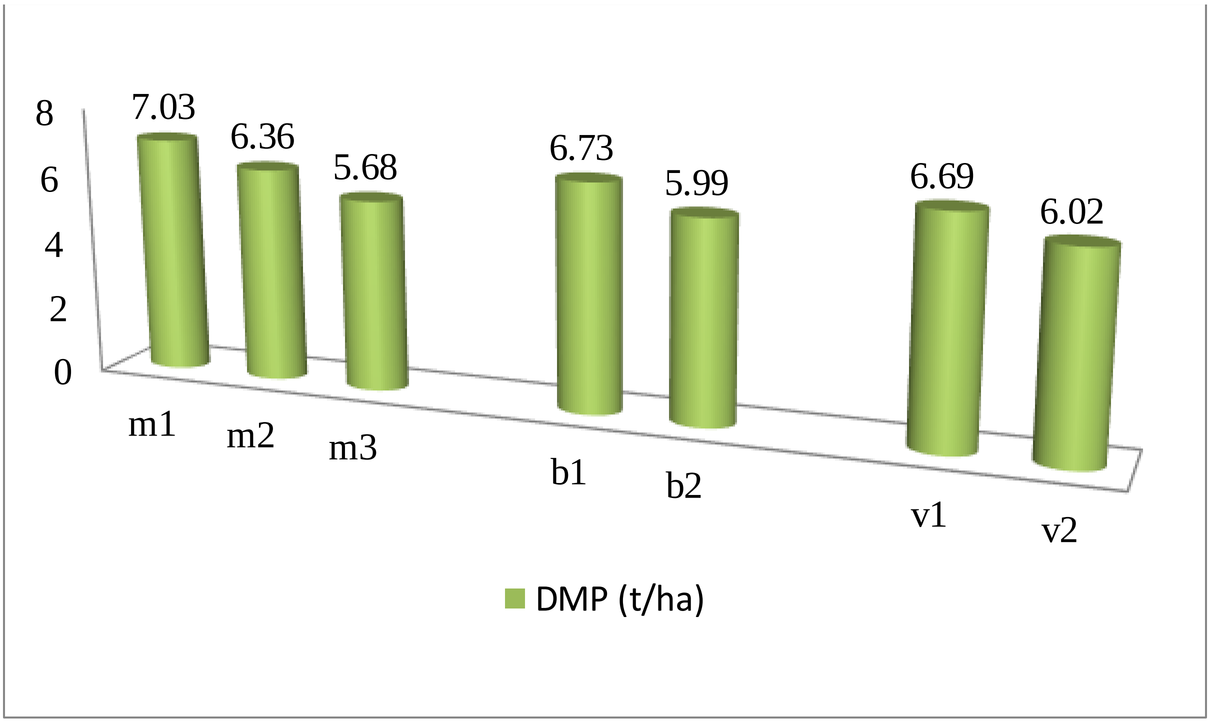


Fig. 7 Effect of levels of organic manure, biofertilizer and varieties on dry matter production

Dry matter production also improved due to biofertilizer treatment (Fig.7). PGPR mix 1 treated plants produced 6.73 t ha^{-1} of dry matter as against 5.99 t ha^{-1} by the plants not treated with biofertilizer (Table 9). Improvement in tuber yield due to the application of PGPR mix 1and retention of higher LAI even during later stages of the crop might have resulted in higher dry matter production due to biofertilizer application.

As in the case of growth characters and yield and yield components, the var. Sree Dhara was found superior in dry matter production than the var. Suphala (Fig 7). The early maturing character of the var. Suphala might have resulted in lower dry matter production.

Utilization index significantly increased with incremental levels of organic manure and due to application of PGPR mix 1 as evident from Table 9 and Fig. 8. Increasing trend in the tuber yield shown by increasing levels of organic manure and due to biofertilizer application might have contributed for higher UI by the respective treatments. No significant varietal difference in utilization index was noticed although the var. Suphala recorded higher UI of 2.28 as against 2.25 for the var. Sree Dhara.

5.4 Quality characters of tubers

The results on quality characters of tuber in terms of starch and protein contents (Table 10) revealed no significant difference in tuber yield due to different levels of organic manure, biofertilizer and varieties. So the dose of organic manure can be standardized for getting higher yields of coleus without change in quality of the tubers. However, the starch and protein contents increased with increase in the level of organic manure and due to biofertilizer application, though the effect was non significant. The var. Sree Dhara recorded higher starch (72.45%) and protein content (7.58%) on dry weight basis than the var. Suphala (70.69% and 6.81% respectively).

Shelf life of tubers was also studied by observing sprouting, microbial decay and physiological loss in weight of tubers. It was found that sprouting started after one month of storage and was completed in all the tubers of all the treatments at the end of two months of storage. Archana (2001) also has reported sprouting of 50% of tubers in the stored samples of coleus tubers within 30-40 days of storage irrespective of the treatments. But no decay of tubers due to microbial attack was observed even when the tubers were stored for more than two months which is in agreement with the findings of Archana (2001). Even after two months of storage, there was no conspicuous physiological loss in weight. At the end of one month and two months of storage the var. Suphala recorded lower values of PLW than the var. Sree Dhara with all treatments indicating better storability of tubers of the var. Suphala.

