STANDARDIZATION OF ORGANIC MANURING IN KASTHURI TURMERIC (*Curcuma aromatica* Salisb.)

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by

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THESIS

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2012

DECLARATION

I hereby declare that this thesis entitled **"Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)"** is 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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We undersigned members of the advisory committee of **Mr. Bhende Siddhesh Shamrao (2009-12-120)** a candidate for the degree of **Master of Science in Horticulture** agree that this thesis entitled **"Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)"** may be submitted by **Mr. Bhende Siddhesh Shamrao (2009-12-120)**, in partial fulfillment of the requirement for the degree.

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Vellayani *Siddhesh S.B.*

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LIST OF ABBREVIATIONS

µm	-Micrometre
AMF	-Arbuscular Mycorrhizal Fungi
Cfu	-Microbial count
CH_4	-Methane
cm	-Centimetre
cm^2	-Square centimetre
cv.	-Cultivar
$d\ S\ m^{-1}$	-Deci siemen per metre
g	-Gram
$g\ m^{-2}$	-Gram per metresquare
$kg\ ha^{-1}$	-Kilogram per hectare
m	-Metre
m^2	-Square metre
mg	-Milligram
$mg\ g^{-1}$	-Milligram per gram
$Mg\ m^{-3}$	-Mega gram per metre cube
nm	-Nanometre
ppm	-Parts per million
$q\ ha^{-1}$	-Quintal per hectare
$t\ ha^{-1}$	-Tonnes per hectare
V/W	-Volume by Weight

INTRODUCTION

1. INTRODUCTION

Kasthuri turmeric (*Curcuma aromatica* Salisb.) belonging to the family Zingiberaceae is a medicinal cum aromatic plant with multiple uses. Several commercially produced cosmetics and ayurvedic preparations contain kasthuri turmeric. Skin care is the major domain of application of this aromatic plant. Rhizomes of *Curcuma aromatica* are also used in medicines as a stomachic, carminative and emmenagogue, for skin diseases and recently as a health food in Japan (Kojima *et al*., 1998).

Even though kasthuri turmeric has got wide range of application, the potential of the plant have not yet been fully realized and reaped and is getting slowly depleted from cultivation due to various reasons. The ignorance about the true identity of the crop is the major reason for the decline in cultivation of this crop. This also makes it easy for vendors to sell any turmeric in disguise of true kasthuri turmeric. Easily available *Curcuma zedoaria* (Manjakoova (Mal.)) is the common *Curcuma* spp. sold at an exorbitant price as kasthuri turmeric by many vendors (Sasikumar, 2000). Detailed study conducted in the Department of Plantation Crops and Spices helped to identify true kasthuri turmeric accessions through morphological, physiological, anatomical, biochemical and RAPD techniques (Alex, 2005).

Another reason for less commercial cultivation is lack of standardized package of practices recommendations for true kasthuri turmeric. Standardization of quality enhanced production technology, can pave the way for commercial cultivation and better utilization of this valuable underexploited crop. As far as the medicinal and cosmetic plants are concerned, the active principles of the plants are generally secondary metabolites and their biosynthesis, though controlled genetically is strongly affected by environmental and cultural factors. It is therefore advised not to use chemical fertilizers and pesticides in the cultivation of these crops. Organic cultivation is a more reliable option in these crops, which is also conducive for long term maintenance of natural resources and agricultural productivity with minimal adverse impact on the environment. It emphasizes optimal crop production with minimal external inputs, reducing dependence on commercial inputs (fertilizers and plant protection chemicals) and substituting them with internal resources. Use of biofertilizers for crop production is gaining momentum as they are environmentally safe when compared to chemical fertilizers. This signifies the possibility of developing an efficient nutrient management system in kasthuri turmeric, with the use of organic manures, and biofertilizers for better productivity as well as maintenance of soil fertility.

Detailed study conducted in the Department of Plantation Crops and Spices revealed the positive and significant influence of different levels of organic manures and microbial inoculants on growth, yield and quality of kasthuri turmeric. A fresh rhizome yield of 396.33 g plant^{-1} was obtained by the application of vermicompost alone @ 25 t ha^{-1}. Application of neemcake @ 6 t ha^{-1} produced significantly higher yield so also FYM @ 40 t ha^{-1}. The study also revealed that application of microbial inoculants significantly influenced the growth, yield and quality of kasthuri turmeric. Combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonads* and *Trichoderma* was found to have profound influence than sole application (Nirmalatha, 2009).

Though organic manures have beneficial effects on soil health and crop productivity, their limited nutrient content and requirement in large quantity is a constraint for their wider usage. Dwindling availability and huge cost of bulky organic manures warrants the need for reducing their quantity through appropriate substitutes. As a cost effective supplement to chemical fertilizers and as a renewable energy source, microbial inoculants can economize the high investment needed for fertilizer usage of N and P (Pandey and Kumar, 2002). Microbial inoculants like *Azospirillum*, *Phosphobacteria* and AMF are capable of enhancing the fertilizer use efficiently, soil fertility status and thus help in improving the yield and quality of crops. Mycorrhizal infection enhances plant growth by increasing the absorbing surface and mobilizing sparingly available nutrient sources or by secretion of ectoenzymes (Rhodes, 1980; Bolan *et al*., 1987).

Considering all these factors, the present investigation was undertaken with the following objectives:

1. To find out the optimum dose and best combination of organic manures and microbial inoculants for the quality enhanced production of kasthuri turmeric (*Curcuma aromatica* Salisb.).
2. To assess the effect of organic manures and microbial inoculants on growth, yield and quality of kasthuri turmeric (*Curcuma aromatica* Salisb.).
3. To assess the effect of organic manures and microbial inoculants on the physical and chemical properties of the soil.
4. To evaluate the effect of organic manures and microbial inoculants on the soil biological properties.
5. To work out the economics of cultivation of various combinations of manures and microbial inoculants and finally,
6. To formulate a cost effective organic manurial recommendation for commercial cultivation of kasthuri turmeric.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Kasthuri turmeric (*Curcuma aromatica* Salisb.) is a medicinal and aromatic plant with multiple uses. Several commercial cosmetics and ayurvedic preparations contain kasthuri turmeric. Rhizomes of *Curcuma aromatica* is also used in medicines as stomachic, carminative and emmenogogue for skin diseases and recently as nutraceutical in Japan (Kojima *et al*., 1998).

Organic manures contain more or less all the nutrient elements required for plant growth. When it is applied to soil, physical, chemical and biological properties of soil will be improved. The organic acids like hydroxyl and tartaric acid, citric acid etc. trap the toxic elements like Fe and Al through chelation and remove them from root environment by forming insoluble precipitates. Organic manures also act as buffer and keep the soil pH within the desired range (Banerjee, 1998). Soil with high bio-diversity can continuously support the growth of healthy crops and are termed 'living soils', which is the basis of organic farming (Nampoothiri, 2001).

Awareness on health issues and environmental issues is spreading fast globally in recent years. In this context, the organic farming system is being projected as a remedy. On-farm recycling of organic wastes and the application of organic manures such as FYM and compost can be adopted to sustain soil health. Apart from these, other organic sources like neem-cake and bio-fertilizers are also used. The biological alternatives to fertilizers are receiving greater attention in the crop production due to price inflation and concerns on environmental effects of chemical fertilizers. The popular bioinoculants are Arbuscular Mycorrhizal Fungi (AMF), *Pseudomonas fluorescens*, *Trichoderma* sp., *Azospirillum* sp. etc. Biofertilizers save N and P requirement up to 50 per cent in most crops and also increases the yield (Kanauja and Naraynan, 2003). Organic manures enhances the quality of produce, in addition to major nutrients, almost all essential plant nutrients, enzymes, hormones, growth regulators etc. are also supplied (Kumaraswamy, 2004). Moreover, the usage of organic manures reduces environmental contamination and also pesticide residue in food (Jothimani and Vanangamudi, 2004).

Though there are reports about organic farming practices in Spices like ginger and turmeric, medicinal and aromatic crops, so far very little work has been standardized for organic practice in true kasthuri turmeric (*Curcuma aromatica* Salisb.). Hence, literature of different organic manures, microbial inoculants and their integrated effect on growth, yield and quality of turmeric and ginger are specifically reviewed in this chapter. Where ever information is lacking pertinent literature on other crops have been included.

2.1. ORGANIC MANURES

2.1.1 Farm yard manure

This is the traditional organic manure and is most readily available to farmers. On an average, well rotten FYM contains 0.5 per cent nitrogen, 0.2 per cent phosphorus and 0.5 per cent potassium (Gaur *et al*., 1971). Farm yard manure (FYM), the most common and readily available traditional organic manure is a mixture of animal shed wastes containing dung, urine and some straw (Gaur, 1994). Organic manures like farm yard manure (FYM) seems to act directly in increasing crop growth and yield either by accelerating respiratory process with increasing cell permeability and hormonal growth action or by combination of all these process which supplies nitrogen, phosphorus and sulphur in available form through biological decomposition and improves physical properties of soil such as aggregation, permeability and water holding capacity

(Purakayastha and Bhatnagar, 1997). FYM improved the soil fertility status, and increased organic carbon content (Hemalatha *et al*., 2000).

2.1.2. Vermicompost

Vermicomposting is the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat as much as their own body weight per day. The excreta or casting of earthworms are rich in nutrients (N, P, K, Ca and Mg) and also in bacterial and actinomycete population (Gaur and Sadasivam, 1993). Vermicompost is a potential source of readily available plant nutrients, growth enhancing substances and a number of beneficial micro organisms like nitrogen fixing, phosphorus solubilising and cellulose decomposing organisms and can substitute or complement chemical fertilizers. It also contains various amino acids and minerals which humidified the organic matter and surrounding soil and act as a biofertilizer for plants (Shanbhag, 1999). Vermicompost is rich in major and minor nutrients. It also has a high bacterial count of 10^{10} consisting of phosphate solubilisers, nitrobacter, actinomycetes, fungi, rhizobium etc. and is free from all pathogens. Vermicompost is a good source of $GA_{3,}$ IAA and cytokinins (Yadav and Yadav, 2003).

2.1.3. Neem cake

Neemcake is rich in plant nutrients, alkaloids like nimbin and nimbidin and certain sulphur compounds which inhibit nitrification process (Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981). Sathianathan (1982) found that neem cake and mahua cake reduced leaching of lime and extended the period of availability of N to the crop. It is also rich in nutrients, supress nematode population and increase insect repellent action. It is a rich source of N, P, K, Ca, and Mg which favours growth of plant (Som *et al*., 1992). Neemcake can influence metered supply of N over a stipulated period of crop growth (Hulagur, 1996). Among the oil cakes, neem cake isolates resulted in increased nutrient use efficiency (NUE) as well as agronomic use efficiency (Kumar and Ali, 2003). Neemcake increases the agronomic use efficiency and nutrient use efficiency and insect repellent action (Nihad, 2005).

2.1.4. Effect of organic manures on growth characters

Khandkar and Nigam (1996) found that growth attributes of turmeric increased with the increase in FYM levels. The highest plant height, number of leaves and number of tillers were recorded with the application of 6 t ha^{-1} of FYM. Gill *et al*. (1999) studied the response of turmeric to nitrogen in relation to application of different levels of farm yard manure (0, 20, 40 and 60 t ha^{-1}) and wheat straw mulch (0 and 6 t ha^{-1}) in terms of growth characters of turmeric and observed that highest plant height, number of leaves and tillers were obtained with the application of 60 t ha^{-1} of FYM. According to Vidyadharan (2000) highest level of FYM applied (20 t ha^{-1}) in arrowroot resulted in increased plant height number of leaves per plant, sucker number per hill and dry matter production. Application of FYM (5 t ha^{-1}) resulted in the highest plant height, number of leaves and number of tillers in turmeric (Selvarajan and Chezhiyan, 2001). In turmeric, application of FYM 15 t ha^{-1} showed its superiority in growth characters during initial stage of growth (Subbarao and Ravishankar, 2001) and (Rakhee, 2002). In Ginger application of FYM recorded maximum plant height at all growth stages compared to other treatments (Sreekala, 2004).

Vadiraj *et al.* (1992) observed that application of vermicompost as potting mixture for cardamom gives significant increase in growthcharacters. Krishnakumar *et al*. (1994) reported better growth and development of seedlings in cardamom nursery by the use of vermicompost in potting medium. Vadiraj *et al*. (1996) found that turmeric varieties, like Armour and Suroma when treated with vermicompost showed 30 per cent increase in plant height and 70 per cent increase in leaf area over control. Mannikeri (2006) reported that in turmeric application of vermicompost @ 15.65 tha^{-1}was found superior with regards to growth parameters like plant height, number of leaves, number of tillers and leaf area. Nirmalatha (2009) reported that in kasthuri turmeric application of vermicompost 25.0 t ha^{-1} recorded the maximum plant height, number of tillers, and number of leaves, leaf area, rhizome spread, rhizome thickness, root spread, root length, root weight and number of fingers.

Som *et al.* (1992) observed that in brinjal maximum plant height was recorded in the treatment receiving neem cake 50 q ha^{-1}. Sadanandan and Hamza (2006) reported that yield increased in the turmeric with the application of neemcake. Sharu (2000) reported that in chilli growth characters like plant height, number of branches obtained by neem cake application was found to be on par with POP (20 t FYM + 70 : 40 : 25 kg NPK ha^{-1}). Santhosh Kumar (2004) observed that neem cake was found to be effective in improving the biometric characters in *Plumbago rosea*. Nirmalatha (2009) reported that in kasthuri turmeric application of neemcake 6.0 t ha^{-1} recorded the maximum plant height, number of tillers, number of leaves, leaf area, rhizome spread, rhizome thickness, root spread, root length, root weight and number of fingers.

2.1.5. Effect of organic manures on yield and yield components

Increase in the yield due to combined application of FYM was reported in ginger by Pawar and Patil (1987). Application of FYM alone resulted in higher yield in elephant foot yam (Patel and Mehta, 1987) and in turmeric (Balashanmugham *et al*., 1987). Shaha (1988) reported that application of FYM (50 t ha^{-1}) produced significantly higher yield in turmeric compared to control. Khandkar and Nigam (1996) found that the yield of turmeric rhizome increased with an increase in FYM level. They recorded a yield of 33 q ha^{-1} with the application of 6 t ha^{-1} of FYM compared to 3 tonnes of FYM (29.5 q ha^{-1}). Gill *et al*. (1999) studied the response of turmeric to graded levels of farm yard manure and straw mulch. Among the different doses of FYM, application of 60 t $ha^{-1}$of FYM recorded the maximum fresh rhizome yield. According to Bai and Augustin (1998) in kacholam, application of FYM increased yield of rhizomes by 2.03 times as compared to that of absolute control. Vidhyadharan (2000) reported that in arrowroot, FYM had profound influence on number of rhizome per plant at harvest the highest number being recorded by the application of 20 t ha^{-1} of FYM while highest rhizome yield obtained by the application of FYM 15 t ha^{-1}. Rakhee (2002) reported that FYM application 15 t ha^{-1} recorded higher rhizome yield, top yield and dry turmeric yield than the POP recommendation (30:30:60 kg NPK ha^{-1} + 40 t ha^{-1} FYM). In ginger application of FYM alone resulted in higher yield (Sreekala, 2004).

In arrowroot intercropped in coconut garden, vermicompost recorded the highest rhizome yield compared to composted coirpith (Maheswarappa *et al*., 1997). Vadiraj *et al*. (1998) observed significant positive influence of vermicompost application with respect to turmeric yield. They recorded higher fresh rhizome yield by the application of 10 t of vermicompost ha^{-1} in all the seven turmeric varieties tested, compared to control. Sunilkumar (2005) reported that in case of sole application of organic manures in coleus, vermicompost, 6 t ha^{-1}recorded the highest yield over FYM, 30 t ha^{-1}. Mannikeri (2006) reported that application of vermicompost @ 15.65 t ha^{-1} resulted in the highest fresh rhizome yield per hectare, cured rhizome yield per hectare in turmeric. Nirmalatha (2009) reported in kasthuri turmeric, application of vermicompost 25 t ha^{-1} recorded maximum fresh and dry rhizome yield and top yield during first and second year of experiment. It also recorded minimum duration to mature.

Sadanandan and Iyer (1986) reported that organic amendments like neem cake and pongamia cake significantly increased ginger yield. In turmeric, Panigrahi and Pattanayak (1988) observed an increased yield of 53 per cent by neem cake over simple fertilizer treatments. In ginger neem cake applied @ 1 t ha^{-1} before planting gave maximum yield (KAU, 1990). Haque *et al*. (1995) reported increased shoot fresh weight with neem cake. An experiment conducted in Kerala Agricultural University, Thrissur, in banana revealed that neem cake containing 5.2 per cent N (950 g plant^{-1}) was the best source in increasing yield (KAU, 1993). In ginger, neem cake applied @ 2 t ha^{-1} produceda high yield of 4884 kg ha^{-1} (Sadanandan and Hamza, 1998).

2.1.6. Effect of organic manures on physiological characters

Maheswarappa *et al*. (1997) found that application of FYM resulted in significantly higher harvest index in arrow root. FYM 20 t ha^{-1} recorded the highest value for DMP at 6 MAP and at harvest in arrow root. (Vidhyadharan, 2000). An experiment on galangal as intercrop in coconut reported an increase in dry matter accumulation in rhizome at harvest due to FYM application (Maheswarappa *et al*., 2000b). According to Rakhee (2002), highest DMP was obtained when FYM was applied @ 15 t ha^{-1} in turmeric and during 2 and 4 MAP and leaf area index was maximum when FYM was applied during initial stages. Application of farm yard manures @15.65 t ha^{-1} resulted in the highest harvest index in turmeric (Mannikeri, 2006).

In turmeric NAR, CGR and RGR was the highest for vermicompost 20 t ha^{-1} treated plants from 120-180 DAP (Rakhee 2002). Velmurughan *et al*. (2006a) found that leaf area, leaf area index, dry matter production were highest with combined application of vermicompost and panchagavya in cauliflower. Mannikeri (2006) reported that in turmeric, application of vermicompost @ 15.65 t ha^{-1} was found superior in physiological characters like dry matter accumulation. Nirmalatha (2009) reported that when vermicompost 25 t ha^{-1} was applied, it recorded maximum values of LAI, HI and rhizome: shoot ratio in kasthuri turmeric.

In chilli DMP and LAI obtained by application of neem cake were found on par with POP (20 t FYM + 75: 40: 25 kg NPK ha^{-1}) as observed by Sharu (2000). Padmanabhan and Chezhiyan (2006) observed that in ashwagandha better response in physiological aspects were found when neem cake was applied. Babu Ratan *et al.* (2006) reported that in banana application of neemcake registered highest leaf area $plant^{-1}$. Nirmalatha (2009) reported that physiological characters like DMP, LAI, CGR and RGR were found to be highly influenced by the application of vermicompost 25.0 t ha^{-1} and neemcake 6.0 t ha^{-1} which were significantly superior to all other treatments in kasthuri turmeric.

2.1.7. Effect of organic manures on biochemical characters

Ravindran and Balanambisan (1987) reported that the starch content of potato increased with the increased rate of application of organics *viz.*, FYM @ 5 t ha^{-1} (72.50 %) and FYM @ 10 t ha^{-1} (75 %). Maheswarappa *et al.* (1997) found that application of FYM resulted in significantly higher starch and crude protein contents in arrow root. Gill *et al.* (1999) reported that among the different doses of FYM, application of 60 t $ha^{-1}$of FYM recorded the highest curcumin content in turmeric. Protein content was the highest in arrowroot by the application of FYM 20 t ha^{-1}, while low crude fibre content by the application of FYM 10 t ha^{-1} (Vidhyadharan, 2000). Premsekhar and Rajashree (2009) reported that FYM 20 t ha^{-1} recorded the highest crude fibre content of fruits compared to control in okra.

Considerable scientific data were generated to testify that the produce obtained by the use of vermicompost is nutritionally superior, tastes good, has good texture and have better keeping qualities (Lampkin, 1990). Starch content of sweet potato tuber was maximum when nitrogen was supplied as vermicompost (Sureshkumar, 1996). Rakhee (2002) reported that when vermicompost was applied to turmeric the volatile oil content was 4.30 per cent and curcumin content was 4.87 per cent. Nirmalatha (2009) reported that biochemical characters like curcumin content, volatile oil, non volatile ether extract (NVEE), crude fibre, starch, total carbohydrates and protein content were significantly influenced by the application of organic manures and vermicompost 25.0 t ha^{-1} was found to be superior to all other treatments in kasthuri turmeric. Use of vermicompost 3 t ha^{-1} recorded the maximum total chlorophyll content than its lower dose of application in chilli (2 t ha^{-1}) (Mog, 2007).

In ginger, application of neem cake @ 2.5 t ha^{-1} enhanced oil content and increased oleoresin content (Sadanandan and Hamza, 1998). Sreekala (2004) reported that neem cake application in ginger recorded volatile oil content of 4.13 per cent and curcumin content (5.77 %), starch content (42.43 %) and NVEE (5.2 %). Neem cake application in turmeric was found to be superior with regard to curcumin recovery (Sadanandan and Hamza, 2006).

2.1.8. Effect of organic manures on soil physical properties

Increase in soil moisture retention due to addition of FYM was observed by Salter and Williams (1963). Havangi and Mann (1970) reported that a continuous application of FYM decreased the bulk density of soil. Maheswarappa (1999) reported that in East Indian galangal cultivation the bulk density of soil decreased by the application FYM @ 32 t ha^{-1} from the initial value. According to Singh *et al*. (2000) in rice application of FYM significantly brought down the bulk density of both surface and subsurface soils in comparison with the control.

The ability of earthworms to influence the soil physical environment by increasing the pore volume, increasing the amount of water soluble aggregates, increasing the incorporation of organic matters and enhancing pedological processes has been reported by Shipitalo and Protz (1988). In rice, increase in the soil nutrient status due to application of vermicompost was reported by Vasanthi and Kumaraswamy (1996). Vadiraj *et al.* (1998) opined that soil applied with vermicompost (10 t ha^{-1}) not only increased the growth and yield of turmeric but also helped to keep soil fertile and productive. Maheswarappa *et al.* (1999) reported that vermicompost application decreased the bulk density of the soil to a greater extent. Nirmalatha (2009) found that vermicompost 25.0 t ha^{-1} recorded the best values for the soil physical characters like bulk density, water holding capacity, electrical conductivity and pH.

When neem cake was applied in rice-fallow rotation for ten years, it improved the water retention characteristics of alluvial sandy loam soil (Biswas *et al.*, 1969). Sadanandan and Hamza (1998) reported improved physical condition of the soil as a result of organic cake application in ginger.

2.1.9. Effect of organic manures on soil chemical properties

Srivastava (1985) observed that increased use of nitrogenous fertilizer decreased organic carbon content and total N, while FYM increased above parameters. Kabeerathumma *et al*. (1990) in a long term manurial experiment in cassava, after thirteen years of continuous cropping observed increased nutrient like N, P, K and organic carbon with the inclusion of FYM and application of respective nutrients to the soil. Application of FYM increased the activity of phosphatase enzymes which enhanced P availability (Bopaiah and Shetty, 1991). Hedge *et al*. (1998) reported that nutrients P and K and organic carbon doubled when FYM or vermicompost was applied and the soil pH changed to neutrality. Radhamadhav *et al.* (1999) observed that incorporation of FYM in field crops improved the phosphorus status of the soil through its slow decomposition. Venkatesh *et al.* (2003) reported that in ginger available N content in the soil after the experiment was enhanced by the application of highest level of FYM.

Haimi and Huhta (1990) reported that earthworms increase the proportion of mineral N available for plants although N was clearly immobilized in the initial stages. Reddy and Mahesh (1995) reported that in green gram an increased availability of N and K in soil by the application of vermicompost compared to FYM. An increased K was detected in soils with earth worm activity (Rao *et al.*, 1996). Available P, K, Ca, Mg and organic carbon content of the rhizosphere soil almost doubled in cardamom when vermicompost was applied for over two years (Hegde *et al.*, 1998). According to Maheswarappa *et al.* (1998), organic carbon content was the highest in vermicompost treated plot compared to other treatments. A perceptible increase in pH was also recorded. Srikanth *et al.* (1999) reported that application of vermicompost alone maintained the pH of soil at neutral condition as compared to inorganic fertilizers. Vermicompost contains various amino acids and minerals which humidify the organic matter and surrounding soil (Shanbhag, 1999). Asha Raj (2005) reported that in slicing cucumber enriched vermicompost application resulted the higher nitrogen content in soil. Mannikeri (2006) reported that in turmeric application of vermicompost @ 15.65 t ha^{-1} resulted in the highest concentration of major nutrients. Nirmalatha (2009) recorded that in kasthuri turmeric available P and K content was significantly superior when vermicompost 25.0 t ha^{-1} was applied.

Sathianathan (1982) found that neem cake reduced leaching loss and extended the period of availability of N to the crop from applied N. Neem cake when applied to ginger, it increased the yield, organic carbon content and potash in the soil (Sadanandan and Iyer, 1986). Neem cake has the capacity of releasing nitrogen over a stipulated period of crop growth (Hulagur, 1996). Neem cake @ 1 kg $plant^{-1}$ along with 600: 300: 600 g

NPK plant^{-1} could maintain available NPK status of the soil at the highest level in khas mandarin (Borah *et al.*, 2001). A neem cake application of 6.0 t ha^{-1} recorded the maximum available N content in soil in kasthuri turmeric (Nirmalatha, 2009).

2.1.10. Effect of organic manures on uptake of N, P and K

Susan *et al*. (1998) reported that inclusion of FYM favors the uptake of N in cassava. Vidyadharan (2000) found significantly higher values of N, P and K uptake at the highest level of FYM (20 t ha^{-1}) in arrow root. Venkatesh *et al*. (2003) reported that, in ginger mother rhizomes, N, P and K uptake significantly increased due to application of P sources and FYM. According to Sheeba (2004), nitrogen uptake was maximum in enriched vermicompost treatment which was on par with 'FYM + full NPK' treatment in amaranthus.

Increased uptake of nutrients and higher yield in tomato (Pushpa, 1996) and also in chilli has been reported by Rajalekshmi (1996) by vermicompost application. Reddy and Mahesh (1995) reported that application of vermicompost increased the N and P uptake in green gram compared to FYM. Jayabal and Kuppuswamy (2001) observed that in rice integrated application of 50 per cent N through vermicompost, increased the uptake of N, P and K over fertilizer alone. Sheeba (2004) reported that, in amaranthus plant uptake of major nutrients was maximum for enriched vermicompost treatment. Application of vermicompost @ 15.65 t ha^{-1} resulted in the highest concentration of major plant nutrient uptake in turmeric (Mannikeri, 2006). Nirmalatha (2009) reported that in kasthuri turmeric uptake of P and K was significantly superior when vermicompost 25.0 t ha^{-1} was applied.

In rye grass, neemcake and karanja cake improved the uptake of nitrogen especially at higher level of application (Hulagar, 1996). Nirmalatha (2009) reported that in kasthuri turmeric application of neem cake 6.0 t ha^{-1} recorded significantly superior uptake of N.

2.1.11. Effect of organic manures on incidence of pests and diseases

Mutitu *et al*. (1988) observed that the *Fusarium oxysporum* sp. *Phaseoleos* bean can be reduced by the application of FYM. Dayakar *et al*. (1995) reported that when FYM was applied along with 50:50 NP fertilizers in pigeon pea, the population of pod borer was lower than the use of straight inorganic fertilizer alone.

The activity of *Apporrectodea trapezoids*, the largest earthworm can substantially decrease the symptoms caused by *Rhizoctonia* in wheat seedlings (Stephen *et al*., 1993). Doube *et al*. (1994) evaluated the control of fungal root disease of cereal crops using earthworms and biocontrol agents, and influence of earth worms on *Rhizobium* populations.

Several other authors also reported that effectiveness of organic amendments (oil seed cake) for management of nematodes in various crops (Abid *et al*., 1995; Sheela *et al*., 1995; Rajani *et al*., 1998). Rajani (1998) investigated the effectiveness of neem cake @ 200 g m^{-2} for managing root-knot nematode in kacholam. Sharu (2000) revealed in chilli that lowest incidence of bacterial wilt was observed when chemical fertilizers and neemcake were applied. The experiment conducted at Kerala Agricultural University revealed that nematode population in soil was found to be minimum in neem cake treatment and maximum in treatment with nitrogen alone (KAU, 2001). Arulmozhiyan *et al*. (2002) recorded lowest disease incidence of *Phytophthora* foot rot in betel vines which received neem cake. Inblack pepper and plumbago crop loss due to root-knot nematode was effectively controlled by neem cake (Santhoshkumar, 2004).

2.1.12. Effect of organic manures on economics of cultivation/ B: C ratio

In the study named 'Influence of different organic manures and *Azospirillum* on growth, yield and quality of ginger', conducted by KAU (1999), a benefit cost ratio of 2.32 was obtained when FYM @ 48 t ha^{-1} was applied. Economics of cultivation showed that the highest net income (Rs. 34,11,680/-) and BCR (1.84) were obtained in arrowroot by the combined application of 10 t FYM, 120 kg N and 80 kg K_2O ha^{-1} along with 50 kg P_2O_5 kg ha^{-1} (Vidyadharan, 2000). Rakhee (2002) reported that in turmeric B: C ratio was maximum when coirpith compost was used and it was on par with FYM, vermicompost and poultry manure treatment. Sekhar and Rajasree (2009) reported that among the treatments, application of FYM @ 20 t ha^{-1} resulted in a higher benefit cost ratio in bhindi (3.56) compared to the lower levels.

According to Arunkumar (2000) vermicompost application at highest dose (37.5 t ha^{-1}) gave the maximum B: C ratio in amaranthus compared to other treatments. Nirmalatha (2009) reported that in kasthuri turmeric application of vermicompost 25.0 t ha^{-1} recorded the maximum B: C ratio of 4.7 and 5.7 during first and second year, respectively.

Economic analysis of different treatments revealed that 80 kg N ha^{-1} through neem coated urea resulted in higher B: C ratio than 100 kg N ha^{-1} through prilled urea in rice (Porwal *et al.*, 1993). Maximum yield and minimum returns per rupee investment was obtained from 600 g N, 300 g P_2O_5, 300 g K_2O + 15 kg neemcake $plant^{-1}$ $year^{-1}$ in acid lime (Ingle *et al.*, 2001).

2.2. MICROBIAL INOCULANTS

The efficiency of microbial inoculants proved to be an effective alternative to obviate the deficiencies realized through the exclusive reliance on chemicals. Microbial biocontrol agents are harmless to human beings and animals, cheaper than pesticides, highly effective throughout the crop growth period with high rhizosphere competence, easy to deliver, improve plant growth, increase yield, bestowed with high cost benefit ratio, environmentally safe, performs in a sustainable way and contributes for sustainable crop production. There is no risk of the pathogen developing resistance and residues in food and ground water. They are compatible with biofertilizer (Kanauja and Narayanan, 2003).

Great emphasis has been laid on development and use of biofertilizers for the last two decades. As a cost effective supplement to chemical fertilizers and renewable energy source biofertilizer can help to economize on the high investment needed for fertilizers use as far as N and P are concerned (Pandey and Kumar, 2002). Microbial inoculants are the products containing living cells of different microorganisms, which have an ability to mobilize nutritionally important elements from non-usable to usable form through biological processes (Arora and Dan, 2003).

2.2.1. *Azospirillum*

Biofertilizers like *Azospirillum* and *Azotobacter* sp. increased nut germination, plant height, stem girth, number of leaves per seedlings, root parameters and total plant biomass in cashew (Ramesh *et al.*, 1998). The influence of different organic manures and *Azospirillum* on growth, yield and quality was found good in most of the crops (KAU, 1999).

2.2.2. Arbuscular Mycorrhizal fungi (AMF)

AMF perform many valuable functions from their host plants. It seeks out nutrients particularly P from far greater soil area than the plant can access by itself. It increased the surface area of root mass. It aids in penetration of small hyphae into sites too small for plant root to reach. It also increases the uptake of N, K, S, Cu and Zn. It aids in better survival during drought. It protects against heavy metals and increases the accumulation of hormones like GA and cytokinin in plants. As the fungus acts as an extension of the root it increases the overall absorption capacity of roots due to morphological and physiological changes in the plant. AMF helps in better development of P solubilizing bacteria in the myco-rhizosphere (Sivaprasad and Meena Kumari, 2005).

2.2.3. *Pseudomonas flourescens*

They are known as plant growth promoting rhizobacteria (PGPR). They are used as biological control agents for the suppression of soil-borne diseases by competing with pathogens for resources such as nutrients, producing antibiotics or activating host defense mechanisms. They often bring about the growth effects synergistically. In case of spices several *Pseudomonas* isolates have been obtained from black pepper and ginger and screened for their ability to suppress pathogens and some were listed for their antagonistic activity on both oomycetes pathogen and nematodes. These isolates were found to enhance growth of host plants (Anandaraj and Sarma, 2003). *Pseudomonas* produces antimicrobial compounds like bacteriocins, pyrrolnitrin, pyoluteorin etc.

2.2.4. *Trichoderma*

The mode of action of *Trichoderma viride* is competition, antibiosis hyperparasitism, hyphal coiling, hyphal penetration, production of lytic enzymes, induced resistance, plant growth promotion etc. The competition for carbon and nitrogen by *T. harzianum* suppressed the infection of *Fusarium oxysporum* for sp. *melonis* (Sivan and Chat, 1989) on several crops through competition. Antibiotics like trichodermin, dermadin, trichoviridin, viridian etc. are produced by *Trichoderma*. Mycoparasitism relies on the production of mycoparasite for the lysis of cell walls. *Trichoderma* induces plant growth like increased germination, early emergence, fresh and dry weight of roots, shoots, root length, yield and flowering.

2.2.5. Effect of microbial inoculants on growth characters

The beneficial effect of *Azospirillum* and *Phosphobacteria* on growth of cardamom was indicated from the studies carried out at Indian Cardamom Research Institute (Muthuramalingam *et al.*, 2000). Nath and Korla (2000) reported that in ginger the highest plant height, number of tillers and number of leaves per plant observed when biofertilizers like *Azospirillum* and *Azotobacteria* were applied. *Azospirillium* has nitrogen fixing ability and are also known to produce growth promoting substance, which favour better growth in turmeric (Subramanian *et al.*, 2003). Inoculation of *Azospirillum* in combination with N profoundly increased the growth and yield of turmeric (Mohan *et al.*, 2004).

VAM treatment recorded more number of tillers, root length, root weight compared to control in ginger (Rohini Iyer and Sundararaju, 1993). According to Sivaprasad (1993) the AMF namely *Glomus multicaule* and *Glomus fasciculatum* significantly enhanced growth of ginger.According to Kandiannan *et al.* (2000) the vine length, number of leaves and dry weight were significantly higher in plants inoculated with selected species and strains of AMF and N fixing bacteria. According to Gupta *et al*. (2003) AMF inoculation in periwinkle enhanced the growth and number of branches. Arora and Sharma (2009) reported that in sorghum inoculation with AM fungi can facilitates the plant growth and thus increase phytoremediation sufficiency.

In general, mycorrhizal inoculations was found beneficial in improving the plant growth compared to control in cardamom (Sreeramulu and Bhagyaraj, 1999). The fluorescent pseudomonas treated pepper plants imparted maximum shoot and root biomass (Diby *et al*., 2001). Raji and Lekha (2003) reported that seed bacterization with talc based formulation of *P. fluorescence* enhanced the root length and height of rice plants. In black pepper when *P. fluorescence* was applied, the growth response was improved (Sivaprasad *et al*., 2003).

According to Joseph (1977), *T. viride* was the most effective isolate for growth enhancement in ginger. Soil application of *Trichoderma* to black pepper cuttings resulted in 100 per cent increase in root dry weight compared to uninoculated pepper cuttings (Anith and Manomohandas, 2001). In the organic production of turmeric, application of biofertilizers like *Trichoderma viride* (7.5 kg ha^{-1}) and *phosphobacteria* (7.5 kg ha^{-1}) was recommended (Ravikumar, 2002). According to Rini (2005) application of *Trichoderma* increased crop growth in tomato and chilli.

Ashithraj (2001) reported that dual combination, Phosphobacteria + AMF was the most effective in increasing the growth characters of black pepper. In birds eye chilli, *Azospirillum* + AMF + *Phosphobacteria* application increased plant height and number of branches per plant (Praneetha and Lakshmanan, 2006).Roy and Hore (2009) reported that in turmeric maximum plant height, number of tillers, number of leaves and weight of clump were obtained in treatment NPK (75%) (150: 60: 210 NPK Kg ha^{-1}) + *Azospirillium* + AMF. Nirmalatha (2009) reported that combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* produced tallest plants with more number of leaves and tillers, maximum leaf area, rhizome spread, rhizome thickness, root spread, root length, root weight and number of fingers in kasthuri turmeric.Plants inoculated with microbial consortia including arbuscular mycorrhizal fungi, *Azospirillum*,*Azotobacter* and *Pseudomonas fluorescens* displayed successful establishment and remarkable growth after two years of inoculation (Singh and Jamaluddin, 2010). Sumathi *et al*. (2011) reported that combined application of *A. lipoferum* + *T. viridae* + *B. megaterium* + *P. fluorescens* recorded maximum number of leaves whereas, *T. viridae* + *B. megaterium* + AM fungi and *A. lipoferum* + *T. viridae* + *B. megaterium* + *P. fluorescens* recorded the highest shoot height in turmeric. Hemashenpagam and Selvaraj (2011) reported that in *Solanum viarum* triple inoculation of *G. aggregatum* + *B. coagulans* + *T. harzainum* in a green house nursery resulted in maximum plant biomass, plant height and plant dry weight.

2.2.6. Effect of microbial inoculants on yield and yield components

In ginger Azofert application enhanced the size and yield of rhizome (Nath and Korla, 2000). According to Subramanian *et al*. (2003), the application of *Azospirillum* increased the yield of turmeric. Inoculation of *Azospirillum* in turmeric increased the yield over control (Mohan *et al*., 2004).

Gupta *et al*. (2003) observed that root colonization of AMF (*Glomus* spp) have significantly increased the fresh biomass yield of periwinkle in comparison to non inoculated control plants. In chilli plants inoculated with AMF produces more number of fruits compared to uninoculated plants (Kanauja and Narayanan, 2003). Saraswathi and Shanmugham (2006) observed that in cassava number of tubers plant^{-1} were more in AMF applied treatments.

Seed or root inoculations with *Pseudomonas* are reported to improve yield of potato (Burr *et al*., 1978). The microbial culture developed at IARI with *Pseudomonas striata* showed that inoculation of seed and seedlings of rice and wheat increased grain yield (Tilak, 1991). Asghar *et al*. (2002) revealed that number of pods plant^{-1}, 1000-grain weight and grain yield was high in *Pseudomonas* treated plants in *B. juncea*. It was found that use of plant growth regulator, (GA_3) and plant growth promoting Rhizobacteria (*Pseudomonas fluorescence*) in cauliflower increased yield (Mohana and Dhandapani, 2006). Kirankumar *et al*. (2008) reported that in tomato *Pseudomonas* B-25 was highly efficient in promoting growth, fruit yield of tomato in the presence of TMV pathogen.

Anandraj and Sarma (2003) reported thatcombined inoculation of *Trichoderma* sp. and *Pseudomonas flourescens* increased the growth and yield in black pepper. Easwaran *et al*. (2003) reported that combined application of *Azospirillum* + *Phosphobacteria* + AMF increased green leaf yield in tea. In *Polyanthus tuberosa* application of AMF + *Azospirillum* + *Phosphobacteria* recorded the maximum number of flowers spike^{-1}, single flower weight, maximum yield ha^{-1} (Praneetha *et al*., 2006). The application of 50 per cent of recommended dose (120:240:120 kg NPK ha^{-1}) as basal and another 50 per cent as top dressing along with *Azospirillum* and *Phosphobacteria* resulted in higher tuber yield (25.87 t ha^{-1}) and ascorbic acid (21.2 mg/100 gm) content in onion (Mahendran *et al.*, 1996). Nirmalatha (2009) reported that in kasthuri turmeric combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* produced rhizomes with maximum fresh and dry rhizome yield as well as top yield and also took minimum days for attaining maturity. Roy and Hore (2009) reported that in turmeric NPK (75%) + *Azospirillium* + AMF recorded maximum projected yield followed by NPK (75%) + *Azotobacter* + AMF as compared to 100% inorganic NPK alone (150: 60: 210 NPK kg ha^{-1}).

2.2.7. Effect of microbial inoculants on physiological characters

Ponmurugan and Baby (2001) reported that physiological parameters like photosynthesis rate, water use efficiency and stomatal conductance were highly influenced by *Pseuodomonas* application in cocoa. *Pseudomonas syringe* interferes with leaf chloroplasts, mitochandria and enhances the photosynthesis process thereby activating the physiological process in sunflower (Robinson *et al*., 2004). The effect of biofertilizers on physiological and biochemical parameters was studied in turmeric by Velmurugan *et al*. (2006b). Nirmalatha (2009) reported that in kasthuri turmeric bio inoculant application highly influenced dry matter production throughout the growth stages. *Azospirillum* + AMF + *Pseudomonas* recorded highest LAI and *Azospirillum* + AMF + *Pseudomonas* + *Trichoderma* was superior also with harvest index, CGR, RGR, NAR and LAD.