5.5 Uptake of nutrients

Although the effects were not significant, N uptake was increasing with the increase in the level of organic manure (Table 11). Uptake of P and K showed significant increase with increasing levels of organic manure (Fig. 9). In sweet potato also, Dhanya (2011) reported the highest uptake of nutrients by the application of 100% RD of NPK through organic manures. The increased uptake of nutrients might have resulted in increasing trend in the tuber yield and dry matter production due to incremental levels of organic manure.

Uptake of N, P and K improved due to the application of PGPR mix 1 which might be due to increased availability of nutrients by the biofertilizer (Fig. 9). The increased uptake of nutrients might have resulted in increased diversion of assimilates into tuber (Fig. 6) as revealed from higher UI due to biofertilizer treatment (Fig.8). So biofertilizer is a valuable component in organic nutrition of coleus.

5.6 Soil nutrient status after the experiment

The nutrient status of the soil after the experiment in terms of organic carbon and available P and K contents showed an increasing trend with incremental levels of organic manure (Table 12). Although the effect was non significant, available N content of the soil also increased with the increase in the level of organic manure. Srivastava (1985) and More (1994) also reported that addition of organic manures increased the status of organic carbon and available N, P and K status of the soil. Inspite of higher tuber yield and higher dry matter production at higher levels of organic manure, higher levels of organic manure also improved the nutrient status of the soil after a crop of coleus. The result is indicative of the fact that organic nutrition not only improves the yield but also improves the fertility status of the soil. Archana (2001) also reported that there was no depletion of soil nutrients when organic manure was applied to coleus at the RD irrespective of the source of organic manure.

Application of biofertilizer PGPR mix 1 significantly improved the available P and K contents of the soil even after the experiment (Table 12) indicating the increased availability of P and K even after the increased uptake by the crop (Table 11).

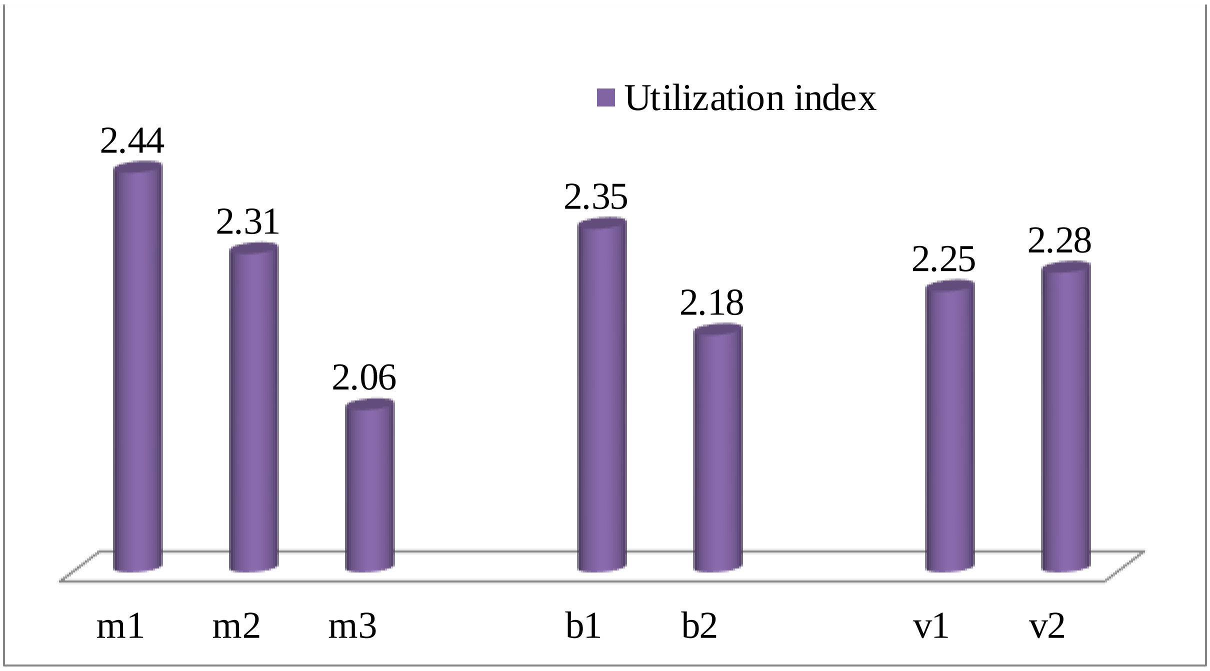


Fig. 8 Effect of levels of organic manure, biofertilizer and varieties on utilization index

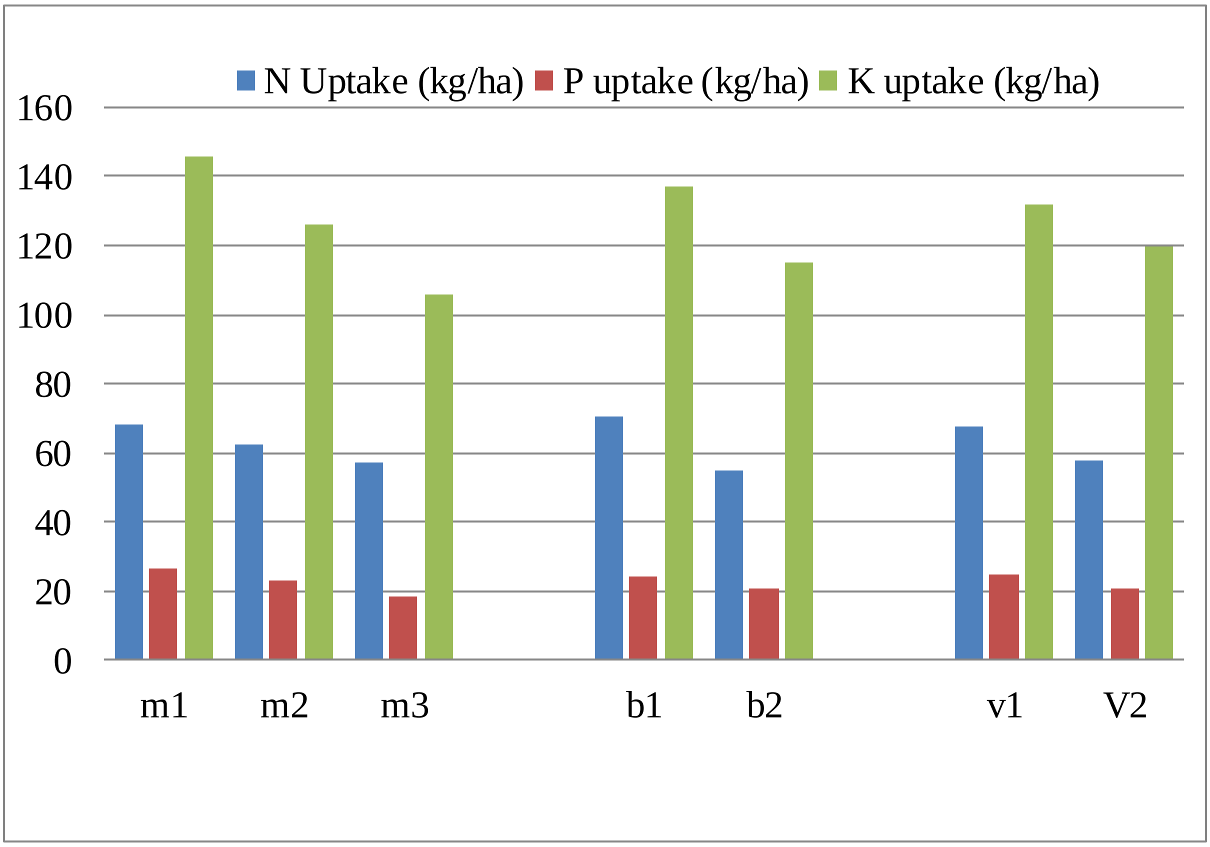


Fig 9. Effect of levels of organic manure, biofertilizer and varieties on nutrient uptake (kg/ha)

No significant difference in nutrient status of the soil was observed due to organic nutrition of two varieties of coleus namely var. Sree Dhara and var. Suphala. The varieties are equally effective in maintaining the soil nutrient status of the soil. Hence varieties can be chosen for getting higher yields or for early maturity without depletion of soil fertility due to varieties.

5.7 Incidence of pest and disease

Coleus is generally infected with the root-knot nematode *Meloidogyne incognita*. In the present study, neem cake @ 1 t ha^{-1}was applied uniformly to all the plots at the time of land preparation as a prophylatic measure against the incidence of root-knot nematode as reported by Nisha (2005). There was no incidence of nematode attack in the crop. The analysis of soil sample from the field at 3 MAP did not reveal the presence of the nematode. But there was the attack of leaf roller at 1½ MAP and of tinged at 3 MAP in few plants in some plots which were controlled as and when observed by giving a uniform spray of neem based pesticide.

5.8 Economics of cultivation

The economics of cultivation was worked out in terms of net income and BCR (Table 13a). Higher net income and BCR could be obtained by the application of 100% or 75% level of organic manure as depicted in Fig. 10 and 11 indicating that application of even 75% level of organic manure is sufficient for producing economic yields of organic coleus. Higher net income was observed due to the application of PGPR mix 1. But no improvement or no decline in BCR was noticed due to biofertilizer treatment. The var. Sree Dhara recorded higher net income and BCR than the var. Suphala which might be due to higher tuber yield produced by the var. Sree Dhara at the same level of organic manure.

Among the treatment combinations (Table 13b), the var. Sree Dhara at 100% level of organic manure + PGPR mix 1 ($m_1b_1v_1$) recorded the highest net income of Rs. 2,65,838 ha^{-1}closely followed by the same variety at 75% level of organic manure + PGPR mix 1 ($m_2b_1v_1$) registering net income of Rs. 2,40,558 ha^{-1}. The highest BCR of 3.10 was recorded by the var. Sree Dhara at 100% level of organic manure + PGPR mix 1 ($m_1b_1v_1$) closely followed by the same variety at 75% level of organic manure without biofertilizer ($m_2b_2v_1$).