2.2.8. Effect of microbial inoculants on biochemical characters

Inoculation with *Azospirillum* increased capsicin and ascorbic acid contents in chilli (Balakrishnan, 1988). Amirithalingam (1988) recorded highest ascorbic acid and capsicin content as a result of *Azospirillum* treatment in chilli.

The quality attributes of tomato namely vitamin C content and TSS significantly increased over control by AMF inoculation (Sundaram and Arangarasan, 1995). AMF inoculated aromatic crops like *Cymbopogon martini* var *motia* have more essential oil than in control plants (Ratti and Janardhan, 1996).

Robinson *et al*. (2004) reported that application of *P. syringe* enhanced production of chlorophyll, ascorbic acid in sunflower. Gomaz *et al*. (2006) found that application of *Pseudomonas* in prickly pear increased oil yield and decreased peroxide value. According to Ponmurugan and Baby (2001), when *Pseudomonas* was applied to cocoa plants increased the amino acid content, chlorophyll content and carotenoids.

The total protein content produced by *Trichoderma* sp. was significantly higher compared to untreated chickpea plants (Srivastava *et al.,* 2002). Sreekala (2004) reported that in ginger highest content of volatile oil and non volatile ether extract was obtained when *Trichoderma* was applied.

Combined inoculation of *Azotobacter* and *Azospirillum* in turmeric revealed that it increased the curcumin and protein content compared to single inoculated and un-inoculated treatments (Jena and Das, 1997). According to Mohan *et al*. (2004) in turmeric, combined application of *Azospirillum* and *Azotobacter* increased curcumin and oleoresin content. Nirmalatha (2009) reported that combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* was significantly superior in quality parameters like curcumin, volatile oil, non volatile ether extract (NVEE), starch, chlorophyll 'a' and chlorophyll 'b'. Sumathi *et al*. (2011) reported that in turmeric combined application of *A. lipoferum* + *T. viridae* + *B. megaterium* + *A. fluorescens* and *A. lipoferum* + *T. viridae* + *B. megaterium* + *A. fluorescens* + AM fungi applied treatments recorded the maximum curcumin content.

2.2.9. Effect of microbial inoculants on soil physical properties

Increasing awareness is being created in favour of adopting biological routes of soil fertility management for preventing soil degradation and for sustained optimum crop production. So production and use of biofertilizers in agriculture assume considerable importance (Verma, 1993). Microorganisms have been shown to promote soil aggregation and thus directly influence root environment and plant growth. Polysaccharides can be of microbial origin. Soil aggregation and other structural improvement of soil under pasture have been attributed to the binding effect of mycorrhizal hypae, as well as to the root exudates (Manickam, 1993). Jacobson (1994) also suggested that mycorrhizae improved soil structure by their stabilizing effect on soil aggregates. Clough and Sutton (1994) observed improved soil texture due to arbuscular mycorrhizal associations.

2.5.10. Soil chemical properties

VAM inoculated papaya varieties showed significant increase in the N, P, K content compared to control (Kennedy and Rangarajan, 2001). Sharma *et al*. (2002) reported that in apple all inoculated treatments had shown significantly higher P, Zn, Cu, Mn and Fe nutrients in soil over uninoculated control. It is possible that application of VAM covert the unavailable nutrients content from the rhizosphere soil to available form resulting in increased contents of P, Zn, Cu, Mn and Fe. According to Zhahir *et al*. (2004), mycorrhizosphere interaction between bacteria and fungi effects P-cycling, thus promoting a sustainable nutrient supply to the plants. Sumathi *et al*. (2011) reported that combined application of *A. lipoferum* + *B. megaterium* recorded the highestelectrical conductivity, *A. fluorescens* + AM fungi recordedhighest organic carbon content, *A. lipoferum* + *T. viridae* + *B. megaterium and A. lipoferum* + *T. viridae* + *B. megaterium* + *A. fluorescens* + AM fungi recorded the highest recorded available nitrogen while *T. viridae* + *A. fluorescens* + AM fungi recorded the highest available phosphorus in turmeric.

2.2.11. Effect of microbial inoculants on uptake of N, P, K

Gaddeda *et al*. (1984) reported that P concentration in apple leaves increased by inoculation with *Glomus fasciculatum* in park dale soil with an exchangeable P content of 13 ppm. Shivasankar and Iyer (1988) reported that in black pepper mycorrhizal plants showed a significant increase in tissue N, P and leaf nitrate reductase activity when compared with control. AMF inoculated black pepper cuttings showed increased P and Zn contents against uninoculated plants (Thomas and Ghai, 1988 and Sivaprasad *et al*., 1992). AMF inoculation in cardamom increased P uptake (Thomas *et al*., 1994). Increased uptake of P, Cu and Mn by AMF inoculated plants has been reported by Wang *et al*. (1997) in tea. An increased uptake of P was also reported by Sreeramulu and Bagyaraj (1999) in cardamom seedling inoculated with *Glomus monosporium*. The symbiotic association of mycorrhizal fungi enhanced the mineral nutrients especially P, K and Zn acquisition in the peppermint (Khalid *et al*., 2001). Sharma *et al*. (2002) studied the effect of VAM on P soil and leaf nutrient status and observed higher P in inoculated plants. Kirankumar *et al*. (2008) observed the highest uptake of NPK was in tomato plants treated with *Pseudomonas* sp. B-25.

According to Joseph (1977) the combined use of AMF and *Trichoderma* in ginger increased K uptake. Rajagopal and Ramarethinam (1997) reported that combined inoculation of *Glomus faciculatum*, *Azospirillum braziliens*, *Phosphobacteria* and digested organic supplements resulted in better growth and nutrients uptake in tea. Hazarika *et al*. (2000) reported that nutrient concentration (N, P and K) and their uptake in green gram inoculated with VAM fungi + *Rhizobium* was significantly greater compared to uninoculated control or plants that received only mycorrhiza or *Rhizobium.*

2.2.12. Effect of microbial inoculants on pest and diseases incidence

According to Joseph (1977), *T. viride* was the most effective isolate for suppression of rhizome rot in ginger. Inoculation of AMF at the time of planting in the nursery or field is recommended for tolerance of crop plants against root pathogen particularly black pepper, cardamom, ginger, turmeric, cowpea and transplanted vegetables (KAU 1996). The positive effect of AMF against pest and diseases was reported in grain legumes (Ray and Dalei, 1998), pepper (Sivaprasad *et al*., 2000) and kacholam (KAU,2003). Priyadarshini (2003) reported that *T. harzianum* was found successful in managing the diseases in amaranthus. Kirankumar *et al*. (2008)

reported that in tomato the incidence of pathogenesis was found markedly less in presence of *Pseudomonas* B-25.

According to Anandaraj and sarma (2003), application of *Pseudomonas flourescens* + *Trichoderma* sp. suppress of root rot in black pepper. Rini (2005) reported that combined application of *Trichoderma* and *Pseudomonas* offered 100 per cent protection against seedling blight in tomato and chilli plants. The application of *Pseudomonas* and *Trichoderma* in chilli and tomato suppressed the diseases caused by *Rhizoctonia solani* and *Fusarium oxysporum* and produced healthy plants (Rini and Sulochana, 2007).

2.2.13. Effect of microbial inoculants on B: C ratio

According to Pradhan (1994) biofertilizers are not only low cost input but also gives high returns under favourable condition.

2.3. EFFECT OF COMBINED APPLICATION OF ORGANIC MANURES AND MICROBIAL INOCULANTS

2.3.1. Effect on growth characters

Sendur *et al*.(1998) showed that use of organic manure like *Azospirillum*, FYM and vermicompost combined with recommended dose of inorganic fertilizers showed better performance in terms of growth and fruit yield of tomato. Sreekala (2004) reported that in ginger, application of FYM and AMF + *Trichoderma* recorded the best morphological characters. Velmurugan *et al*. (2006c) reported that in turmeric highest plant height, number of leaves, number of tillers was recorded in the treatment farm yard manure + *Azospirillum* + *Phosphobacteria* + VAM. Patil (2008) reported that in capsicum soil application of FYM 50 per cent + vermicompost 50 per cent + biofertilizer recorded higher plant height, more number of leaves, less number of days to flower initiation, more number of fruits per plant, higher fruit weight per plot and this characters were on par with FYM 50 per cent + vermicompost 50 per cent + neem cake @ 500 kg ha^{-1}. Padmapriya *et al*. (2010) reported that in *Gymnema sylvestre* FYM (25 t ha^{-1}) + recommended dose of fertilizer (90:45:35 kg ha^{-1} of NPK ha^{-1}) combined with foliar spraying of panchagavya and manchurian mushroom extract each at 3 per cent and humic acid at 0.3 per cent, recorded highest plant height, number of leaves, number of branches, leaf area, fresh biomass and dry biomass throughout its growth stages.

2.3.2. Effect on physiological characters

According to Sreekala (2004), in ginger physiological parameters like DMP, CGR, LAI and HI were higher in plots treated with FYM+ AMF and FYM + NC + AMF + *Trichoderma*. In plumbago highest DMP and harvest index was obtained in the treatment containing FYM + NC along with microbial inoculants. Highest NAR was observed by plants supplied with FYM + vermicompost and microbial inoculants (Nihad 2005). In turmeric Velmurugan *et al*. (2006b) reported that combined application of microbial inoculants like *Azospirillum* + AMF + FYM recorded highest leaf area, leaf area index, total dry matter production and harvest index.

2.3.3. Effect on yield and yield components

The plot treated with 5 t of FYM + 50 % N + *Azospirillium* (5 kg ha^{-1}) showed highest yield in turmeric (Subramanian *et al*., 2003). Manohar Rao *et al.* (2005) reported that in turmeric highest dry yield was recorded in the crop applied with neemcake 1.25 t ha $^{-1}$ + FYM 12.5 t ha^{-1} + RDF, followed FYM 25 t ha^{-1} + RDF over RDF (188:70:120 NPK Kg ha $^{-1}$). Geethakumari (2005) reported that application of poultry manure /neem cake /farm yard manure to supply 100 kg N ha $^{-1}$ (N equivalent basis) in combination with seedling dip of *Azospirillum* and foliar application of 2 per cent pseudomonas combined with cow’s urine spray at

5 per cent concentration was the best economic organic nutrient schedule for increasing the productivity of bhindi. Santoshkumar and Shashidhara (2006) observed that in chilli application of organics *viz.,* FYM @ 10 t ha^{-1} along with 100 per cent RDF resulted in higher fruit yield over 100 per cent RDF followed by the combined application of FYM @ 5 t ha^{-1} + chilli stalk @ 5 t ha^{-1} along with 100 per cent RDF + secondary and micronutrients + bio-fertilizers. Kannan *et al*. (2006) reported that in tomato application of 75 per cent N as vermicompost with *Azospirillum* recorded 45 per cent higher yield of tomato. In cabbage combined application of organic manure (Vermicompost) and bionoculants (*Azospirillum* + AMF + *Phosphobacteria)* recorded the maximum yield (Taiyab *et al*., 2006).

Meena and Marimuthu (2006) found that highest yield was recorded in the combination green manure + neem cake and *Pseudomonas fluorescence* application. Sable *et al.* (2007) observed that in tomato higher number of branches and fruit yield with the combination of 50 per cent N through neem cake and 50 per cent N through vermicompost were recorded. Velmurugan *et al*. (2006c) reported that in turmeric combined application of farm yard manure along with *Azospirillum* + *Phosphobacteria* + VAM recorded the supremacy for yield attributes like more number of mother rhizomes per plant^{-1}, higher weight of mother rhizomes, primary rhizome and secondary rhizome and greater yield plant^{-1},yield plot^{-1} and highest estimated yield. Leela *et al*. (2009) reported in soyabean that the highest seed yield was obtained in the treatment recommended N applied through urea + 50 per cent N applied through FYM + PSB which accounted for 60.50 per cent seed yield increased over control. Shashidhar *et al*. (2009) reported that mulberry raised with 100 per cent Recommended N through 20 per cent each of compost + *Glyricidia maculate* + castorcake + vermicompost and urea + 10 kg each of *Azospirillum brasilense* + *Aspergillus awamori* bio-fertilizer + remaining P, K through chemical fertilizers + Recommended FYM recorded significantly maximum leaf yield per plant and hectare. Murugan *et al*. (2011) reported that in black gram application of NEC together with *Rhizobium leguminosarum bv. Phaseoli* (RHL) and *Pseudomonas fluorescence* (PSF) recorded the highest grain yield, which is 120, 233 and 88 per cent higher than that of district, state and national average productivity.

2.3.4. Effect on biochemical aspects

AMF inoculated Cymbopogon martini var. motia produced more oil than control plants (Ratti and Janardhan, 1996). The influence of different organic manures and *Azospirillum* on growth, yield and quality of ginger was reported (KAU, 1999). The results revealed that 15 per cent increase in essential oil content was noticed where, 25 per cent N were substituted through *Azospirillum.* Manohar Rao *et al.* (2005) reported that in turmeric among the quality character, curcumin content was maximum with neemcake 1.25 t ha^{-1} + FYM 12.5 t ha^{-1} + RDF while essential oil and oleoresin were recorded maximum in treatment vermicompost 1.0 t ha^{-1} alone over RDF (188:70:120 NPK kg ha^{-1}). According to Kannan *et al.*, (2006) application of organic manures + *Azospirillum* improved quality of tomato fruits.

Vermicompost along with application of *Azospirillum* + *Phosphobacteria* improved total chlorophyll content and ascorbic acid in cabbage (Taiyab, 2006). Jayasree and Annamma (2006) reported that in chilli panchagavya + organic manure demonstrated the maximum shelf life and the 'organic manures alone' (on nutrient equivalent basis) showed the highest ascorbic acid content of chilli fruits. Naik (2006) reported that oleoresin per cent in chilli increased by the application of poultry manure 7.50 t ha^{-1}, vermicompost @ 10 t ha^{-1}, FYM (50 %) + vermicompost (50 %), FYM (50 %) + neem cake (50 %), respectively over RDF alone. The extractable colour value also increased with application of FYM (50 %) + poultry manure (50 %), FYM (50 %) + neem cake (50 %) over RDF alone. Velmurugan *et al*. (2006b) reported that in turmeric among the different treatment combinations, higher content of curcumin and oleoresin was recorded under the application of farm yard manure + *Azospirillum* + *Phosphobacteria* + VAM. Padmapriya *et al*. (2010) reported that in *Gymnema* *sylvestre*, the treatment combination of FYM (25 t ha^{-1}) + vermicompost (5 t ha^{-1}) + neem cake (250 kg ha^{-1}) + foliar spraying of panchagavya and manchurian mushroom extract each at 3 per cent and humic acid at 0.3 per cent, registered the highest and the best quality parameters like crude gymnemic acid content.

2.3.5. Effect on soil dynamics

Subbiah (1990) observed that when adequate amount of farm yard manure was added to the soil with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of soil. Even though FYM has low nutrient availability, the use of microbial inoculants resulted in better utilization of nutrients. VAM converts unavailable nutrient contents of rhizosphere soil to the available forms. Murugan *et al*. (2011) reported that combined inoculation of *Rhizobium leguminosarum bv. phaseoli* + *Pseudomonas fluorescence* with NEC was found most promotive for soil organic carbon, N and P availability in black gram.

2.3.6. Effect on plant uptake

Integrated nutrient management studies in betel vine by Mozhiyan and Thamburaj (1998) revealed highest uptake of N, P, K and Ca and Mg with the application of *Azospirillium* along with FYM and nitrogen through inorganic way. The experiment conducted in Kerala Agricultural University (KAU, 1999) revealed that in ginger, the treatment involving FYM alone at 48 t ha^{-1} with substitution of 50 per cent N and 25 per cent N through *Azospirillium* recorded higher total uptake of N, P and K at 180 DAP. In ginger, application of FYM 48 t ha^{-1} + 25 per cent N through *Azospirillum* recorded higher total uptake of N, P and K (KAU, 1999). In *Plumbago rosea* the treatment FYM + Neem cake (50 % N of POP) + microbial inoculants gave the highest N, P, K uptake (Nihad, 2005).

2.3.7. Effect on pest and disease

Study on the effect of organic manures and *Azospirillum* on growth, yield and quality of ginger resulted minimum incidence of soft rot in plots treated with neem cake alone @ 3.8 t ha^{-1} (KAU 1999). Basal application of neem cake combined with seed treatment (10 g kg^{-1}) of *Trichoderma* and soil application (40^{th} day after sowing) of *T. viride* reduced stem rot incidence and enhanced yield under field conditions to control soil-borne diseases (Sivaprasad and Meena Kumari, 2005). Meena and Marimuthu (2006) found that incorporation of green manure, neem cake and *Pseudomonas fluorescens* application in tomato as seed treatment (10 g kg^{-1} seed) /soil application (2.5 kg / 50 kg FYM ha^{-1}) and seedling dip (0.2 per cent) was found to be effective in managing *Fusarium* wilt disease. The highest yield was recorded in the combination green manure + neem cake and *Pseudomonas fluorescence* application.

2.3.8. Effect on B: C ratio

According to Niranjana (1998), B: C ratio and net returns were maximum for dual inoculation with 75 per cent POP and *Azospirillum* with 50 per cent POP in amaranthus. Raj (1999) observed that application of farm yard manure along with neem cake at 150 kg ha^{-1} and *Azospirillum* recorded the highest B: C ratio in bhindi. An experiment conducted at Kerala Agricultural University (KAU, 1999) in ginger revealed the positive influence of different organic manures, and *Azospirillum* on growth, yield and quality. In *Plumbago rosea* the treatment supplied with FYM + NC (50% N of POP) + microbial inoculants recorded the highest B: C ratio (2.73:1) which was significantly different from the rest of the treatments (Nihad, 2005). Manohar Rao *et al.* (2005) reported that in turmeric maximum net income and B: C ratio obtained in the treatment neemcake 1.25 t ha^{-1} + FYM 12.5 t ha^{-1} + RDF followed by FYM 25 t ha^{-1} + RDF over RDF (188:70:120 NPK Kg ha^{-1}). Asha Raj (2005) found that in slicing cucumber B: C ratio was highest for plants supplied with FYM + *Azospirillum* over POP recommendations of Kerala Agricultural University.

2.4. EFFECT OF MICROBIAL INOCULANTS / ORGANIC MANURES AND COMBINED EFFECT OF THESE BOTH ON SOIL BIOLOGICAL PROPERTIES

2.4.1. Soil microbial load

Nambiar (1994) described the effect of organic and inorganic source of N on soil microbial population. In these observations when N was supplied through an inorganic source of ammonium sulphate, soil fungi, actinomycetes population was found to increase. The bacterial population was slightly reduced. However, a different trend was observed when N was supplied through an organic source of FYM alone, where hike in bacterial count and actinomycetes population was observed in comparision with the control while the fungal population was declined compared to control population. Brady (1996) suggested the possibilities of an intense intermicrobial rivalry for food in soil which may dominate or suppress certain microorganisms.

Biedenbeck *et al*. (1996) observed that soil fungal and bacterial population increased with increase in N application as they were tolerant to acidity. Application of cattle slurry on high and low fertility sites during spring resulted in higher microbial population during the growing season (Paul and Beauchamp, 1996). Singh *et al*. (1998) reported that N application at moderate levels improved the bacterial and fungal population in soil while higher level of N application favoured the actinomycetes population in soil. Acea and Carballas (1998) reported the favourable influence of cattle slurry application as an organic source of nitrogen on bacterial population and its inhibitory effect on actinomycetes population.

Rajasree (1999) reported that in bitter gourd application of fertilizers sources along with FYM as organic source (1:2 N substitution ratio) resulted in lower bacterial population of 14.13 ($1x10^8$) compared to other treatments and bacterial population was affected by ratios of N substitutions and general reduction in the count was noticed as compare to the initial population of 13.1 ($1x 10^8$). She also reported that levels of N from 200 to 250 and 300 kg ha^{-1} increased the fungal population from 76.96 ($1 x 10^4$) to 78.21 ($1 x 10^4$) and then to 83.45 ($1 x 10^4$) respectively. Leka (2011) recorded that when Enteroplantin-K-Planticola SL 09- based biofertilizer was applied along with five other treatments including solid well rotten FYM @ 30 t ha^{-1} in potato, the fungal count was found decreasing. Several animals and plant pathogenic fungi, bacteria, actinomycetes, viral, protozoan and helminthes are sensitive to neem preparations, with antiseptic properties (Kabeh and Jalingo, 2007).