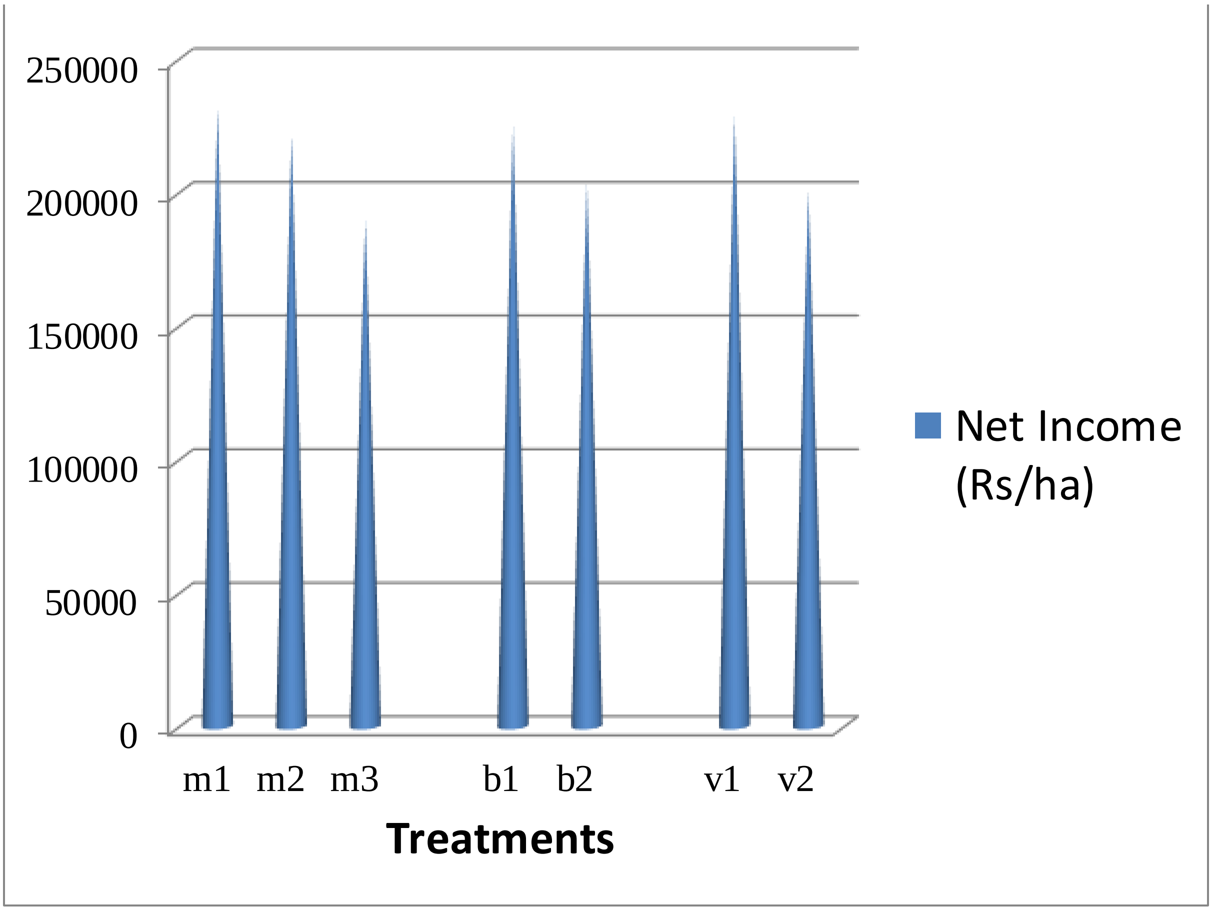


Fig 10. Effect of levels of organic manure, biofertilizer and varieties on net income (Rs/ha)

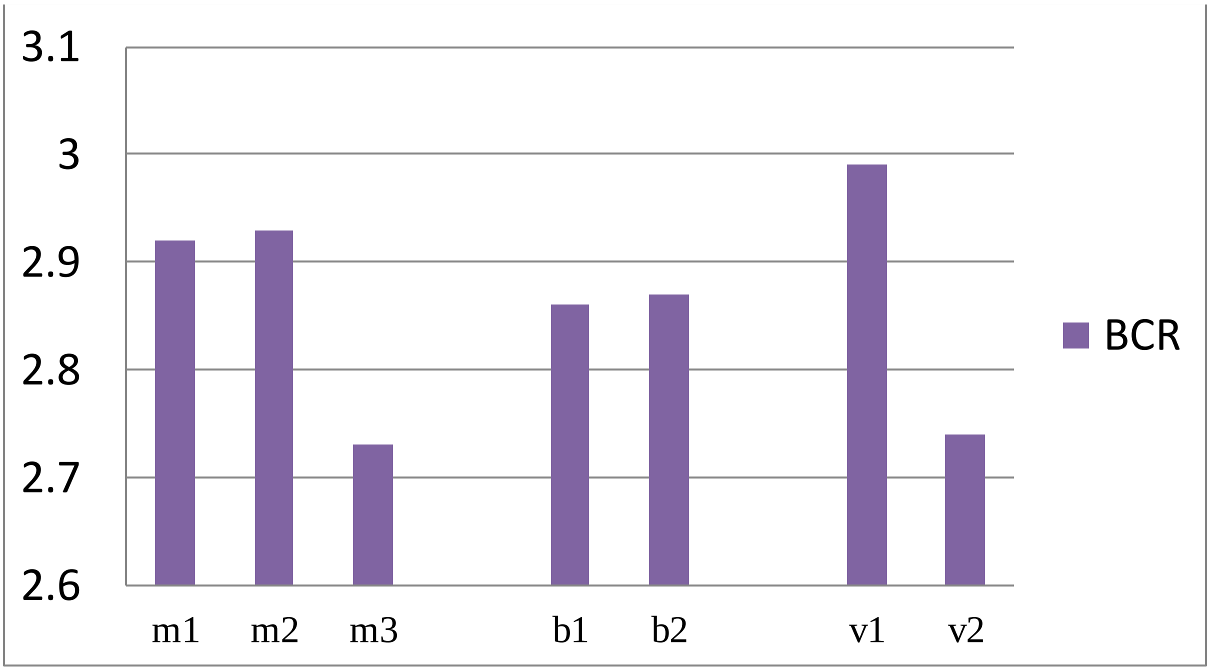


Fig 11. Effect of levels of organic manure, biofertilizer and varieties on benefit cost ratio

In the case of the var. Suphala also, the treatment combination involving 100% level of organic manure + PGPR mix 1($m_1b_1v_2$) recorded the highest net income of Rs. 2,21,388 ha^{-1} closely followed by 75% level of organic manure + PGPR mix 1 ($m_2b_1v_2$ – Rs. 2,17,208 ha^{-1}).Hence both varieties recorded the highest net income with 100% level of organic manure along with PGPR mix 1. With respect to BCR, the var. Suphala along with 75% or 100% levels of organic manure without PGPR mix 1 ($m_2b_2v_2$ and $m_1b_2v_2$ respectively) recorded higher BCR of 2.87 and 2.81 respectively. At all levels of organic manure with or without PGPR mix 1, the var. Sree Dhara recorded higher net income and BCR than the var. Suphala combined with respective treatments.

The results clearly revealed that coleus is amenable for organic cultivation. Application of 100% RD of NPK (60:60:100 kg/ha) through organic manures (6t FYM + 3t CPC + 3 t Wood ash ha^{-1}) along with PGPR mix 1 and the recommended basal dose of FYM @ 10 t ha^{-1} is necessary for getting higher yields of organic coleus.

During the normal planting season var. Sree Dhara produced higher yields, net income and BCR than the var. Suphala. But the var. Suphala which is recommended for year round cultivation is found to be early maturing than the var. Sree Dhara.

SUMMARY

SUMMARY

The field experiment was carried out at the Instructional Farm attached to College of Agriculture, Vellayani from August to December 2011 to standardize an organic nutrient package for coleus and work out the economics of cultivation. The treatments consisted of factorial combinations of three levels of organic manure (to supply100%, 75% and 50% RD of 60:60:100 kg NPK ha^{-1}), two levels of biofertilizer (with PGPR mix 1 and without biofertilizer) and two varieties (Sree Dhara and Suphala). The trial was laid out in 3 x 2 x 2 asymmetrical factorial RBD with three replications. Neem cake @ 1 t ha^{-1} was applied uniformly to all the plots. The results of the study are summarised below.

The plant height was not significantly influenced by different levels of organic manure or biofertilizer. The var. Sree Dhara was significantly taller than the var. Suphala during later stages of growth. Regarding the interaction effect, the var. Sree Dhara applied with 100 % level of organic manure and PGPR mix1 recorded the highest value and the var. Suphala with 50 % level of organic manure without PGPR mix1 recorded the lowest value.

Significant influence of levels of organic manure on number of branches per plant was observed at 1MAP only, at which stage the effect of 100% and 75% levels were on par but superior to 50% level. No significant effect due to biofertilizer application was observed on number of branches per plant. The var. Sree Dhara produced significantly higher number of branches during the later stages of the growth than the var. Suphala.

Leaf production was significantly influenced by the levels of organic manureonly at 1MAP and 3MAP. At 1MAP, the effect of 100 % and 75% levels of organic manure were on par but superior to 50% level, while at 3MAP 100% level produced significantly higher number of leaves. Application of PGPR mix 1 produced significant effect on number of leaves only at 1MAP. The var. Suphala produced more leaves at 1 MAP but the var. Sree Dhara dominated at other stages. The interaction M x V was significant at 4 MAP. The treatment combinations involving the var. Sree Dhara recorded higher values than those with the var. Suphala. The var. Sree Dhara recorded the highest number of leaves with 50% level of organic manure but was on par with 75% level while the var. Suphala recorded the highest number of leaves with 75% level.