2.4.2. AMF root colonization

VAM gives good results with *Rhizobium* + 50% recommended dose of N in *Stylosanthes guianensis* cv. Schofield for herbage production. (Sreedurga, 1993). Kavitha (1996) found in maize highest value of mycorrhizal colonization in VAM applied plots. AMF colonization was found to be higher when applied with phosphate solubilising bacteria compare to control, or when it applied singly, also it increases the nutrient content of pod in vegetable cowpea (Meena, 1999). In cowpea dual inoculation of AMF + PSB with 15 kg P_2O_5 ha^{-1} along with 25 t ha^{-1} of FYM is ideal for getting maximum AMF root colonization per cent with maximum pod and haulm yield which obtain higher B:C ratio of 1.51 (Meena and Shahul, 2002).

Chitin added to sand soil based cultivation substrates stimulated the root colonization, growth of extra radial mycelium and production of spores of AMF fungi was observed in host plants like *Plantago lanceolata, Allium* *ampelloprasum* and *Lactuca sativa*. Stimulation of AMF sporulation was observed when autoclaved mycelium of *Fusarium oxysporum* was used instead of chitin. Increased numbers of actinomycetes in the substrates as a result of chitin treatment were recorded (Milan Gryndler *et al*., 2003). AMF application recorded the maximum AMF colonization percentage in rice and recorded the higher yield (Jayakiran, 2004).

Nirmalatha (2009) reported that combined application of microbial inoculants recorded the maximum AMF root colonization than the control in kasthuri turmeric at different stages of crop growth. Sumathi *et al*. (2011) reported that AMF colonization was found highest in *A. lipoferum* + *T. viridae* applied plots and all the microbial inoculants applied treatments recorded the maximum AMF colonization than that of control. Hemashenpagam and Selvaraj (2011) reported that in green house study of *Solanum viarum* triple inoculation of *G. aggregatum* + *B. coagulans* + *T. harzainum* resulted in the maximum mycorrhizal root colonization and spore numbers in the root zone soil of the inoculated plants.

MATERIALS AND METHODS

3.MATERIALS AND METHODS

Studies on "Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)" were carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram during 2010-2011. The objective of the study was to formulate a cost effective organic manurial recommendation for kasthuri turmeric, which has a high cosmetic value.

The details of the materials used and methods adopted for the study are presented in this chapter.

3.1. LOCATION

The field experiments were conducted at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The area is situated at 8^o 30' North latitude and 76^o 54' East longitude at an altitude of 29 m above MSL.

3.2. SOIL

The soil of the experimental site is red loam and belongs to Vellayani series which comes under the Order Oxisol.

3.3. SEASON

The field experiment was conducted during May 2010 to January 2011.

3.4. SEED MATERIAL AND VARIETY

The planting material used was kasthuri turmeric, IISR accession collected from healthy rhizome bits of disease and pest free plants with at least one bud weighing 15-20 g.

3.5. EXPERIMENT

The field experiment was laid out with the following technical programme:

Outline of technical programme

Design : RBD

Material : IISR accession of kasthuri turmeric

Replication : 3

Plot size : 1.2 x 3 m

No. of plots : 27

No. of treatments : 9

RI

T_8	T_5	T_1	T_9	T_2	T_3	T_6	T_7	T_4

RII

T_5	T_7	T_2	T_1	T_4	T_9	T_6	T_8	T_3

RIII

T_5	T_2	T_3	T_7	T_1	T_4	T_6	T_9	T_8

Fig.1 Layout of experimental field

Plate 1. General view of the experimental plot

3.5.1.Treatments

T_1 - FYM 40.0 t ha^{-1} + mi

T_2 - Vermicompost (VC) 25.0 t ha^{-1} + mi

T_3 - Neemcake (NC) 6.0 t ha^{-1} + mi

T_4 - FYM 20.0 t ha^{-1} + mi

T_5 - Vermicompost 12.5 t ha^{-1} + mi

T_6 - Neemcake 3.0 t ha^{-1} + mi

T_7 - FYM 20.0 t ha^{-1} + VC 6.25 t ha^{-1} + NC 1.5 t ha^{-1} + mi

T_8 -FYM 20.0 t ha^{-1} + VC 3.125 t ha^{-1} + NC 0.75 t ha^{-1} + mi

T_9 - Absolute control with no organic manures and microbial inoculants.

mi - *Azospirillum* + AMF + *Trichoderma* + *Pseudomonas*

(Microbial inoculants were applied as per the recommended practices)

Commercial formulations of *Azospirillum*, AMF, *Trichoderma* and *Pseudomonas* obtained from the Department of Microbiology, College of Agriculture, Vellayani were used.

3.5.2. Planting

Rhizome bits were planted at a depth of 5 cm with buds facing upwards at a spacing of 30 x 30 cm and covered with soil. AMF 2-3 g per pit was applied at the time of planting to all treatments excluding control.

3.5.3. Applications of manures and fertilizers

Full dose of organic manures as per the treatments were applied as basal dose at the time of planting. Commercial inoculum of AMF 2-3 g per pit was applied at the time of planting. In the case of *Trichoderma*, slurry was prepared by dissolving 20 g in 1 litre of water and the rhizomes were dipped in it and then dried for 30 minutes under shade before planting. *Azospirillum* was mixed with the organic manures in a ratio of 1:25 and applied. Two per cent suspension of *Pseudomonas* was applied as soil drenching at the rate of 5-10 ml per pit just after planting.

3.5.4. After cultivation

Hand weeding was done during first and second month and forth month whereas, earthing up and mulching were done at two and four months after planting. The crop was raised as rainfed but with need based life saving irrigations.

3.5.5. Plant protection

Pest and disease incidence was recorded periodically and timely plant protection measures were taken.

3.5.6. Harvesting

The crop was harvested when the above ground portion were completely dried up (at around 230 days after planting). Top yield as well as rhizome yield were recorded at the time of harvest.

3.5.7. Observations

Five observational plants per replication were taken from each treatment and the plants were tagged for taking biometric observations at bimonthly intervals starting from second to sixth months after planting. The yield and yield components were recorded and biochemical analyses were made only during harvest.

3.5.7.1. Growth characters

3.5.7.1.1. Plant height

The height of the plants was measured from the base of the main pseudostem to the tip of the top most leaf and was expressed in cm.

3.5.7.1.2. Number of tillers

Numbers of tillers were determined by counting the number of aerial shoots arising around a single plant.

3.5.7.1.3. Number of leaves

Numbers of leaves were determined by counting the number of leaves of all the tillers of a plant at bimonthly intervals from 2 MAP.

3.5.7.1.4. Leaf area

The length and width of leaves were measured at bimonthly intervals from 2 MAP and the leaf area in cm^2 was calculated based on length and breadth method.

The following relationship was used for computing the leaf area in turmeric (Randhawa *et al.*, 1985).

Y = 4.09 + 0.564 (Length x Breadth)
Y = Leaf area
Length = Length of the leaf in cm
Breadth = Breadth of leaf in cm.

3.5.7.1.5. Rhizome spread

The horizontal spread of rhizome was measured during harvest and expressed in cm.

3.5.7.1.6. Rhizome thickness

Rhizome thickness was measured during harvest using micrometer screw gauge and expressed in cm.

3.5.7.1.7. Number of fingers

The total numbers of fingers like primary, secondary and tertiary from the mother rhizome were counted.

3.5.7.1.8. Root length

The plants were uprooted with whole rhizome and maximum length of roots were measured and the mean length expressed in cm.

3.5.7.1.9. Root spread

Root spread was measured during harvest by spreading the root system on a marked paper and measuring the spread of the root system at its broadest part and expressed in cm.

3.5.7.1.10. Root weight

Roots were separated from individual plants at harvest and fresh weight was taken and dried in hot air oven at 70^{o}C till constant weight was obtained, weighed again and expressed in g plant^{-1}.

3.5.7.2. Yield and yield components

3.5.7.2.1. a. Rhizome yield - fresh

The fresh rhizome yield of observational plants from each treatment was recorded at the time of harvest and the mean expressed in g plant^{-1}.

3.5.7.2.1. b. Rhizome yield - dry

The fresh rhizomes were washed, chopped and allowed to dry under sun for three days. It was then kept in hot air oven at 70^{o}C till constant weight was obtained and the dry rhizome yield was expressed in g plant^{-1}.

3.5.7.2.2. Crop duration

The number of days taken from planting to harvest was recorded for each treatment.

3.5.7.2.3. Top yield

The yield of above ground portion of observational plants under each treatment was recorded at the time of harvest and the mean expressed in g plant^{-1} on dry weight basis.

3.5.7.3. Physiological characters

3.5.7.3.1. Dry matter production (DMP)

The leaves, petioles, pseudostem, rhizomes and roots of the uprooted plants were separated and dried to a constant weight at 70^{o}C in a hot air oven. The sum of dry weights of component parts gave the total dry matter production of the plant and expressed in g plant^{-1}.

3.5.7.3.2. Leaf area index (LAI)

Leaf area index was calculated at bimonthly intervals from two MAP. Five sample plants were randomly selected for each treatment and numbers of leaves on each plant were counted. Maximum length and width of leaves from all the sample plants were recorded separately and leaf area was calculated based on length and breadth method.

$$\text{LAI} = \frac{\text{Sum of leaf area of N sample (cm}^2\text{)}}{\text{Area of land covered by N plants (cm}^2\text{)}}$$

3.5.7.3.3. Harvest index (HI)

Harvest index was calculated during harvest as the ratio of dry weight of rhizome to the dry weight of whole plant.

$$HI = \frac{Y\ econ}{Y\ biol}$$ where,

Y econ - total dry weight of rhizome

Y biol - total dry weight of plant

3.5.7.4 Biochemical characters

Biochemical analysis was done at the time of harvest.

3.5.7.4.1. Biochemical analysis of rhizome

3.5.7.4.1.1. Curcumin content

Curcumin content of rhizomes was estimated by the official analytical method suggested by Sadasivam and Manickam (1991).

$$\text{Percentage of curcumin} = \frac{0.0025 \text{ x } A_{425} \text{ x volume made up x dilution factor x } 100}{0.42 \text{ x weight of sample (g) x } 1000}$$

since, 0.42 absorbance at 425 nm = 0.0025 g curcumin.

3.5.7.4.1.2. Volatile oil

Coarsely ground powder of dried rhizome was used for estimating volatile oil. The method adopted was hydro distillation using Clevenger distillation apparatus for three hours. The oil content was expressed in percentage (V/W) on dry weight basis.

3.5.7.4.1.3. Non volatile ether extract

Non volatile ether extract (NVEE) was estimated according to AOAC (1973) and expressed as percentage on dry weight basis.

3.5.7.4.1.4. Crude fibre

The fibre content of the rhizomes was estimated by acid and alkali digestion method (Sadasivam and Manickam, 1991).

3.5.7.4.1.5. Starch

Starch content in dried rhizomes was estimated by potassium ferricyanide method (Ward and Pigman, 1970).

3.5.7.4.2. Biochemical analysis of leaf

3.5.7.4.2.1. Chlorophyll content (chlorophyll a, chlorophyll b and total chlorophyll)

Photosynthetic pigments namely chlorophyll a, chlorophyll b and total chlorophyll were estimated by the method described by Sadasivam and Manickam (1991).

3.5.7.5. Soil analysis

Soil analysis was done before and after the experiment.

3.5.7.5.1 Soil physical properties

3.5.7.5.1.1. Bulk density

Bulk density was determined by core method (Gupta and Dakshinamoorthy, 1980).

3.5.7.5.1.2. Water holding capacity

This was determined by undisturbed core sample method (Gupta and Dakshinamoorthy, 1980).

3.5.7.5.2 Soil chemical properties

3.5.7.5.2.1. pH

Soil pH was determined by pH meter with electrodes (Jackson, 1973).

3.5.7.5.2.2. EC

Soil electrical conductivity was read in Electrical conductivity meter.

3.5.7.5.2.3. Organic carbon

Soil organic carbon was estimated by Walkley and Black's rapid titration method (Jackson, 1973).

3.5.7.5.2.4. Available Nitrogen

Available Nitrogen in soil was determined by Alkaline permanganate method (Subbiah and Asija, 1956).

3.5.7.5.2.5. Available phosphorus

Available phosphorus in the soilwas determined by Bray No.1 method using spectro-photometer (Jackson 1973).

3.5.7.5.2.1.6. Available potassium

Available potassium was extracted using Neutral normal ammonium acetate and available K was read in Flame photometer (Jackson, 1973).

3.5.7.5.3 Soil biological properties

Soil biological properties estimated before and after the experiment.

3.5.7.5.3.1. Total microbial load

Total microbial load i.e., fungal, bacterial and actinomycete load were calculated before and after the experiment. Soil samples were taken randomly from the experimental plot before the field experiment. These values were compared with that of the composite soil samples taken from the different treatment plots after the crop harvest.

The microbial population in the rhizosphere soil was estimated by the serial dilution plate technique (Johnson and Curl, 1972). One g of soil was taken and transferred to 100 ml of sterile water and shaken for 5-10 minutes using a rotary shaker. From this stock suspension, different dilutions of 10^{-2}, 10^{-3},10^{-4},10^{-5},10^{-6} were prepared. The fungal population was estimated at 10^{-4} dilution while 10^{-6} dilution was used for bacterial and actinomycetes population.

The numbers of colony forming units (cfu) of microbes were calculated using the formula.

$$\text{cfu} = \frac{\text{Average number of colony developed x dilution factor}}{\text{Weight of soil taken}}$$

3.5.7.5.3.1.1. Total bacterial load

The media used to find out the bacterial load was Nutrient Agar.

Composition of Nutrient Agar

Beef extract	-	3 g
Peptone	-	5 g
$NaCl_2$	-	5 g
Agar	-	20 g
Distilled water	-	1000 ml
pH	-	7.0

3.5.7.5.3.1.2. Total fungal load

The media used was Rose Bengal Agar and the total fungal load was calculated.

Composition of Rose Bengal Agar

Glucose	-	10 g
Peptone	-	5 g
K_2HPO_4	-	1 g
$MgSO_4\ 7H_2O$	-	0.5g
Streptomycin	-	30 mg

Agar	-	20 g
Rose Bengal	-	0.035 g
Distilled water	-	1000 ml
pH	-	7.0

3.5.7.5.3.1.3. Total actinomycetes load

Total actinomycetes load was calculated using Kenknight's media.

Composition of Kenknight's media

Dextrose	-	1.0 g
KH_2PO_4	-	0.10 g
$NaNO_3$	-	0.10 g
KCl	-	0.10 g
$MgSO_4.7H_2O$	-	0.10g
Agar	-	15.0 g
Distilled water	-	1000 ml
pH	-	7.0

3.5.7.5.3.1.4. AMF colonization percentage

AMF colonization percentage was recorded at bimonthly interval starting from second month after inoculation.

Treat the root bits in FAA for 24 hrs, then boil or autoclave by adding 10 per cent KOH. Neutralize with 1 per cent HCl for 5 min. then keep it in the trypan blue strain (0.05 %) for full night. Observe the roots under low power and high power microscope.

3.5.7.6. Plant analysis

3.5.7.6.1. Uptake of major nutrients (N, P, K)

The plant aerial portion and rhizome were chopped separately and dried in a hot air oven at 70 ^{0} C till constant weights obtained. It was then powdered separately for analysis. The methods adopted were:

Nitrogen was estimated by Microkjeldahl method (Jackson, 1973).

For the analysis of P and K, diacid extracts were prepared by digesting 1g of the sample in 15 ml of 2:1 concentrated nitric perchloric acid mixture. Aliquots of digests were taken for the analysis of total P and K. P was dertermined colorimetrically by Vanedomolybdo phosphoric yellow colour method (Jackson, 1973). The yellow colour was read in a spectro- photometer at a wavelength of 470 nm.

K was estimated using flame photometer and expressed in percentage (Piper, 1967).

The uptake of nitrogen, phosphorous and potassium by the plant was calculated by multiplying the respective nutrient content of the plant with dry weight of the plant parts and expressed in kg ha^{-1}.

3.5.7.7. Incidence of pest and disease

Incidence of pests and diseases were noted at regular intervals and timely control measures were taken.

3.5.7.8. Economics of cultivation / B: C ratio

The economics of cultivation was worked out after taking into account the cost of cultivation and prevailing market price of kasthuri turmeric. For calculating the cost, the different variable cost items like planting materials, manures, plant protection items, irrigation, labour charges etc. were considered at existing market rate during 2010-2011.

The net income was calculated as follows:

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

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

3.6. STATISTICAL ANALYSIS

The experimental data were analysed by applying the analysis of variance technique as applied to Randomised Block Design (Panse and Sukhatme, 1985). For statistical analysis, treatments were grouped into four different groups. As FYM + mi group (M_1), Vermicompost + mi group (M_2), Neemcake + mi group (M_3) and FYM + Vermicompost + Neemcake + mi group (M_4) and treatments were categorized as their full and half dose of each group (manures).

Significance was tested by F test. CD at 1 per cent or 5 per cent level of significance was provided wherever the effects were found to be significant.

RESULTS

4. RESULTS

The study entitled, "Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram during 2010-2011. The data collected from the field experiment were statistically analyzed and the results are presented in this chapter.

For statistical analysis, treatments were divided into four different groups *viz*., FYM + mi group (M_1),Vermicompost (VC) + mi group (M_2), Neemcake (NC) + mi group (M_3) and FYM + Vermicompost (VC) + Neemcake (NC) + mi group (M_4) and treatments were categorized as their full and half dose of each group (manures). So finally, for statistical analysis the different treatments were as given below:

M_1 d - Full dose of FYM - FYM 40.0 t ha^{-1} + mi (T_1),

M_2 d - Full dose of Vermicompost -Vermicompost (VC) 25.0 t ha^{-1} + mi (T_2),

M_3 d - Full dose of Neemcake - Neemcake (NC) 6.0 t ha^{-1} + mi (T_3),

M_1 d/2 -Half dose of FYM - FYM 20.0 t ha^{-1} + mi (T_4),

M_2 d/2 - Half dose of Vermicompost - Vermicompost 12.5 t ha^{-1} + mi (T_5),

M_3 d/2 - Half dose of Neemcake - Neemcake 3.0 t ha^{-1} + mi (T_6),

M_4 d -Half dose of FYM + 1/4 th dose of Vermicompost + 1/4 th dose of Neemcake - FYM 20.0 t ha^{-1} + VC 6.25 t ha^{-1} + NC 1.5 t ha^{-1} + mi (T_7),

M_4 d/2-Half dose of FYM + 1/8th dose of Vermicompost + 1/8 th dose of Neemcake -FYM 20.0 t ha^{-1} + VC 3.125 t ha^{-1} + NC 0.75 t ha^{-1} + mi (T_8),

M_0 d_0 - Absolute control with no organic manures and microbial inoculants (T_9).

4.1. GROWTH CHARACTERS

4.1.1. Plant height (cm)

As observed in the Table 1, the height of the plants in kasthuri turmeric influenced by the application of different treatments and the control plants produced significantly lower plant height throughout the crop growth stage.

At 2 MAP, plants applied with organic manures and microbial inoculants except M_3 d/2 and M_1 d/2 produced significantly superior plant height than control plants to which no organic manures and microbial inoculants were applied. Treatments M_1 d/2 (65.73) and M_3 d/2 (57.07) were on par with control, whereas treatments M_4 d/2 (74.47), M_3 d (74.33), M_1 d (73.40), M_2 d/2 (72.53), M_4 d (72.20) and M_1 d/2 (65.73) were on par with M_2 d (77.53). At 4 MAP and 6 MAP similar trend was noticed.

At 4 and 6 MAP the height of M_3 d/2 (100.40 and 115.87 cm respectively) and M_1d/2 (109.00 and 126.33 cm respectively) plants were on par with the control. At 6 MAP, M_2 d (143.13) on par with M_2 d/2 (139.27), M_3 d (139.20), M_4 d (137.67), M_4 d/2 (134.33) and M_1 d (133.87).

M_2 d recorded the maximum plant heights i.e.77.53, 127.33 and 143.13 at 2,4 and 6 MAP respectively, while M_0d_0 recorded lowest plant heights i.e. 56.50, 99.13 and 111.03 at 2,4 and 6 MAP respectively.

In the group analysis of different treatments, organic manures and microbial inoculants applied plants recorded significantly superior plant height than the control plants in all three growth stages, except at 4 MAP. At 2 MAP and 6 MAP, M_2 recorded the highest plant height (75.03 and 141.20 respectively) which was on par with M_1 and M_4. At 4 MAP M_2, M_1 and M_4were found superior to M_3.