Levels of organic manure significantly influenced LAIat 1MAP and 4MAP. At 1MAP, 100% and 75% levels were on par in their effects on LAIwhile at 4MAP, 100% level

was superior to other levels. PGPR mix 1 treated plots produced significantly higher LAI during initial and final stages of the crop. The var. Suphala dominated with respect to LAI at 1MAP while the var. Sree Dhara dominated during the later stages of growth. The interaction M x V was significant at 4 MAP. At all M levels, the var. Sree Dhara recorded higher values than the var. Suphala. The interaction M x B x V was significant at 1 MAP and 4MAP. In general, the var. Suphala recorded higher LAI at all levels of organic manure with and without biofertilizer during the initial stage. But the treatment combinations involving the var. Sree Dhara dominated during the later stage of the crop.

Levels of organic manure produced significant influence on the number of tubers as well as number of marketable tubers per plant and the effects of 100% and 75% levels were on par. Application of PGPR mix 1 registered significant effect on these yield components. The var. Sree Dhara was found superior in this regard.

With regard to the percentage number of marketable tubers per plant, there was no significant difference in the effects of levels of organic manure and biofertilizer. But there was significant varietal difference and the var. Suphala recorded significantly higher percentage than the var. Sree Dhara.

Weight of tubers and marketable tubers per plant increased with increase in the level of organic manure and due to application of biofertilizer. The var. Sree Dhara dominated over the var. Suphala with respect to these characters.

No significant difference in percentage weight of marketable tubers per plant was noticed due to levels of organic manure or due to varieties. But PGPR mix 1 treated plants recorded higher percentage weight of marketable tubers per plant.

Tuber yield per ha showed an increasing trend with increase in the level of organic manure recording the highest yield with 100% level. Application of PGPR mix 1 significantly improved the tuber yield. The var. Sree Dhara recorded higher tuber yield than the var. Suphala.

Dry matter production significantly increased with the incremental doses of organic manure and also due to application of PGPR mix 1. The var. Sree Dhara was found superior in dry matter production.

Utilization index significantly improved with increase in the level of organic manure and due to biofertilizer application. No significant varietal difference was noticed in utilization index.

No significant difference was observed in quality characters of tuber such as starch and protein contents. Sprouting of tubers started one month after storage and was completed at the end of two months of storage. No decay of tubers due to microbial attack was observed even when the tubers were stored for two months. At the end of one month of storage,PLW increased with the increase in the level of organic manure. Higher PLW was observed due to biofertilizer application. The var. Suphala showed significantly lower PLW than the var. SreeDhara. To sum up, the tubers could be stored for one month without sprouting, microbial decay and appreciable physiological loss in weight.

Uptake of N increased with increasing levels of organic manure but the effect was not significant. Uptake of P and K significantly increased with incremental doses of organic manure. Application of PGPR mix 1 enhanced the uptake of nutrients. The var. Sree Dhara dominated in the uptake of nutrients.

Soil nutrient status after the experiment in terms of organic carbon and available P and K contents increased with increase in the level of organic manure. Application of PGPR mix 1 improved the status of available P and K in soil. Available N in the soil was not influenced by the treatments. There was no significant difference in nutrient status of the soil after the experiment due to varieties. The interaction M x V was significant and there was a decreasing trend in the content of soil available K after the experiment with reduction in the level of organic manure along with both varieties.

No incidence of nematode attack was observed in the crop. Attack of leaf roller and tinged was noticed which was controlled by neem based pesticide.

There was no significant difference in net income and BCR between 100% and 75% levels of organic manure but were superior to 50% level. Higher net income was obtained due to biofertilizer application. The var. Sree Dhara recorded higher net income and BCR than the var. Suphala. Regarding interaction, at all levels of organic manure with or without biofertilizer, the var. Sree Dhara registered higher net income than the respective treatments with the var. Suphala.

The study revealed that coleus has great potential for organic cultivation. Application of 100% RD of NPK (60:60:100 kg/ha) through organic manures (6t FYM + 3t CPC + 3 t wood ash ha^{-1}) along with PGPR mix 1 and the recommended basal dose of FYM @ 10 t ha^{-1} is necessary for getting higher yields of organic coleus. During the normal planting season, var. Sree Dhara produced higher yields, net income and BCR than the var. Suphala. But the var. Suphala which is recommended for year round cultivation is found to be early maturing than the var. Sree Dhara.

Future line of work

Different combinations of different organic manures like FYM, CPC, poultry manure and neem cake may be tried.Appropriate dose of the biofertilizer, PGPR mix 1and its method of application may be standardized. The performance of the photo insensitive var. Suphala round the year in the southern zone may be evaluated and agro techniques may be standardized.

REFERENCES

7. REFERENCES

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

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.

Ashokan, P. K. and Sreedharan, C. 1977. Influence of levels and time of application of potash and growth, yield and quality of tapioca. *J. Root Crops* 3(2): 14.