Table 1. Effect of organic manures and microbial inoculants on plant height (cm) in *Curcuma aromatica* Salisb. at different growth stages

Treatments / Manures	2 MAP	4 MAP	6 MAP
M_1 d (T_1)	73.40	117.13	133.87
M_2 d (T_2)	77.53	127.33	143.13
M_3 d (T_3)	74.33	121.60	139.20
M_1 d/2 (T_4)	65.73	109.00	126.33
M_2 d/2 (T_5)	72.53	123.20	139.27
M_3 d/2 (T_6)	57.07	100.40	115.87
M_4 d (T_7)	72.20	122.93	137.67
M_4 d/2 (T_8)	74.47	120.00	134.33
M_0 d_0 (T_9)	56.50	99.13	111.03
CD (Treatments)	12.941	18.144	17.806
M_1 (FYM + mi)	69.57	113.07	130.10
M_2 (VC + mi)	75.03	125.27	141.20
M_3 (NC + mi)	65.70	111.00	127.53
M_4 (FYM + VC+ NC + mi)	73.33	121.47	136.00
CD (Manures)	9.151	12.829	12.591
$F_{1,16}$ (M_0T_0 Vs M)	9.904 **	8.367 *	12.957 **

*significant at 5 per cent **significant at 1 per cent

4.1.2. Number of tillers

There was no significant difference found in the number of tillers of the plants from various treatments at different stages of growth (Table 2).

However at 2 MAP, M_2 d/2 (0.53) and M_4 d/2 (0.53), at 4 and 6 MAP, M_3 d/2 recorded the highest value (0.93) for number of tillers. Control (M_0d_0)

recorded the lowest values i.e. 0.07, 0.13 and 0.20 at 2, 4 and 6 MAP respectively. In the group analysis of different treatments, M_3 recorded the maximum value (0.67) while M_1 and M_4 recorded the minimum value (0.33) at 6 MAP.

Table 2. Effect of organic manures and microbial inoculantson number of tillers in *Curcuma aromatica* Salisb. at different growth stages.

Treatments / Manures	2 MAP	4 MAP	6 MAP
M_1 d (T_1)	0.20	0.33	0.27
M_2 d (T_2)	0.07	0.27	0.27
M_3 d (T_3)	0.07	0.20	0.40
M_1 d/2 (T_4)	0.20	0.60	0.40
M_2 d/2 (T_5)	0.53	0.67	0.53
M_3 d/2 (T_6)	0.47	0.93	0.93
M_4 d (T_7)	0.40	0.47	0.40
M_4 d/2 (T_8)	0.53	0.40	0.27
M_0 d_0 (T_9)	0.07	0.13	0.20
CD (Treatments)	0.599	0.574	0.592
M_1 (FYM + mi)	0.20	0.47	0.33
M_2 (VC + mi)	0.30	0.47	0.40
M_3 (NC + mi)	0.27	0.57	0.67
M_4 (FYM + VC+ NC + mi)	0.47	0.43	0.33
CD (Manures)	0.424	0.406	0.419
$F_{1,16}$ (M_0T_0 Vs M)	1.300 ^{NS}	2.970 ^{NS}	1.240 ^{NS}

NS-Not significant

4.1.3. Number of leaves

As observed in Table 3, leaf production in kasthuri turmeric was significantly influenced by the application of different treatments and the control plants produced significantly lower number of leaves throughout the crop growth period.

At 2 MAP, M_2 d/2 recorded the highest number (8.73) which was on par with all other treatments except control.

At 4 MAP, almost similar trend continued. However, M_2 d plants produced significantly lower number of leaves which was on par with control plants.

At 6 MAP, significantly superior leaf production was recorded in M_3 d/2 (12.07) followed by M_1 d (11.53), M_2 d/2 (11.20) and M_1 d/2 (11.13). Control plants recorded the lowest number which was on par with M_4 d/2, M_3 d, M_4 d, and M_2 d.

In the group analysis of different treatments, all groups were found to have similar effect in leaf production at 2 and 4 MAP. At 6 MAP, M_1 and M_3 produced significantly more number of leaves (11.33 and 10.93 respectively) than the control and M_1 was found on par with M_3 whereas M_2 (10.13) and M_4 (9.87) on par with control.

Table 3. Effect of organic manures and microbial inoculants on number of leaves in *Curcuma aromatica* Salisb. at different growth stages

Treatments / Manures	2 MAP	4 MAP	6 MAP
M_1 d (T_1)	6.93	9.80	11.53
M_2 d (T_2)	6.47	8.53	9.07
M_3 d (T_3)	6.73	8.80	9.80
M_1 d/2 (T_4)	7.07	10.87	11.13
M_2 d/2 (T_5)	8.73	11.73	11.20
M_3 d/2 (T_6)	7.60	11.73	12.07
M_4 d (T_7)	7.87	9.33	9.53
M_4 d/2 (T_8)	8.13	9.87	10.20
M_0 d_0 (T_9)	5.27	7.00	8.47
CD (Treatments)	2.565	3.049	2.401
M_1 (FYM + mi)	7.00	10.33	11.33
M_2 (VC + mi)	7.60	10.13	10.13
M_3 (NC + mi)	7.17	10.27	10.93
M_4 (FYM + VC+ NC + mi)	8.00	9.60	9.87
CD (Manures)	1.813	2.156	1.698
$F_{1,16}$ (M_0T_0 Vs M)	5.746 *	8.172 *	6.109 *

*significant at 5 per cent

4.1.4. Leaf area (cm^2)

As observed in Table 4, leaf area in kasthuri turmeric was influenced by the application of different treatments and the control plants produced significantly lower leaf area throughout crop growth.

At 2 MAP, M_2 d recorded the highest leaf area (286.73) which was on par with all other treatments except M_3 d/2 (137.49) which was on par with control (129.47).

During 4 MAP also M_2 d recorded the highest leaf area (587.15) which was on par with all other treatments except M_4 d/2 (486.65) and M_3 d/2 (407.88) which were found on par with control (385.27).

At 6 MAP also similar trend continued and M_2 d recorded the highest value (716.79) which was on par with M_4 d (677.66), M_2 d/2 (660.59), M_1 d (642.31) and M_1d/2 (642.01), whereas M_4 d/2 (614.22), M_3 d (580.38) and M_3 d/2 (510.52) were on par with control (474.60).

M_2 drecorded the highest value for leaf area than all other treatments throughout the growth period, while the lowest leaf area was recorded by the control plant.

In the group analysis of different treatments, M_2 applied plant recorded the highest leaf area in all growth stages (245.58, 564.25 and 688.69 respectively) and M_2 was on par with M_4 and M_1.

Table 4. Effect of organic manures and microbial inoculants on leaf area (cm^2) in *Curcuma aromatica* Salisb. at different growth stages

Treatments / Manures	2 MAP	4 MAP	6 MAP
M_1 d (T_1)	224.29	532.14	642.31
M_2 d (T_2)	286.73	587.15	716.79
M_3 d (T_3)	232.72	517.82	580.38
M_1 d/2 (T_4)	216.23	498.19	642.01
M_2 d/2 (T_5)	204.42	541.36	660.59
M_3 d/2 (T_6)	137.49	407.88	510.52
M_4 d (T_7)	246.05	525.86	677.66
M_4 d/2 (T_8)	223.03	486.65	614.22
M_0 d_0 (T_9)	129.47	385.27	474.60
CD (Treatments)	72.351	111.559	163.634
M_1 (FYM + mi)	220.26	515.17	642.16
M_2 (VC + mi)	245.58	564.25	688.69
M_3 (NC + mi)	185.11	462.85	545.45
M_4 (FYM + VC+ NC + mi)	234.54	506.26	645.94
CD (Manures)	51.160	78.884	115.700
$F_{1,16}$ (M_0T_0 Vs M)	12.892 **	10.333 **	7.258 *

*significant at 5 per cent **significant at 1 per cent

4.1.5. Rhizome spread (cm)

As observed in Table 5, rhizome spread in kasthuri turmeric was influenced by the application of different treatments and plants applied with organic manures and microbial inoculants recorded significantly superior rhizome spread than the control plants. M_2 d recorded the highest value (22.82) which followed by M_3 d (22.41), M_4 d (22.16), M_1 d (22.12), M_2 d/2 (21.12), M_4 d/2

(20.99), M_3 d/2 (20.96) and M_1d/2 (20.87), whereas M_0d_0 recorded the lowest value (16.12). In group analysis of different treatments, all the groups found equally effective in giving the better rhizome spread and the highest value for this character was recorded by M_2 (21.97) followed by M_3 (21.69), M_4 (21.57) and M_1 (21.49).

Table 5. Effect of organic manures and microbial inoculants on rhizome spread (cm) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Rhizome spread (cm)
M_1 d (T_1)	22.12
M_2 d (T_2)	22.82
M_3 d (T_3)	22.41
M_1 d/2 (T_4)	20.87
M_2 d/2 (T_5)	21.12
M_3 d/2 (T_6)	20.96
M_4 d (T_7)	22.16
M_4 d/2 (T_8)	20.99
M_0 d_0 (T_9)	16.12
CD (Treatments)	3.230
M_1 (FYM + mi)	21.49
M_2 (VC + mi)	21.97
M_3 (NC + mi)	21.69
M_4 (FYM + VC+ NC + mi)	21.57
CD (Manures)	2.283
$F_{1,16}$ (M_0T_0 Vs M)	6.457 *

*significant at 5 per cent

4.1.6. Rhizome thickness (cm)

Plants applied with organic manures and microbial inoculants produced significantly superior in rhizome thickness than the control plants (Table 6). M_2 d recorded the highest value (2.79) followed by M_3 d (2.78), M_4 d (2.73), M_1 d (2.70), M_2 d/2 (2.66), M_4 d/2 (2.64), M_3 d/2 (2.61) and M_1 d/2 (2.59), whereas M_0d_0 recorded the lowest value (2.31).

In the group analysis of different treatments, all groups were found equally effective in giving the better rhizome thickness and the highest value was recorded by M_2 (2.73) followed by M_3 (2.70), M_4 (2.69) and M_1 (2.65).

4.1.7. Number of fingers

All treatments except M_3 d/2 and M_1 d/2 were significantly superior with regard to number of fingers than the control plants (Table 7). M_2 d recorded the highest value (32.33) followed by M_3 d (27.27), M_4 d (26.73), M_1 d (26.07), whereas, M_1 d/2 produced the lowest number (25.13) followed by M_3 d/2 (25.20), which were on par with control (19.12).

In the group analysis of different treatments all groups were found equally effective in producing better number of rhizomes, and the highest value was recorded by M_2 (29.17) followed by M_4 (26.27), M_3 (26.23) and M_1 (25.60).

Table 6. Effect of organic manures and microbial inoculants on rhizome thickness (cm) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Rhizome thickness (cm)
M_1 d (T_1)	2.70
M_2 d (T_2)	2.79
M_3 d (T_3)	2.78
M_1 d/2 (T_4)	2.59
M_2 d/2 (T_5)	2.66
M_3 d/2 (T_6)	2.61
M_4 d (T_7)	2.73
M_4 d/2 (T_8)	2.64
M_0 d_0 (T_9)	2.31
CD (Treatments)	0.254
M_1 (FYM + mi)	2.65
M_2 (VC + mi)	2.73
M_3 (NC + mi)	2.70
M_4 (FYM + VC+ NC + mi)	2.69
CD (Manures)	0.180
$F_{1,16}$ (M_0T_0 Vs M)	7.821 *

*significant at 5 per cent

Table 7. Effect of organic manures and microbial inoculants on number of fingers in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Number of fingers
M_1 d (T_1)	26.07
M_2 d (T_2)	32.33
M_3 d (T_3)	27.27
M_1 d/2 (T_4)	25.13
M_2 d/2 (T_5)	26.00
M_3 d/2 (T_6)	25.20
M_4 d (T_7)	26.73
M_4 d/2 (T_8)	25.80
M_0 d_0 (T_9)	19.12
CD (Treatments)	6.335
M_1 (FYM + mi)	25.60
M_2 (VC + mi)	29.17
M_3 (NC + mi)	26.23
M_4 (FYM + VC+ NC + mi)	26.27
CD (Manures)	4.480
$F_{1,16}$ (M_0T_0 Vs M)	7.365 *

*significant at 5 per cent

4.1.8. Root length (cm)

Treatments M_2 d, M_3 d and M_4 d produced significantly superior root length than the control plants (Table 8). M_2 d recorded the highest value (24.37) followed by M_3 d (24.07), M_4 d (23.85) M_1 d (22.00), M_2 d/2 (21.31), M_4 d/2 (21.24), M_3 d/2 (20.85) and M_1 d/2 (20.28), while M_1 d, M_2 d/2, M_4 d/2, M_3 d/2 and M_1 d/2 were found on par with control, whichrecorded the minimum root length (18.91).

In the group analysis of different treatments, M_2 recorded the highest value (22.84) followed by M_4 (22.55) and M_3 (22.46) whereas, M_1 (21.41) was on par with control.

4.1.9. Root spread (cm)

M_2 d and M_3 d recorded significantly superior root spread than the control plants and all other treatments (Table 9). M_2 d recorded the highest value (34.91) which was on par with M_3 d (33.51) whereas, M_2 d/2 (30.37), M_4 d/2 (30.07), M_3 d/2 (29.02) and M_1 d/2 (29.01) were on par with the control (26.99).

In the group analysis of different treatments M_2 recorded the highest value (32.64) followed by M_3 (31.27) and M_4 (30.69).

Table 8. Effect of organic manures and microbial inoculants on root length (cm) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Root length (cm)
M_1 d (T_1)	22.00
M_2 d (T_2)	24.37
M_3 d (T_3)	24.07
M_1 d/2 (T_4)	20.28
M_2 d/2 (T_5)	21.31
M_3 d/2 (T_6)	20.85
M_4 d (T_7)	23.85
M_4 d/2 (T_8)	21.24
M_0 d_0 (T_9)	18.91
CD (Treatments)	4.117
M_1 (FYM + mi)	21.41
M_2 (VC + mi)	22.84
M_3 (NC + mi)	22.46
M_4 (FYM + VC+ NC + mi)	22.55
CD (Manures)	2.911
$F_{1,16}$ (M_0T_0 Vs M)	5.238 *

*significant at 5 per cent

Table 9. Effect of organic manures and microbial inoculants on root spread (cm) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Root spread (cm)
M_1 d (T_1)	30.89
M_2 d (T_2)	34.91
M_3 d (T_3)	33.51
M_1 d/2 (T_4)	29.01
M_2 d/2 (T_5)	30.37
M_3 d/2 (T_6)	29.02
M_4 d (T_7)	31.31
M_4 d/2 (T_8)	30.07
M_0 d_0 (T_9)	26.99
CD (Treatments)	3.414
M_1 (FYM + mi)	29.95
M_2 (VC + mi)	32.64
M_3 (NC + mi)	31.27
M_4 (FYM + VC+ NC + mi)	30.69
CD (Manures)	2.414
$F_{1,16}$ (M_0T_0 Vs M)	11.770 **

**significant at 1 per cent

4.1.10. Root weight (g)

There was no significant difference in the fresh root weight of the plants from various treatments at harvest (Table 10). All the treatments were found on par with control. In the group analysis of different treatments also similar trend was noticed.

In case of dry root weight, plants applied with treatments M_2 d, M_3 d produced significantly superior dry root weights than control plants (Table 10). M_2 d recorded the highest value (7.79) which was on par with all other treatments except control, but M_4 d (7.11), M_1 d (6.61), M_2 d/2 (6.37), M_4 d/2 (5.77), M_3 d/2 (5.33) and M_1 d/2 (5.25) were found on par with control.

In the group analysis of different treatments, M_2 recorded the highest value (7.08) followed by M_4 (6.44), M_3 (6.40) and M_1 (5.93) whereas, M_1 was on par with control.

4.2. YIELD AND YIELD COMPONENTS

4.2.1.1 Rhizome yield (fresh) (g plant $^{-1}$)

All treatments except M_3 d/2, M_1 d/2 recorded significantly superior fresh rhizome yield than the control plants (Table 11). M_2 d recorded the highest value (456.99) followed by M_3 d (437.42), M_4 d (428.81), M_1 d (399.49), M_2 d/2 (383.32) and M_4 d/2 (382.89) whereas, M_3 d/2 (377.10) and M_1 d/2 (366.84) were on par with control which recorded the lowest fresh rhizome yield (257.49).

In the group analysis of different treatments, all groups found equally effective in producing the better fresh rhizome yield and the highest value for this character was recorded by M_2 (420.16) which was followed by M_3 (407.26) , M_4 (405.85) and M_1 (383.17).

Table 10. Effect of organic manures and microbial inoculants on root weight (g) in *Curcuma aromatica* Salisb. at harvest

Treatments /Manures	Fresh root weight (g)	Dry root weight (g)
M_1 d (T_1)	17.55	6.61
M_2 d (T_2)	19.45	7.79
M_3 d (T_3)	18.36	7.47
M_1 d/2 (T_4)	11.64	5.25
M_2 d/2 (T_5)	17.29	6.37
M_3 d/2 (T_6)	13.23	5.33
M_4 d (T_7)	17.67	7.11
M_4 d/2 (T_8)	15.15	5.77
M_0 d_0 (T_9)	9.97	3.47
CD (Treatments)	10.952	3.862
M_1 (FYM + mi)	14.59	5.93
M_2 (VC + mi)	18.37	7.08
M_3 (NC + mi)	15.79	6.40
M_4 (FYM + VC+ NC + mi)	16.41	6.44
CD (Manures)	7.744	2.731
$F_{1,16}$ (M_0T_0 Vs M)	2.658 ^{NS}	4.795 *

NS-Not significant *significant at 5 per cent

Table 11. Effect of organic manures and microbial inoculants on fresh rhizome yield (g $plant^{-1}$) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Fresh rhizome yield (g $plant^{-1}$)
M_1 d (T_1)	399.49
M_2 d (T_2)	456.99
M_3 d (T_3)	437.42
M_1 d/2 (T_4)	366.84
M_2 d/2 (T_5)	383.32
M_3 d/2 (T_6)	377.10
M_4 d (T_7)	428.81
M_4 d/2 (T_8)	382.89
M_0 d_0 (T_9)	257.49
CD (Treatments)	120.258
M_1 (FYM + mi)	383.17
M_2 (VC + mi)	420.16
M_3 (NC + mi)	407.26
M_4 (FYM + VC+ NC + mi)	405.85
CD (Manures)	85.035
$F_{1,16}$ (M_0T_0 Vs M)	11.877 **

**significant at 1 per cent

4.2.1.2 Rhizome yield (dry) (g $plant^{-1}$)

All treatments except M_1 d/2 recorded significantly superior dry rhizome yield than control (Table 12). M_2 d recorded the highest value (82.56) which was on par with M_3 d (79.09), M_4 d (77.18), M_1 d (71.66), M_4 d/2 (69.01), M_2 d/2 (69.00) whereas, M_1 d/2 (66.19) was on par with control (M_0 d_0) which recorded the lowest dry rhizome yield (46.34).

In the group analysis of different treatments, all groups were found equally effective in producing the better dry rhizome yield and the highest value for this character was recorded by M_2 (75.78) which was followed by M_3 (73.59), M_4 (73.10) and M_1 (68.69).

Table 12. Effect of organic manures and microbial inoculants on dry rhizome yield (g $plant^{-1}$) in *Curcuma aromatica* Salisb.at harvest

Treatments / Manures	Dry rhizome yield (g $plant^{-1}$)
M_1 d (T_1)	71.66
M_2 d (T_2)	82.56
M_3 d (T_3)	79.09
M_1 d/2 (T_4)	66.19
M_2 d/2 (T_5)	69.00
M_3 d/2 (T_6)	68.09
M_4 d (T_7)	77.18
M_4 d/2 (T_8)	69.01
M_0 d_0 (T_9)	46.34
CD (Treatments)	21.489
M_1 (FYM + mi)	68.69
M_2 (VC + mi)	75.78
M_3 (NC + mi)	73.59
M_4 (FYM + VC+ NC + mi)	73.10
CD (Manures)	15.195
$F_{1,16}$ (M_0T_0 Vs M)	12.159 **

**significant at 1 per cent

4.2.2. Crop duration (days)

As observed in Table 13, in kasthuri turmeric plants applied with organic manures and microbial inoculants recorded significantly lesser crop duration than the control plants. Plants applied with treatments M_4 d/2, M_1 d, M_3 d, M_2 d, M_4 d, M_2 d/2 and M_1 d/2 recorded significantly lesser crop duration than the control plants. M_4 d/2 recorded the lowest crop duration (221.67) followed by M_1 d (222.67), M_3 d (224.67), M_2 d (225.00), M_4 d (225.33), M_2 d/2 (227.67) and M_1 d/2 (228.00) whereas, M_0 d_0 (235.00) and M_3 d/2 (231.67) recorded comparatively more days for maturation of the crop.

In the group analysis of different treatments, plants applied with organic manures and microbial inoculants recorded significantly lower in crop durations than the control plants where no manures were applied. M_3 (228.17) found on par with M_2 (226.33) and M_1 (225.33) while, M_4 (223.50) recorded significantly lowest value among the groups.

4.2.3. Top yield (g plant^{-1})

There was no significant difference in dry and fresh top yield from various treatments at harvest and similar trend was recorded in the group analysis of different treatments (Table 14).