Ayyaswamy, M., Chinnaswamy, C. and Sundarsingh, S. D. 1996. Effect of irrigation regimes, comrade cropping and soil amendments on the yield and economics of cassava, groundnut and sesamum. *Madras Agric. J.* 83(1): 338-341.

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, 204 p.

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

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

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

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

Geetha, K., Elizabeth, K. Syriac and Rajan, K.C. 2000. Integrated nutrient management for cassava. In: *Abstracts of papers, ISOTUC III,* International Symposium on Tropical Root and Tuber Crops, 19-22 January, 2000, Thiruvananthapuram, Kerala, India, pp. 44-45.

Gomes, J. DEC, Carvelho, P. C. L. De, Crvelho, F. L. C and Rodrigus, E. M. 1983. Use of organic fertilizer in the recovery of low fertility soils planted to cassava. *Revista Brasileira de Mandioca,* 2 (2): 63-76.

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

KAU, 2007. *Package of Practices Recommendations: Crops*. Kerala Agricultural University, Thrissur, 334 p.

KAU, 2011. *Package of Practices Recommendations: Crops*. Kerala Agricultural University, Thrissur, 360 p.

Kurien, T., Maini, S. B., Indira, P. and Ramunujam, P. 1976. Regulation of the levels of cyanogenic glucoside in cassava. *J. Root Crops* 2(2): 39-43.

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 arrowroot grown as intercrop in coconut garden. *J. Root Crops* 23(2): 131-137.

Mohankumar, C. R., Mandal, R. C., Nair, G. M. and Hrishi, N. 1976. Effect of FYM and NPK on cassava. In: Cock, J., Mac Intyre, R. and Graham, M. (eds.), *Proceedings of the Fourth Symposium of the International Society for Tuber Crops, 1-7 August, 1976*. Centro Internacional de Agricultura Tropicale, Cali, Columbia, pp. 122-124.

Mohankumar, C. R. and Nair, G. M. 1979. Note on the effect of planting material and levels of farmyard manure on the yield of *Dioscorea alata*. *J. Root Crops 5* (1): 17-18.

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. 174 p.

More, S. D. 1994. Effect of farm waste and organic manures on soil properties, nutrient availability and yield of rice-wheat grown in sodic vertisol. *J. Indian Soc. Soil Sci.* 42: 253-256.

Nair, G.M., Potty, V.P. and Susan John, K. 2001. Influence of biofertilizer (*Azospirillum*) on the growth and yield of sweet potato. *J. Root Crops* 27 (1) :210-213.

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.

Palaniswami, M.S and Peter, K.V.2008. Tuber and Root Crops. In: *Horticulture science series-09* (ed. Peter, K.V). New India Publishing Agency, New Delhi, pp. 95.

Pamila, V. R. 2003. Integrated nutrient management for short duration cassava in low lands. M. Sc. (Ag.) Thesis, Kerala Agricultural University, Thrissur, 73 p.

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*. Central Tuber Crops Research Institute, Thiruvananthapuram, pp. 307-311.

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

Patel, B. M. and Mehta, H. M. 1987. Effect of FYM, spacing and nitrogen application on chemical constituents of elephant foot yam (*Amorphophallus companulatus*). *Gujarat Agri. Univ. Res. J.* 13(1): 46-47.

Pillai, N. G, Mohankumar, B., Nair, P. G., Kabeerathumma, S. and Mohankumar, C. R. 1987. Effect of continuous application of manures and fertilizer on the yield and quality of cassava in laterite soils. In: *Proceedings of the National Symposium on Production and Utilization of Tropical Tuber Crops*. 27-29 November, 1985. Central Tuber Crops Research Institute, Thiruvananthapuram, pp. 109-114.

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

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.

Ravindran, C. S. and Balanambisan. 1987. Effect of FYM and NPK on the yield and quality of sweet potato. *J. Root Crops* 13(1): 35-44.

Sahota, T. S. 1983. Direct and residual effect of FYM, P and inorganic sources of nitrogen on cassava *(Manihot utilissima L.). Indian Agric.* 20: 23-26.

Saikia, J. and Borah, P. 2007. *Azospirillum* biofertilizer in sweet potato: growth, yield and economics. *J. Root Crops* 33(1): 38-42.

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. *Tech. Bull.* 1331 Service. USDA, 180 p.

Srivastava, O. P. 1985. Role of organic matter in soil fertility. *Indian J. Agric. Chem.* 18(92): 257.

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. and Potty, V.P. 2005. Response of cassava (*Manihot esculenta* Crantz) to biofertilizers., *J. Root Crops* 31(2):100-105.

Suja, G. and Nayar, T. V. R. 2006. Organic tuber production: Issues, prospects and future strategies. *Kisan World* 33(11): 58-59.

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 20th Kerala Science Congress 2008*, 28-31 January, 2008, Thiruvananthapuram, 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.

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 a national seminar, Thiruvananthapuram, Kerala. Central Tuber Crops Research Institute, Sree Kariyam, Thiruvananthapuram, Kerala, pp. 267-272.