Table 13. Effect of organic manures and microbial inoculants on crop duration (days) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Crop duration (days)
M_1 d (T_1)	222.67
M_2 d (T_2)	225.00
M_3 d (T_3)	224.67
M_1 d/2 (T_4)	228.00
M_2 d/2 (T_5)	227.67
M_3 d/2 (T_6)	231.67
M_4 d (T_7)	225.33
M_4 d/2 (T_8)	221.67
M_0 d_0 (T_9)	235.00
CD (Treatments)	7.013
M_1 (FYM + mi)	225.33
M_2 (VC + mi)	226.33
M_3 (NC + mi)	228.17
M_4 (FYM + VC+ NC + mi)	223.50
CD (Manures)	4.959
$F_{1,16}$ (M_0T_0 Vs M)	13.647 **

**significant at 1 per cent

Table 14. Effect of organic manures and microbial inoculants on top yield (g $plant^{-1}$)in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Fresh yield (g $plant^{-1}$)	Dry yield (g $plant^{-1}$)
M_1 d (T_1)	31.10	20.19
M_2 d (T_2)	39.77	23.19
M_3 d (T_3)	38.43	20.91
M_1 d/2 (T_4)	22.84	17.15
M_2 d/2 (T_5)	29.61	19.97
M_3 d/2 (T_6)	29.07	17.15
M_4 d (T_7)	30.99	20.29
M_4 d/2 (T_8)	29.57	19.28
M_0 d_0 (T_9)	22.56	14.26
CD (Treatments)	27.177	15.094
M_1 (FYM + mi)	26.97	18.67
M_2 (VC + mi)	34.69	21.58
M_3 (NC + mi)	33.75	19.03
M_4 (FYM + VC+ NC + mi)	30.28	19.78
CD (Manures)	19.217	10.673
$F_{1,16}$ (M_0T_0 Vs M)	0.850^{NS}	1.064^{NS}

NS- Non Significant

4.3. PHYSIOLOGICAL CHARACTERS

4.3.1. Dry matter production (g $plant^{-1}$)

All treatments applied with organic manures and microbial inoculants recorded significantly superior dry matter production than control (Table 15). M_2 d recorded the highest value (113.54) which was on par with M_3 d (107.48),

M_4 d (104.58), M_1 d (98.47), M_2 d/2 (95.34), M_4 d/2 (94.07) whereas, control recorded the lowest dry matter production (64.07).

In the group analysis of different treatments, M_2 recorded the highest value (104.44) which was on par with M_4 (99.32), M_3 (99.02) and M_1 (93.53).

Table 15. Effect of organic manures and microbial inoculants on dry matter production (g plant^{-1}) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Dry matter production (g plant^{-1})
M_1 d (T_1)	98.47
M_2 d (T_2)	113.54
M_3 d (T_3)	107.48
M_1 d/2 (T_4)	88.59
M_2 d/2 (T_5)	95.34
M_3 d/2 (T_6)	90.57
M_4 d (T_7)	104.58
M_4 d/2 (T_8)	94.07
M_0 d_0 (T_9)	64.07
CD (Treatments)	21.349
M_1 (FYM + mi)	93.53
M_2 (VC + mi)	104.44
M_3 (NC + mi)	99.02
M_4 (FYM + VC+ NC + mi)	99.32
CD (Manures)	15.096
$F_{1,16}$ (M_0T_0 Vs M)	21.486 **

** significant at 1 per cent

4.3.2. Leaf area index

As observed in Table 16, leaf area index was influenced by the application of different treatments and the control plants produced significantly lower leaf area index throughout the crop growth period.

At 2 MAP, M_4 d recorded the highest value (2.174), which was on par with all other treatments except M_3 d/2.

During 4 MAP, all treatments applied with organic manures and microbial inoculants recorded significantly superior leaf area indexthan the control plants. M_4 d recorded the maximum value (4.931) which was on par with M_4 d/2 (4.376), M_2 d (4.150), M_2 d/2 (4.130) and M_1d/2 (3.887).

At 6 MAP, M_4 d recorded the maximum leaf area index (8.258) followed by M_2 d (7.860), M_2 d/2 (7.828), M_4 d/2 (7.763), M_3 d (7.237), M_1 d/2 (7.184) M_1 d (7.065) and M_3 d/2 (6.758).

M_0d_0 recorded the minimum leaf area index throughout the crop growth period (0.767, 2.316 and 4.467 at 2, 4 and 6 MAP respectively).

In the group analysis of different treatments, 2 MAP and 4 MAP, M_4 recorded the highest value (2.081 and 4.654 respectively) which was on par with M_2 (2.019 and 4.140 respectively). At 6 MAP also M_4 (8.011) recorded the highest value which was followed by M_2 (7.844), M_1 (7.124) and M_3 (6.997).

Table 16. Effect of organic manures and microbial inoculants on leaf area index *Curcuma aromatica* Salisb.at different growth stages

Treatments / Manures	2 MAP	4 MAP	6 MAP
M_1 d (T_1)	1.718	3.830	7.065
M_2 d (T_2)	2.074	4.150	7.860
M_3 d (T_3)	1.738	3.828	7.237
M_1 d/2 (T_4)	1.718	3.887	7.184
M_2 d/2 (T_5)	1.964	4.130	7.828
M_3 d/2 (T_6)	1.145	3.490	6.758
M_4 d (T_7)	2.174	4.931	8.258
M_4 d/2 (T_8)	1.988	4.376	7.763
M_0 d_0 (T_9)	0.767	2.316	4.467
CD (Treatments)	0.759	1.097	1.876
M_1 (FYM + mi)	1.718	3.858	7.124
M_2 (VC + mi)	2.019	4.140	7.844
M_3 (NC + mi)	1.441	3.659	6.997
M_4 (FYM + VC+ NC + mi)	2.081	4.654	8.011
CD (Manures)	0.537	0.776	1.326
$F_{1,16}$ (M_0T_0 Vs M)	15.230 **	20.606 **	20.805 **

**significant at 1 per cent

4.3.3. Harvest index

All treatments recorded significantly superior harvest index than control (Table 17). M_3 d/2 recorded the highest harvest index (0.7546) which was on par with M_1 d/2 (0.7431), M_2 d (0.7407), M_4 d (0.7407), M_1 d (0.7271), M_3 d (0.7266), M_4 d/2 (0.7255) and M_2 d/2 (0.7215) whereas control (M_0 d_0) recorded the lowest harvest index (0.5338).

In the group analysis of different treatments, all groups recorded better harvest index and the highest value for this character was recorded by M_3 (0.741) which was followed by M_1 (0.735), M_4 (0.733) and M_2 (0.731).

Table 17. Effect of organic manures and microbial inoculants on harvest index in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Harvest index
M_1 d (T_1)	0.7271
M_2 d (T_2)	0.7407
M_3 d (T_3)	0.7266
M_1 d/2 (T_4)	0.7431
M_2 d/2 (T_5)	0.7215
M_3 d/2 (T_6)	0.7546
M_4 d (T_7)	0.7407
M_4 d/2 (T_8)	0.7255
M_0 d_0 (T_9)	0.5338
CD (Treatments)	0.144
M_1 (FYM + mi)	0.735
M_2 (VC + mi)	0.731
M_3 (NC + mi)	0.741
M_4 (FYM + VC+ NC + mi)	0.733
CD (Manures)	0.102
$F_{1,16}$ (M_0T_0 Vs M)	15.685 **

**significant at 1 per cent

4.4. BIOCHEMICAL CHARACTERS

4.4.1. Curcumin content (%)

There was no significant difference in curcumin content from various treatments at harvest (Table 18). All the treatments were on par with control and in the group analysis of different treatments also same trend was noticed.

M_2 d recorded the maximum value (0.0853) followed by M_3 d and M_4 d (0.0729 and 0.0665 respectively) while, M_0d_0 recorded the lowest value (0.0288).

In the group analysis of different treatments, M_2 recorded the maximum value (0.0720) while, M_1 recorded the minimum value (0.0520).

4.4.2. Volatile oil (%)

As observed in Table 19, significant difference was found among various treatments in volatile oil content of the rhizomes. All treatmentswere significantly superior in volatile oil content than the control plants. M_2 d recorded highest value for volatile oil (6.60) which was on par with M_3 d (6.50) whereas, M_0d_0 recorded the lowest value (5.10).

In the group analysis of different treatments, M_2 recorded significantly superior volatile oil content (6.29) than all other groups whereas, M_1 recorded the minimum value (5.77) among the groups.

Table 18. Effect of organic manures and microbial inoculants on in curcumin content (%) *Curcuma aromatica* Salisb.at harvest

Treatments / Manures	Curcumin content (%)
M_1 d (T$_1$)	0.0605
M_2 d (T$_2$)	0.0853
M_3 d (T$_3$)	0.0729
M_1 d/2 (T$_4$)	0.0441
M_2 d/2 (T$_5$)	0.0580
M_3 d/2 (T$_6$)	0.0526
M_4 d (T$_7$)	0.0665
M_4 d/2 (T$_8$)	0.0565
M_0 d_0 (T$_9$)	0.0288
CD (Treatments)	0.0658
M_1 (FYM + mi)	0.0520
M_2 (VC + mi)	0.0720
M_3 (NC + mi)	0.0630
M_4 (FYM + VC+ NC + mi)	0.0620
CD (Manures)	0.0465
$F_{1,16}$ (M_0T_0 Vs M)	2.046 ^{NS}

NS-Not significant

Table 19. Effect of organic manures and microbial inoculants on volatile oil (%) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Volatile oil (%)
M_1 d (T_1)	5.96
M_2 d (T_2)	6.60
M_3 d (T_3)	6.50
M_1 d/2 (T_4)	5.59
M_2 d/2 (T_5)	5.98
M_3 d/2 (T_6)	5.70
M_4 d (T_7)	6.20
M_4 d/2 (T_8)	5.92
M_0 d_0 (T_9)	5.10
CD (Treatments)	0.110
M_1 (FYM + mi)	5.77
M_2 (VC + mi)	6.29
M_3 (NC + mi)	6.10
M_4 (FYM + VC+ NC + mi)	6.06
CD (Manures)	0.078
$F_{1,16}$ (M_0T_0 Vs M)	601.395 **

**significant at 1 per cent

4.4.3. Non volatile ether extract (%)

All treatments except M_1 d/2 recorded significantly superior non volatile ether extract than control (Table 20). M_2 d recorded the highest value (6.73), which was on par with M_3 d, and M_4 d (6.63 and 6.39 respectively) whereas, M_1 d/2 was on par with control (M_0d_0) which recorded the lowest value (4.97).

In the group analysis of different treatments, M_2 recorded the highest value (6.22) followed by M_3 (6.12) and M_4 (5.99) whereas, M_1 recorded the lowest value (5.72) among the groups.

4.4.4. Crude fibre (%)

All treatments except M_1 d/2, M_3 d/2 were significantly lower in crude fibre content than control (Table 21). Among the treatments M_2 d (2.13), M_3 d (2.27) and M_4 d (2.48) recorded the lowest values for crude fibre content than all other treatments whereas, control (M_0d_0) recorded the maximum value (3.06) which was on par with M_1 d/2 (3.03) and M_3 d/2 (2.98).

In the group analysis of different treatments, M_2 recorded the lowest value (2.39) than all other groups while, M_1 recorded maximum value (2.85) among the groups.

Table 20. Effect of organic manures and microbial inoculants on non volatile ether extract (%) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Non volatile ether extract (%)
M_1 d (T_1)	6.33
M_2 d (T_2)	6.73
M_3 d (T_3)	6.63
M_1 d/2 (T_4)	5.10
M_2 d/2 (T_5)	5.70
M_3 d/2 (T_6)	5.60
M_4 d (T_7)	6.39
M_4 d/2 (T_8)	5.60
M_0 d_0 (T_9)	4.97
CD (Treatments)	0.405
M_1 (FYM + mi)	5.72
M_2 (VC + mi)	6.22
M_3 (NC + mi)	6.12
M_4 (FYM + VC+ NC + mi)	5.99
CD (Manures)	0.286
$F_{1,16}$ (M_0T_0 Vs M)	53.121 **

**significant at 1 per cent

Table 21. Effect of organic manures and microbial inoculants on crude fibre (%) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Crude fibre (%)
M_1 d (T_1)	2.67
M_2 d (T_2)	2.13
M_3 d (T_3)	2.27
M_1 d/2 (T_4)	3.03
M_2 d/2 (T_5)	2.66
M_3 d/2 (T_6)	2.98
M_4 d (T_7)	2.48
M_4 d/2 (T_8)	2.81
M_0 d_0 (T_9)	3.06
CD (Treatments)	0.106
M_1 (FYM + mi)	2.85
M_2 (VC + mi)	2.39
M_3 (NC + mi)	2.62
M_4 (FYM + VC+ NC + mi)	2.64
CD (Manures)	0.075
$F_{1,16}$ (M_0T_0 Vs M)	135.524 **

**significant at 1 per cent

4.4.5. Starch (%)

As observed in the Table 22, all treatments recorded significantly superior starch content than the control. M_2 d recorded the highest value (22.58) for starch content which was on par with M_3 d (22.44) whereas, M_0d_0 recorded the lowest value for starch (20.15). In the group analysis of different treatments, M_4 recorded significantly superior starch content (22.00) and whereas, M_1 recorded the lowest value (21.29) among the groups.

Table 22. Effect of organic manures and microbial inoculants on starch content (%) in *Curcuma aromatica* Salisb. at harvest

Treatments / Manures	Starch (%)
M_1 d (T_1)	21.93
M_2 d (T_2)	22.58
M_3 d (T_3)	22.44
M_1 d/2 (T_4)	20.66
M_2 d/2 (T_5)	20.81
M_3 d/2 (T_6)	20.75
M_4 d (T_7)	22.17
M_4 d/2 (T_8)	21.83
M_0 d_0 (T_9)	20.15
CD (Treatments)	0.140
M_1 (FYM + mi)	21.29
M_2 (VC + mi)	21.70
M_3 (NC + mi)	21.60
M_4 (FYM + VC+ NC + mi)	22.00
CD (Manures)	0.098
$F_{1,16}$ (M_0T_0 Vs M)	916.037 **

**significant at 1 per cent

4.4.6. Chlorophyll 'a' (mg g^{-1})

There was no significant difference found in the chlorophyll 'a' content of the plants from various treatments at 6 MAP and in the group analysis also similar trend was recorded (Table 23).

Table 23. Effect of organic manures and microbial inoculants on chlorophyll 'a' (mg g^{-1}) in *Curcuma aromatica* Salisb. at 6 MAP

Treatments / Manures	Chlorophyll 'a' (mg g^{-1})
M_1 d (T_1)	0.416
M_2 d (T_2)	0.734
M_3 d (T_3)	0.427
M_1 d/2 (T_4)	0.290
M_2 d/2 (T_5)	0.449
M_3 d/2 (T_6)	0.347
M_4 d (T_7)	0.464
M_4 d/2 (T_8)	0.389
M_0 d_0 (T_9)	0.278
CD (Treatments)	0.359
M_1 (FYM + mi)	0.353
M_2 (VC + mi)	0.592
M_3 (NC + mi)	0.387
M_4 (FYM + VC+ NC + mi)	0.427
CD (Manures)	0.254
$F_{1,16}$ (M_0T_0 Vs M)	1.609 ^{NS}

NS-Not significant

4.4.7. Chlorophyll ‘b’ (mg g^{-1})

There was no significant difference found in the chlorophyll ‘b’ content of the plants from various treatments at 6 MAP and in the group analysis also similar trend was recorded (Table 24).

Table 24. Effect of organic manures and microbial inoculants on chlorophyll ‘b’ (mg g^{-1}) in *Curcuma aromatica* Salisb. at 6 MAP

Treatments / Manures	Chlorophyll ‘b’ (mg g^{-1})
M_1 d (T$_1$)	0.300
M_2 d (T$_2$)	0.368
M_3 d (T$_3$)	0.317
M_1 d/2 (T$_4$)	0.216
M_2 d/2 (T$_5$)	0.300
M_3 d/2 (T$_6$)	0.222
M_4 d (T$_7$)	0.313
M_4 d/2 (T$_8$)	0.289
M_0 d_0 (T$_9$)	0.195
CD (Treatments)	0.236
M_1 (FYM + mi)	0.258
M_2 (VC + mi)	0.334
M_3 (NC + mi)	0.270
M_4 (FYM + VC+ NC + mi)	0.301
CD (Manures)	0.167
$F_{1,16}$ (M_0T_0 Vs M)	1.328 ^{NS}

NS-Not significant

4.4.8. Total chlorophyll (mg g^{-1})

There was no significant difference found in the total chlorophyll content of the plants from various treatments at 6 MAP and in the group analysis also similar trend was recorded (Table 25).

Table 25. Effect of organic manures and microbial inoculants on total chlorophyll (mg g^{-1}) in *Curcuma aromatica* Salisb. at 6 MAP

Treatments / Manures	Total chlorophyll (mg g^{-1})
M_1 d (T_1)	0.715
M_2 d (T_2)	1.102
M_3 d (T_3)	0.745
M_1 d/2 (T_4)	0.506
M_2 d/2 (T_5)	0.749
M_3 d/2 (T_6)	0.569
M_4 d (T_7)	0.777
M_4 d/2 (T_8)	0.678
M_0 d_0 (T_9)	0.473
CD (Treatments)	0.443
M_1 (FYM + mi)	0.611
M_2 (VC + mi)	0.926
M_3 (NC + mi)	0.657
M_4 (FYM + VC+ NC + mi)	0.727
CD (Manures)	0.314
$F_{1,16}$ (M_0T_0 Vs M)	2.687 ^{NS}

NS-Not significant

4.5. SOIL ANALYSIS

4.5.1. Soil physical properties

4.5.1.1 Bulk density (Mg m^{-3})

Table 26, represents the values for bulk density before and after the experiment. No significant difference in the soil bulk density was noticed among the treatments before and after the experiment. In the group analysis also same trend was noticed.

However, after the experiment a reduction in the soil bulk density was recorded in all plots except the control (M_0d_0) where the bulk density remained the same. Maximum increase in the bulk density was recorded by M_3 d and M_4 d.

4.5.1.2. Water holding capacity (%)

No significant difference was noticed due to the different treatments in the water holding capacity of the soil and in the group analysis also same trend was noticed (Table 27).

However, in general there was an increase in the water holding capacity of the soil after the experiment, though a significant difference was not noticed among the treatments. Higher doses of organic manure application along with microbial inoculants (M_1 d, M_2 d, M_3 d and M_4 d) had a corresponding increase in the water holding capacity and vice versa (M_1 d/2, M_2 d/2, M_3 d/2 and M_4 d/2) whereas, control (M_0 d_0) recorded minimum increase in the water holding capacity.

Table 26. Effect of organic manures and microbial inoculants on bulk density ($Mg\ m^{-3}$) before and after the experiment

Treatments / Manures	Initial B.D. ($Mg\ m^{-3}$)	Final B.D. ($Mg\ m^{-3}$)
M_1 d (T_1)	1.33	1.29
M_2 d (T_2)	1.30	1.26
M_3 d (T_3)	1.33	1.27
M_1 d/2 (T_4)	1.18	1.16
M_2 d/2 (T_5)	1.35	1.31
M_3 d/2 (T_6)	1.26	1.23
M_4 d (T_7)	1.33	1.28
M_4 d/2 (T_8)	1.28	1.26
M_0 d_0 (T_9)	1.16	1.16
CD (Treatments)	0.267	0.269
M_1 (FYM + mi)	1.25	1.22
M_2 (VC + mi)	1.32	1.29
M_3 (NC + mi)	1.30	1.25
M_4 (FYM + VC+ NC + mi)	1.31	1.27
CD (Manures)	0.189	0.190
$F_{1,16}$ (M_0T_0 Vs M)	1.954 ^{NS}	1.100 ^{NS}

NS-Not significant

Table 27. Effect of organic manures and microbial inoculants on water holding capacity (%) before and after the experiment

Treatments / Manures	Initial W.H.C (%)	Final W.H.C (%)
M_1 d (T_1)	22.61	28.89
M_2 d (T_2)	21.10	27.71
M_3 d (T_3)	22.35	28.89
M_1 d/2 (T_4)	22.03	25.31
M_2 d/2 (T_5)	21.96	26.65
M_3 d/2 (T_6)	21.32	25.30
M_4 d (T_7)	22.70	28.60
M_4 d/2 (T_8)	22.00	25.19
M_0 d_0 (T_9)	22.88	23.99
CD (Treatments)	0.950	7.063
M_1 (FYM + mi)	22.32	27.10
M_2 (VC + mi)	21.53	27.18
M_3 (NC + mi)	21.83	27.09
M_4 (FYM + VC+ NC + mi)	22.35	26.89
CD (Manures)	0.672	4.994
$F_{1,16}$ (M_0T_0 Vs M)	6.698 *	1.512 ^{NS}

NS-Not significant *significant at 5 per cent

4.5.2. Soil chemical properties

4.5.2.1. pH

The soils of the experimental plots were slightly acidic with pH ranging from 6.39 to 6.59. After the experiment also, the pH range remained somewhat unchanged (6.38 - 6.59). No significant difference in soil pH was noticed among the treatments and in the group analysis also same trend was recorded (Table 28). However, in M_1 d, M_2 d/2, M_4 d/2 and M_0 d_0 slight increase in soil pH was noticed after the experiment whereas in M_3 d, M_1 d/2 and M_3 d/2 a decrease was noticed whereas, soil pH remained unchanged in treatments M_2 d and M_4 d.