Veenavidyadharan. 2000. Integrated nutrient management for arrowroot (*Maranta arundinacea* L.) under partial shade. M.Sc. (Ag.). thesis. Kerala Agricultural University, Thrissur, 107 p.

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.

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

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.

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

Wildjajanto, D. D. and Widodo. 1982. The effect of farmyard manure and nitrogen fertilizer on growth and production of potatoes. *Bull. Penalitian Horticultura* 9: 27-34.

ABSTRACT

PRODUCTION TECHNOLOGY FOR ORGANIC COLEUS

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ABSTRACT

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ABSTRACT

An investigation entitled "Production technology for organic coleus" was undertakenat College of Agriculture, Vellayani from August to December 2011 to standardize an organic nutrient package for coleus and work out the economics of cultivation. The treatments consisted of factorial combinations of three levels of organic manure (to supply100%, 75% and 50% recommended dose of 60:60:100 kg NPK ha^{-1}), two levels of biofertilizer (with PGPR mix 1 and without biofertilizer) and two varieties (Sree Dhara and Suphala). The trial was laid out in 3 x 2 x 2 asymmetrical factorial RBD with three replications. Neem cake @ 1 t ha^{-1} was applied uniformly to all the plots.

Growth characters like plant height and number of branches per plant were not significantly influenced by different levels of organic manure or biofertilizer application. But levels of organic manure exerted significant influence on leaf number and LAI during early and later stages of crop growth. During the initial stage, 100% and 75% levels of organic manure were on par in their effects on leaf number and LAI but during later stage of the crop, 100% level was superior to other levels. Application of PGPR mix 1 produced higher LAI during initial and final stages of the crop. The var. Sree Dhara produced taller plants with more number of branches during later stages of growth. But the var. Suphala produced higher leaf number and LAI during the initial stage while the var. Sree Dhara dominated at other stages of growth.

Yield components like number of tubers and marketable tubers per plant were influenced by levels of organic manure but the effects of 100% and 75% levels were on par. But an increasing trend in the weight of tubers and marketable tubers per plant was observed with increase in the level of organic manure. Application of PGPR mix 1 exerted profound influence on these yield components. The var. Sree Dhara dominated over the var. Suphala in these yield components but the var. Suphala recorded significantly higher percentage number of marketable tubers per plant.

Tuber yield showed an increasing trend with incremental doses of organic manure recording the highest yield with 100% level. Application of PGPR mix 1 improved the yield. The var. Sree Dhara produced higher yield than the var. Suphala.

Dry matter production and utilization index increased with increase in the level of organic manure and also due to application of PGPR mix 1. The var. Sree Dhara was found superior in dry matter production.

Quality characters of tuber such as starch and protein contents were not influenced by the treatments. The tubers could be stored for one month without sprouting, microbial decay and appreciable physiological loss in weight.

Increasing levels of organic manure significantly increased the uptake of P and K but failed to produce significant effect on N uptake. Application of PGPR mix 1 enhanced the nutrient uptake. The var. Sree Dhara registered higher uptake of nutrients than the var. Suphala.

Soil nutrient status after the experiment in terms of organic carbon and available P and K contents increased with increase in the level of organic manure. Application of PGPR mix 1 improved the status of available P and K in soil. Available N in the soil was not influenced by the treatments. There was no significant difference in nutrient status of the soil after the experiment due to varieties.

Higher net income and BCR could be obtained by the application of 100% or 75% levels of organic manure. Application of PGPR mix 1 increased the net income. The var. Sree Dhara recorded higher net income and BCR than the var. Suphala.

The study revealed that coleus has great potential for organic cultivation. Application of 100% RD of NPK (60:60:100 kg ha^{-1}) through organic manures (6t FYM + 3t CPC + 3 t wood ash ha^{-1}) along with PGPR mix 1 and the recommended basal dose of FYM @ 10 t ha^{-1} is necessary for getting higher yields of organic coleus. During the normal planting season,var. Sree Dhara produced higher yields, net income & BCR than the var. Suphala. But the var. Suphala which is recommended for year round cultivation is found to be early maturing than the var. Sree Dhara.

APPENDICES

APPENDIX – I

Weather parameters during the experimental period (August 2011 - December 2011)

Standard weeks	Maximum temperature (^0C)	Relative Humidity (%)	Rainfall (mm)
31	29.6	84.8	13.1
32	29.8	80.0	15.0
33	30.4	77.1	1.5
34	29.5	83.4	3.0
35	29.4	87.4	86.5
36	29.9	83.4	18.0
37	30.0	85.2	84.5
38	30.2	85.2	0.5
39	30.1	79.4	0.0
40	31.1	76.4	0.5
41	31.6	75.8	0.0
42	31.4	80.0	23.5
43	29.6	87.0	19.0
44	29.2	88.5	48.0
45	31.0	80.2	41.5
46	31.1	81.6	0.0
47	30.1	81.4	8.2
48	29.2	88.9	111.0
49	30.7	80.6	0.5
50	31.0	82.6	17.0
51	30.5	76.4	5.0
52	29.3	82.8	36.0