Table 28. Effect of organic manures and microbial inoculants on soil pH before and after the experiment

Treatments / Manures	Initial soil pH	Final soil pH
M_1 d (T$_1$)	6.53	6.58
M_2 d (T$_2$)	6.54	6.54
M_3 d (T$_3$)	6.59	6.49
M_1 d/2 (T$_4$)	6.58	6.54
M_2 d/2 (T$_5$)	6.42	6.51
M_3 d/2 (T$_6$)	6.39	6.38
M_4 d (T$_7$)	6.51	6.51
M_4 d/2 (T$_8$)	6.51	6.59
M_0 d_0 (T$_9$)	6.41	6.52
CD (Treatments)	0.349	0.410
M_1 (FYM + mi)	6.55	6.56
M_2 (VC + mi)	6.48	6.52
M_3 (NC + mi)	6.49	6.44
M_4 (FYM + VC+ NC + mi)	6.51	6.55
CD (Manures)	0.247	0.290
$F_{1,16}$ (M_0T_0 Vs M)	0.670 ^{NS}	0 ^{NS}

NS-Not significant

4.5.2.2. EC (d S m^{-1})

There was no significant difference found in the soil electrical conductivity by the different treatments and in the group analysis also same trend was recorded (Table 29).

However, substantial increase in EC was noticed in vermicompost applied treatments (M_2 d and M_2 d/2) followed by combined application of organic manures in higher and lower dose (M_4 d and M_4 d/2).

Table 29. Effect of organic manures and microbial inoculants on electrical conductivity (d S m^{-1}) before and after the experiment

Treatments / Manures	Initial E.C. (d S m^{-1})	Initial E.C. (d S m^{-1})
M_1 d (T_1)	0.214	0.321
M_2 d (T_2)	0.243	0.390
M_3 d (T_3)	0.236	0.339
M_1 d/2 (T_4)	0.183	0.323
M_2 d/2 (T_5)	0.174	0.340
M_3 d/2 (T_6)	0.181	0.262
M_4 d (T_7)	0.325	0.381
M_4 d/2 (T_8)	0.213	0.377
M_0 d_0 (T_9)	0.237	0.263
CD (Treatments)	0.182	0.145
M_1 (FYM + mi)	0.198	0.322
M_2 (VC + mi)	0.208	0.365
M_3 (NC + mi)	0.209	0.301
M_4 (FYM + VC+ NC + mi)	0.269	0.379
CD (Manures)	0.128	0.103
$F_{1,16}$ (M_0T_0 Vs M)	0.064^{NS}	2.308^{NS}

NS-Not significant

4.5.2.3. Organic carbon (%)

A general increase in soil organic carbon was recorded in all treatments after the experiment and M_1 d, M_2 d, M_3 d, M_2 d/2 showed an increase and in the group analysis M_2 recorded the highest increase compared to other manures. However, no significant difference was noticed among the treatments and in the group analysis also same trend followed (Table 30).

4.5.2.4.1. Available N (kg ha^{-1})

An increase in available nitrogen was noticed in all treatments after the experiment. All treatments except M_1 d/2, M_4 d/2 were significantly superior in available nitrogen content than the control (Table 31). M_3 d recorded the highest value (341.70) which was on par with M_1 d (313.99) whereas, M_1 d/2 (271.75) and M_4 d/2 (265.63) were on par with control (M_0d_0) which recorded the lowest value (243.75).

In the group analysis of different treatments, M_3 recorded the maximum value (316.19) which was on a par with M_2 (293.59) but found superior to M_1 (292.87) and M_4 (284.73).

Table 30. Effect of organic manures and microbial inoculants on organic carbon content (%) before and after the experiment

Treatments / Manures	Initial O.C. (%)	Final O.C. (%)
M_1 d (T_1)	0.590	1.025
M_2 d (T_2)	0.990	1.385
M_3 d (T_3)	0.775	1.170
M_1 d/2 (T_4)	0.875	0.965
M_2 d/2 (T_5)	0.745	1.140
M_3 d/2 (T_6)	0.690	0.735
M_4 d (T_7)	1.040	1.303
M_4 d/2 (T_8)	0.695	1.025
M_0 d_0 (T_9)	0.995	1.016
CD (Treatments)	0.303	0.285
M_1 (FYM + mi)	0.733	0.995
M_2 (VC + mi)	0.868	1.263
M_3 (NC + mi)	0.733	0.953
M_4 (FYM + VC+ NC + mi)	0.868	1.164
CD (Manures)	0.214	0.201
$F_{1,16}$ (M_0T_0 Vs M)	3.309 ^{NS}	0.587 ^{NS}

NS-Not significant

Table 31. Effect of organic manures and microbial inoculants on available nitrogen (kg ha^{-1}) before and after the experiment

Treatments / Manures	Initial available N (kg ha^{-1})	Final Available N (kg ha^{-1})
M_1 d (T$_1$)	225.82	313.99
M_2 d (T$_2$)	228.71	305.58
M_3 d (T$_3$)	230.43	341.70
M_1 d/2 (T$_4$)	228.83	271.75
M_2 d/2 (T$_5$)	234.81	281.60
M_3 d/2 (T$_6$)	239.17	291.32
M_4 d (T$_7$)	235.34	303.82
M_4 d/2 (T$_8$)	237.81	265.63
M_0 d_0 (T$_9$)	239.33	243.75
CD (Treatments)	11.950	32.563
M_1 (FYM + mi)	227.32	292.87
M_2 (VC + mi)	231.75	293.59
M_3 (NC + mi)	234.80	316.51
M_4 (FYM + VC+ NC + mi)	236.57	284.73
CD (Manures)	8.450	23.025
$F_{1,16}$ (M_0T_0 Vs M)	2.518 ^{NS}	21.308 **

NS-Not significant **significant at 1 per cent

4.5.2.4.2. Available P (kg ha^{-1})

An increase in available phosphorus content was noticed after the experiment. However, no significant difference in available phosphorus content was noticed among the treatments and in the group analysis also same trend was followed (Table 32).

Maximum increase in the available phosphorus was recorded by M_2 d followed by M_3 d, M_4 d and M_1 d whereas treatments M_1 d/2, M_2 d/2, M_3 d/2 and M_4 d/2 recorded only minimum increase compared to their full dose application. In general, vermicompost application recorded the maximum increase in available phosphorus after the experiment whereas, application of FYM was found less effective.

Table 32.Effect of organic manures and microbial inoculants on available phosphorus (kg ha^{-1}) before and after the experiment

Treatments / Manures	Initial available P (kg ha^{-1})	Final available P (kg ha^{-1})
M_1 d (T_1)	61.17	72.24
M_2 d (T_2)	54.80	77.97
M_3 d (T_3)	51.97	70.66
M_1 d/2 (T_4)	51.82	56.38
M_2 d/2 (T_5)	59.10	66.13
M_3 d/2 (T_6)	58.54	61.06
M_4 d (T_7)	54.77	70.00
M_4 d/2 (T_8)	62.72	69.52
M_0 d_0 (T_9)	58.24	60.78
CD (Treatments)	11.673	12.938
M_1 (FYM + mi)	56.49	64.31
M_2 (VC + mi)	56.95	72.05
M_3 (NC + mi)	55.25	65.86
M_4 (FYM + VC+ NC + mi)	58.74	69.76
CD (Manures)	8.254	9.149
$F_{1,16}$ (M_0T_0 Vs M)	0.112^{NS}	2.484^{NS}

NS-Not significant

4.5.2.4.3. Available K (kg ha^{-1})

A general increase in available K content was noticed after the experiment though significant difference was not noticed among the treatments (Table 33).

M_2 drecorded the maximum increase in the available potassium followed by M_3 d, M_2 d/2, M_1 d and M_4 d. M_1 d/2, M_3 d/2 and M_4 d/2 recorded only minimum increase compared to their higher dose of application. In general, application of vermicompost recorded the highest increase in the available potassium content while the lowest increase was recorded by FYM application.

Table 33. Effect of organic manures and microbial inoculants on available potassium (kg ha^{-1}) before and after the experiment

Treatments / Manures	Initial available K (kg ha^{-1})	Final available K (kg ha^{-1})
M_1 d (T_1)	386.03	456.96
M_2 d (T_2)	486.08	624.96
M_3 d (T_3)	398.72	486.08
M_1 d/2 (T_4)	367.36	377.07
M_2 d/2 (T_5)	371.84	448.00
M_3 d/2 (T_6)	236.69	264.32
M_4 d (T_7)	416.64	477.84
M_4 d/2 (T_8)	327.04	376.32
M_0 d_0 (T_9)	351.11	367.44
CD (Treatments)	226.436	298.249
M_1 (FYM + mi)	376.69	417.01
M_2 (VC + mi)	428.96	536.48
M_3 (NC + mi)	317.71	375.20
M_4 (FYM + VC+ NC + mi)	371.84	427.08
CD (Manures)	160.114	210.89
$F_{1,16}$ (M_0T_0 Vs M)	0.080 ^{NS}	0.459 ^{NS}

NS-Not significant

4.5.3. Soil biological properties

4.5.3.1 Bacterial count

In plot applied with M_1 d the bacterial population was reduced to 25 x 10^6 from 58 x10^6, But in treatment M_2 d where vermicompost was applied along with microbial inoculants, the difference in the bacterial population was much higher (Table 34). The treatment M_3 d was found the best treatment for reducing the phytopathogenic bacterial population in the soil i.e. the initial population of bacteria was 315.50 x10^6 which was reduced to 47.50 x 10^6. In group analysis, maximum reduction in phytopathogenic bacteria was in M_2 i.e. from 206.25 x 10^6 to 47.75 x 10^6 which was followed by M_3 i.e. from 191.25 x 10^6 to 53.25 x 10^6.

4.5.3.2. Fungal count

The number of fungal propagules have shown a decreasing trend when the different organic manures were given in half dose (Table 35). Maximum reduction of pathogenic fungal population was found in the treatment M_3 d/2 which was followed by M_4 d/2 and M_1 d/2. The full dose of various organic manures did not shown any decrease in number of fungal propagules, instead it increased. Group analysis indicated that neemcake and microbial inoculants applied together gave the maximum reduction of soil fungi (M_3).

4.5.3.3. Actinomycetes count

The treatments M_3 d, M_2 d/2 and M_4 d were significantly superior in the case of actinomycetes count i.e. actinomycetes count in soil was reduced maximum when vermicompost was applied @ 12.5 t ha^{-1} along with microbial inoculants (Table 36) i.e. in the treatments M_2 d/2 the initial population of 196 x 10^6 of actinomycetes was reduced to 29.5 x 10^6. This was highly significant also. The treatment M_2 d/2 was followed by M_3 d and M_4 d. In group analysis also all the groups (M_2, M_3 and M_4) were found superior except M_1.

4.5.3.4. Mycorrhizal count (%)

Mycorrhizal colonization percentage was found increasing in treatments M_2 d/2, M_3 d/2, M_4 d and M_4 d/2 as the plant is growing (Table 37). The maximum percentage colonization was noticed in the treatment M_3 d/2 (28.00) at 6 MAP followed by the M_2 d/2 (24.33). But at 4 MAP the maximum colonization percentage was recorded in M_1 d (44.67) followed by M_2 d (36.00) and this was statistically significant also.

Treatments M_1 d, M_2 d, M_3 d recorded their effect in the early growth stages whereas M_1 d/2, M_2 d/2, M_3 d/2, M_4 d and M_4 d/2 shown their effects in the later growth stages.

Throughout the growth stages, all treatments recorded significantly superior colonization than control. At 2 MAP and 4 MAP, M_1 d recorded significantly superior root colonization (37.33 and 44.67 respectively). But at 6 MAP, M_3 d/2 recorded significantly superior root colonization (28.00) whereas, minimum colonization percentage was recorded in M_4 d/2 at 2, 4 and 6 MAP i.e. 4.00, 7.33 and 10.33 respectively other than the control.

Table 34. Effect of organic manures and microbial inoculants on soil bacterial count before and after the experiment

Treatments / Manures	Initial bacterial count (10^6)	Final bacterial count (10^6)
M_1 d (T_1)	58.00	25.00
M_2 d (T_2)	155.00	37.50
M_3 d (T_3)	315.50	47.50
M_1 d/2 (T_4)	44.00	53.00
M_2 d/2 (T_5)	257.50	58.00
M_3 d/2 (T_6)	67.00	59.00
M_4 d (T_7)	65.50	67.50
M_4 d/2 (T_8)	109.00	31.00
M_0 d_0 (T_9)	38.00	59.00
CD (Treatments)	164.343	16.158
M_1 (FYM + mi)	51.00	39.00
M_2 (VC + mi)	206.25	47.75
M_3 (NC + mi)	191.25	53.25
M_4 (FYM + VC+ NC + mi)	87.25	49.25
CD (Manures)	116.21	11.425
$F_{1,16}$ (M_0T_0 Vs M)	3.221 ^{NS}	4.946 *

*significant at 5 per cent

Table 35. Effect of organic manures and microbial inoculants on soil fungal count before and after the experiment

Treatments / Manures	Initial fungal count (10^4)	Final fungal count (10^4)
M_1 d (T_1)	11.00	51.00
M_2 d (T_2)	30.50	104.50
M_3 d (T_3)	16.50	45.00
M_1 d/2 (T_4)	65.00	43.50
M_2 d/2 (T_5)	56.50	45.00
M_3 d/2 (T_6)	130.00	47.50
M_4 d (T_7)	61.00	44.00
M_4 d/2 (T_8)	57.50	30.00
M_0 d_0 (T_9)	10.00	42.50
CD (Treatments)	30.174	21.833
M_1 (FYM + mi)	38.00	47.25
M_2 (VC + mi)	43.50	74.75
M_3 (NC + mi)	73.25	46.25
M_4 (FYM + VC+ NC + mi)	59.25	37.00
CD (Manures)	21.336	15.438
$F_{1,16}$ (M_0T_0 Vs M)	19.647 **	1.540 ^{NS}

NS-Not significant **significant at 1 per cent

Table 36. Effect of organic manures and microbial inoculants on soil actinomycetes count before and after the experiment

Treatments / Manures	Initial actinomycetes count (10^6)	Final actinomycetes count (10^6)
M_1 d (T_1)	6.00	40.00
M_2 d (T_2)	62.00	45.00
M_3 d (T_3)	122.50	38.00
M_1 d/2 (T_4)	16.50	33.50
M_2 d/2 (T_5)	196.00	29.50
M_3 d/2 (T_6)	60.50	34.00
M_4 d (T_7)	81.50	23.50
M_4 d/2 (T_8)	65.00	34.00
M_0 d_0 (T_9)	198.00	48.50
CD (Treatments)	30.16	10.313
M_1 (FYM + mi)	11.25	36.75
M_2 (VC + mi)	129.00	37.25
M_3 (NC + mi)	91.50	36.00
M_4 (FYM + VC+ NC + mi)	73.25	28.75
CD (Manures)	21.326	7.292
$F_{1,16}$ (M_0T_0 Vs M)	154.055 **	16.959 **

**significant at 1 per cent

Table 37. Effect of organic manures and microbial inoculants on mycorrhizal colonization (%) in *Curcuma aromatica* Salisb.at different growth stages

Treatments / Manures	2 MAP	4 MAP	6 MAP
M_1 d (T_1)	37.33	44.67	22.00
M_2 d (T_2)	28.33	36.00	22.67
M_3 d (T_3)	9.67	28.00	16.67
M_1 d/2 (T_4)	18.33	9.67	17.33
M_2 d/2 (T_5)	4.67	18.33	24.33
M_3 d/2 (T_6)	12.67	11.33	28.00
M_4 d (T_7)	5.33	13.33	13.00
M_4 d/2 (T_8)	4.00	7.33	10.33
M_0 d_0 (T_9)	1.00	1.33	4.00
CD (Treatments)	2.657	3.615	1.703
M_1 (FYM + mi)	27.83	27.17	19.67
M_2 (VC + mi)	16.50	27.17	23.50
M_3 (NC + mi)	11.17	19.67	22.33
M_4 (FYM + VC+ NC + mi)	4.67	10.33	11.67
CD (Manures)	1.879	2.556	1.204
$F_{1,16}$ (M_0T_0 Vs M)	223.119 **	238.511 **	644.447 **

**significant at 1 per cent

4.6. PLANT ANALYSIS

4.6.1. Uptake of nitrogen (kg ha^{-1})

As observed in the Table 38, uptake of nitrogen in kasthuri turmeric plants was influenced by the application of different organic manures and microbial inoculants and all treatments recorded significantly superior N uptake than control. M_2 d recorded the highest value (102.48) which was on par with M_3 d (93.54) and M_4 d (88.19). M_1 d recorded an uptake of 80.25 which was on par with M_2 d/2, M_4 d/2 and M_3 d/2 (74.87, 71.23 and 64.76 respectively). M_1 d/2 recorded an uptake of 61.12 whereas the control (M_0d_0) recorded the lowest value (40.74).

Among the groups, M_2recorded the highest value (88.68) which was on par with M_4 (79.71) and M_3 (79.15) and found superior to M_1 (70.69).

4.6.2. Uptake of phosphorus (kg ha^{-1})

As observed in the Table 39, uptake of phosphorus in kasthuri turmeric plants was influenced by the application of different organic manures and microbial inoculants and all treatments except M_3 d/2, M_2 d/2, M_1 d/2 recorded significantly superior P uptake than the control. Treatments M_4 d recorded the highest value (59.76) which was on par with M_2 d (55.15), M_1 d (54.09) and M_4 d/2 (48.39). M_3 d recorded an uptake of 45.04 whereas, treatments M_3 d/2 (29.49), M_2 d/2 (27.68) and M_1 d/2 (23.59) were on par with control (M_0 d_0) which recorded the lowest value (18.84).

In the group analysis, M_4 recorded significantly superior P uptake (54.08) than other groups.

4.6.3. Uptake of potassium (kg ha^{-1})

As observed in the Table 40, uptake of potassium in kasthuri turmeric plants was influenced by the application of different organic manures and microbial inoculants and all treatments recorded significantly superior uptake of K than control. Treatment M_3 d recorded the highest value (262.56) which was on par with M_2 d (260.88) and M_4 d (232.92). M_1 d recorded an uptake of 212.02 which was on par with M_4 d/2 and M_2 d/2 (192.93 and 187.15 respectively). M_1 d/2 and M_3 d/2 recorded an uptake of 149.57 and 145.59 respectively, which were on par with M_4 d/2. Control (M_0d_0)recorded the lowest K uptake (97.20).

In the group analysis, highest value was recorded by M_2 (224.02) followed by M_4 (212.93) and M_3 (204.08) which were on par and significantly superior to M_1 (180.80).

4.7. INCIDENCE OF PESTS AND DISEASES

Pest and disease incidence were recorded periodically and no serious pest and disease incidence were noticed.

Plant protection measures were carried out for stem borer (*Conogethes punctiferalis*) and lema beetle (*Lema* spp.) by spraying 4 per cent Neem oil (azadirachtine 400-500 ppm) and placing neemcake in the leaf axils. Copper hydroxide 0.3 per cent solution was sprayed at the start of leaf blight disease (*Colletotrichum capsici*).

Table 38. Effect of organic manures and microbial inoculants on uptake of nitrogen (kg ha^{-1}) in *Curcuma aromatica* Salisb.

Treatments / Manures	Uptake of nitrogen (kg ha^{-1})
M_1 d (T_1)	80.26
M_2 d (T_2)	102.48
M_3 d (T_3)	93.54
M_1 d/2 (T_4)	61.12
M_2 d/2 (T_5)	74.87
M_3 d/2 (T_6)	64.76
M_4 d (T_7)	88.19
M_4 d/2 (T_8)	71.23
M_0 d_0 (T_9)	40.74
CD (Treatments)	17.218
M_1 (FYM + mi)	70.69
M_2 (VC + mi)	88.68
M_3 (NC + mi)	79.15
M_4 (FYM + VC+ NC + mi)	79.71
CD (Manures)	12.175
$F_{1,16}$ (M_0T_0 Vs M)	40.605 **

**significant at 1 per cent

Table 39. Effect of organic manures and microbial inoculants on uptake of phosphorus (kg ha^{-1}) in *Curcuma aromatica* Salisb.

Treatments / Manures	Uptake of phosphorus (kg ha^{-1})
M_1 d (T_1)	54.09
M_2 d (T_2)	55.15
M_3 d (T_3)	45.04
M_1 d/2 (T_4)	23.57
M_2 d/2 (T_5)	27.68
M_3 d/2 (T_6)	29.49
M_4 d (T_7)	59.76
M_4 d/2 (T_8)	48.39
M_0 d_0 (T_9)	18.84
CD (Treatments)	12.115
M_1 (FYM + mi)	38.83
M_2 (VC + mi)	41.42
M_3 (NC + mi)	37.26
M_4 (FYM + VC+ NC + mi)	54.08
CD (Manures)	8.567
$F_{1,16}$ (M_0T_0 Vs M)	31.49 **

**significant at 1 per cent

Table 40. Effect of organic manures and microbial inoculants on uptake of potassium (kg ha^{-1}) in *Curcuma aromatica* Salisb.

Treatments / Manures	Uptake of potassium (kg ha^{-1})
M_1 d (T_1)	212.02
M_2 d (T_2)	260.88
M_3 d (T_3)	262.56
M_1 d/2 (T_4)	149.57
M_2 d/2 (T_5)	187.15
M_3 d/2 (T_6)	145.59
M_4 d (T_7)	232.92
M_4 d/2 (T_8)	192.93
M_0 d_0 (T_9)	97.20
CD (Treatments)	45.79
M_1 (FYM + mi)	180.80
M_2 (VC + mi)	224.02
M_3 (NC + mi)	204.08
M_4 (FYM + VC+ NC + mi)	212.93
CD (Manures)	32.381
$F_{1,16}$ (M_0T_0 Vs M)	44.648 **

**significant at 1 per cent

4.8. ECONOMICS OF CULTIVATION/ B: C RATIO

The economics of cultivation of kasthuri turmeric using organic various treatments is given in Table 41. Among the nine treatments, M_2 d recorded the highest gross income of Rs. 7, 21,750 /- followed by M_3 d (Rs. 6, 96,000/-) and M_4 d (Rs.6, 70,250 /-) whereas, the lowest gross income was recorded by M_0 d_0 (Rs. 3, 35,250 /-). Highest cost of cultivation was incurred in the treatment M_2 d (3, 04,954 /-) followed by M_4 d (Rs. 2, 64,860 /-) and M_1 d (Rs. 2, 48,977 /-) whereas M_0 d_0 recorded the lowest cost of cultivation (Rs.1, 89,063 /-).

Highest net income was obtained from M_3 d (Rs. 4, 67,935 /-) followed by M_2 d (Rs. 4, 16,796 /-) , M_4 d (Rs. 4, 05,390 /-), M_3 d/2 (Rs. 3,81,270 /-), M_1 d (Rs. 3,70,773 /-), M_4 d/2 (Rs. 3,63,090 /-), M_2 d/2 (Rs. 3,56,536 /-), and M_1 d/2 (Rs. 3, 05,040 /-). M_0 d_0 registered the lowest net income of Rs. 1, 46,187 /-.

In the cost benefit analysis, treatment M_3 d recorded the highest B: C ratio of 3.05 followed by M_3 d/2 (2.92). Better B: C ratios were also observed with treatments M_4 d/2, M_1 d/2, M_4 d, M_1 d, M_2 d/2 (2.57, 2.55, 2.53, 2.49 and 2.43 respectively). M_2 d recorded a B: C ratio of 2.37 whereas, the control (M_0 d_0) recorded the lowest B: C ratio (1.77).

Table 41. Effect of organic manures and microbial inoculants on economics of cultivation / B: C ratio in *Curcuma aromatica* Salisb.

Treatments	Yield/Plot (kg.)	Fresh yield (t/ha.)	Gross income (Rs.)	Cost of cultivation (Rs.)	Net income (Rs.)	B:C ratio
M_1 d (T_1)	11.804	24.79	619750	248977	370773	2.49
M_2 d (T_2)	13.748	28.87	721750	304954	416796	2.37
M_3 d (T_3)	13.257	27.84	696000	228065	467935	3.05
M_1 d/2 (T_4)	9.562	20.08	502000	196960	305040	2.55
M_2 d/2 (T_5)	11.533	24.22	605500	248964	356536	2.43
M_3 d/2 (T_6)	11.052	23.21	580250	198980	381270	2.92
M_4 d (T_7)	12.767	26.81	670250	264860	405390	2.53
M_4 d/2 (T_8)	11.314	23.76	594000	230910	363090	2.57
M_0 d_0 (T_9)	6.386	13.41	335250	189063	146187	1.77

DISCUSSION

5. DISCUSSION

The effect of different combinations of organic manures and microbial inoculants (mi) on growth, yield and quality of kasthuri turmeric is discussed here based on the field experiment conducted during the year 2010-2011.

5.1. GROWTH CHARACTERS

5.1.1. Plant height (cm)

The effect of organic manures and microbial inoculants on plant height of kasthuri turmeric was significantly higher to control and was most prominent in vermicompost + mi (M_2 d) treated plants (Fig. 2). This may be due to the increase in soil fertility level in the amended soils which is evidenced by the higher available N in the soil. Role of organic manures in maintaining soil health and their influence on growth and development of crop has been well documented (Sultan, 1995; Singh *et al.,* 1997). Organic manures influences plant growth through its effect on the physical, chemical and biological properties of soil besides providing nutrients to the plants (Marlores *et al.*, 1992; Thampan, 1995). Besides influencing the physico chemical properties of soil, vermicompost is also known to contain growth promoting substances, enhance microbial activity and prevent nitrogen loss by leaching (Shinde *et al*., 1992; Sultan, 1995). Compared to the availability of nutrients from most of the bulky organic manures, the release of nutrients from the added vermicompost is more and could be the reason for higher plant heights. The result of present investigation is in agreement with the findings of Nirmalatha (2009). Mannikeri (2006) reported that in turmeric, application of vermicompost 15.65 t ha^{-1} was found superior with regard to growth parameters like plant height. Krishnakumar *et al*. (1994) reported better growth and development of seedlings in cardamom nursery by the use of vermicompost in potting medium. Vadiraj *et al*. (1996) found that turmeric varieties like Armour and Suroma when treated with vermicompost showed 30 per cent increase in plant height over control. Use of vermicompost 3 t ha^{-1}

recorded maximum plant height than its lower dose of application (2 t ha^{-1}) in carrot (Mog, 2007). With increase in doses of vermicompost (doses from 1.25 to 19 t ha^{-1}) there was an increasing trend for growth in strawberry as observed by Singh *et al*. (2010).

Combined application of the three organic manures (FYM, VC and NC) in full and half dose + mi (M_4 d and M_4 d/2), full dose of neemcake + mi (M_3 d), full dose of FYM + mi(M_1 d) also were equally effective treatments for producing significantly superior plant heights. The report of Patil (2008) that in capsicum, soil application of FYM 50 per cent + vermicompost 50 per cent + biofertilizer recorded higher plant height which was on par with FYM 50 per cent + vermicompost 50 per cent + neem cake 500 kg ha^{-1} is in agreement with the above observation. Neem cake contains high amount of nitrogen and an increase in plant growth is expected as has been reported by several workers (Singh and Sitaramaiah, 1971; Gowda, 1972; Khan *et al*., 1974).

Neemcake and FYM in half dose + mi (M_3 d/2 and M_1 d/2) were found to be less effective in producing better plant height especially during the later stages of growth. This can be due to lack of availability of sufficient quantity of nutrients in lower doses of manures for optimum growth of kasthuri turmeric. Significant influence of higher dose of FYM in increasing the plant height in turmeric has been reported by Khandkar and Nigam (1996) and Gill *et al.* (1999) and in arrowroot by Vidyadharan (2000).

5.1.2. Number of tillers

Better tiller production was recorded in organic manure and microbial inoculants applied plants than control plants (M_0 d_0). This showed that organic manure and microbial inoculants application has got positive influence in increasing the tiller production in kasthuri turmeric. Soils amended with organic manures have the ability to retain moisture, improve soil structure and cation exchange capacity, have a higher rate of plant growth hormones and humic acids, higher microbial population and activity, and less root pathogens or soil borne

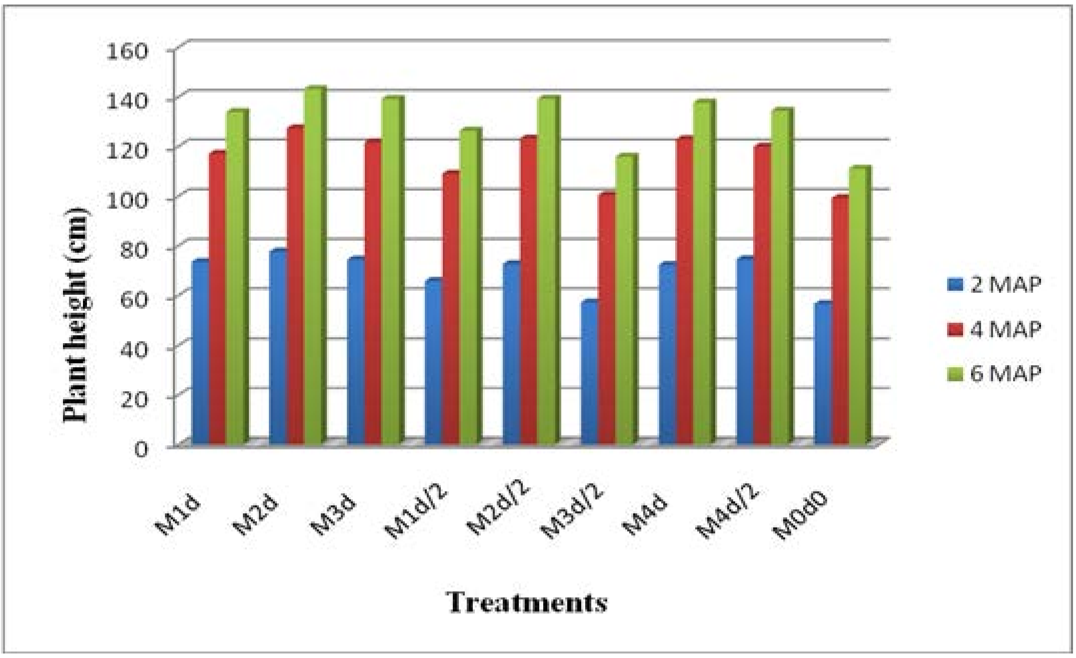


Fig. 2 Effect of organic manures and microbial inoculants on plant height (cm) in *Curcuma aromatica* Salisb.at different growth stages

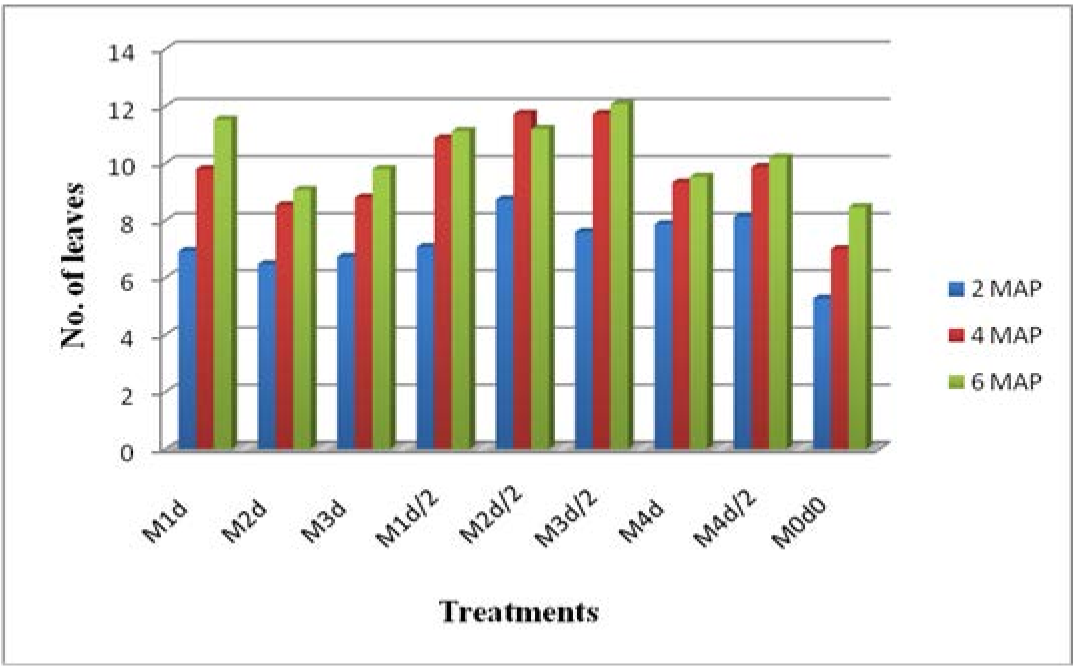


Fig. 3 Effect of organic manures and microbial inoculants on number of leavesin *Curcuma aromatica* Salisb.at different growth stages

diseases (Hoitink, 1980; Tomati *et al*., 1988; Alvarez *et al*., 1995; Domininguez and Edwards, 1999; Subler *et al*., 1998; Muscolo *et al*., 1999; Carpenter-Boggs *et al*., 2000; Atiyeh *et al*., 2002; Arancon *et al*., 2003a; Postma *et al*., 2003; Perner *et al*., 2006) and overall improvement in plant growth and yield (Kale *et al*., 1992; Arancon *et al*., 2003b, 2004).

In the present experiment no significant difference in tiller production was noticed among the treatments. However, during the later stages of crop growth, application of neemcake 3 t ha^{-1} + mi (M_3 d/2) was found to have more positive influence in tiller production than other organic manures. This may be attributed to comparatively slow and gradual release of available nutrients from neem cake. Control (M_0 d_0) recorded the lowest value throughout the crop growth. Subbiah *et al*. (1983) reported that incorporation of organic residues did not influence the number of tillers in rice. Shimi (2011) reported similar results in rhizosphere management of vetiver.

5.1.3. Number of leaves

In the case of number of leaves, organic manures and microbial inoculants applied plants produced significantly more number of leaves compared to control (M_0 d_0). Among the treatments, half dose of neemcake + mi (M_3 d/2) produced the highest number of leaves followed by full dose of FYM + mi (M_1 d) and half dose of vermicompost + mi (M_2 d/2) (Fig. 3). Neemcake and FYM along with microbial inoculants recorded significantly superior leaf production than vermicompost. Neem cake promotes slow and controlled release of nitrogen which might have resulted in higher number of leaves. The present observation is in full agreement with the finding of Nirmalatha (2009), who reported that application of neemcake 6.0 t ha^{-1} recorded maximum number of leaves in kasthuri turmeric than other organic manures. The positive influence of neemcake in increasing the leaf production in amaranthus has been reported by Arunkumar (2000). The report of Rao *et al*. (2005) in turmeric that neemcake 1.25 t ha^{-1}

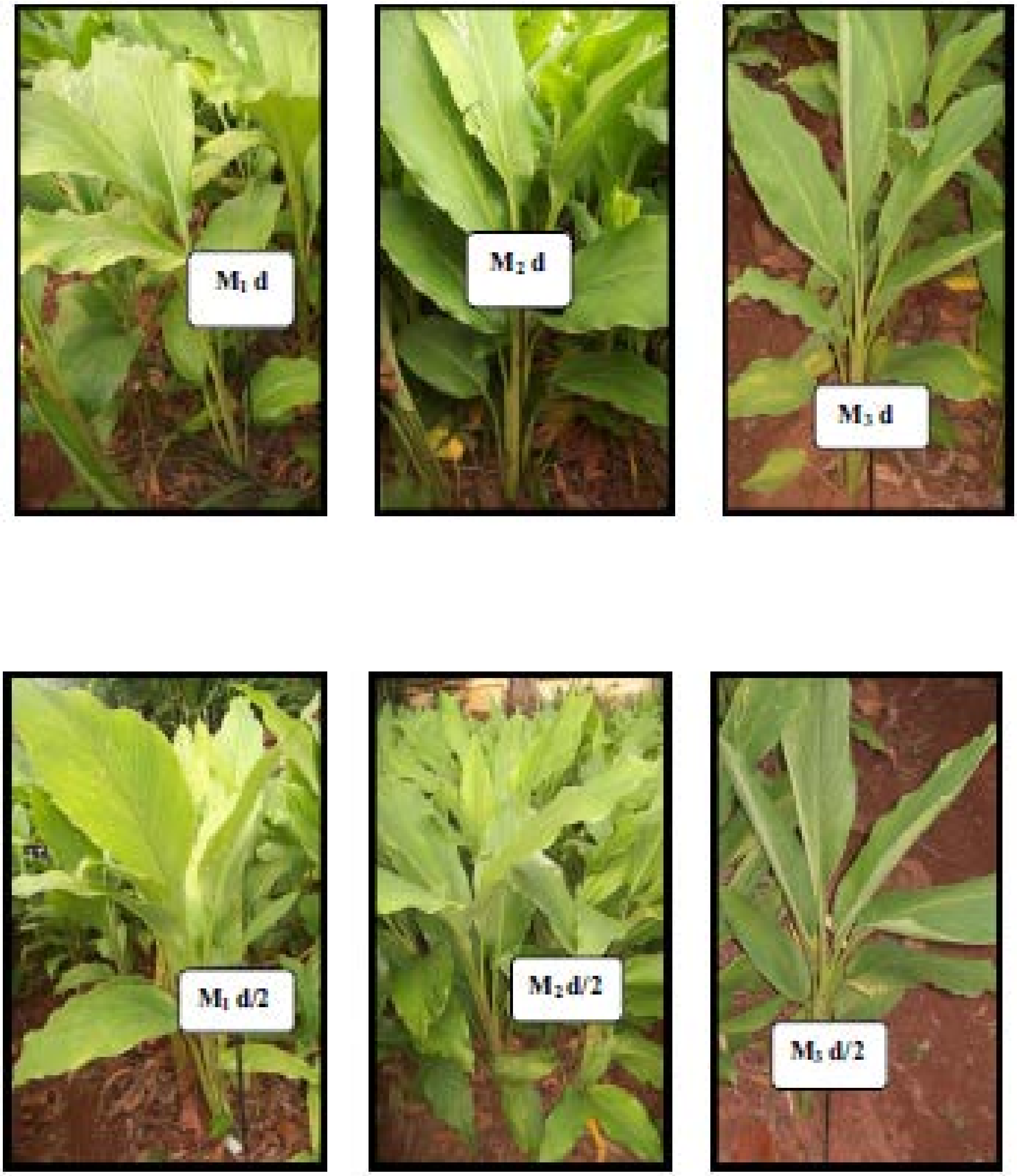


Plate 2. Effect of organic manures and microbial inoculants on plant growth in *Curcuma aromatica* Salisb.

Plate 2. Effect of organic manures and microbial inoculants on plant growth in *Curcuma aromatica* Salisb. (continued…)

Plate 3. Difference between the treatments at field condition

along with FYM 12.5 t ha^{-1} and recommended dose of fertilizers recorded the highest number of leaves is also in partial agreement with the present finding. Increase in number of leaves in turmeric with increasing levels of FYM has been reported by Khandkar and Nigam (1996). Gill *et al*. (1999) also observed highest number of leaves in turmeric with the highest dose of FYM.

From the study it was clear that organic manures applied singly along with microbial inoculants has more influence on kasthuri turmeric leaf production than combined application of organic manures + mi (M_4 d and M_4 d/2).

5.1.4. Leaf area (cm^2)

There was significant increase in the leaf area of kasthuri turmeric by the application of different organic manures along with microbial inoculants. Among the various treatments, vermicompost full and half dose + mi (M_2 d and M_2 d/2) were found to be the best followed by the combined application of organic manures + mi (M_4 d) and FYM full and half dose + mi (M_1 d and M_1 d/2) (Fig. 4). The positive influence of organic manure application was noticed throughout the growth period and vermicompost application maintained the superiority all throughout. Nirmalatha (2009) reported that in kasthuri turmeric vermicompost 25.0 t ha^{-1} recorded the maximum leaf area than their relative lower doses. The finding of 70 per cent increase in leaf area over control in turmeric by the application of vermicompost by Vadiraj *et al*. (1996) also supports the present finding. Neemcake application either full or half dose + mi (M_3 d and M_3 d/2) didn't have much influence on leaf area. However, when it was applied along with other organic manures (M_4 d) significant leaf area increase was noticed. Similar observation has been made by Sangeetha *et al*. (2010) that combined application of FYM and neemcake recorded maximum leaf area in rice, than their single application. The report of Naik (2006) that vermicompost along with neemcake recorded the maximum leaf area in chilli than their single or use with any other combinations also, is in agreement with the above finding.

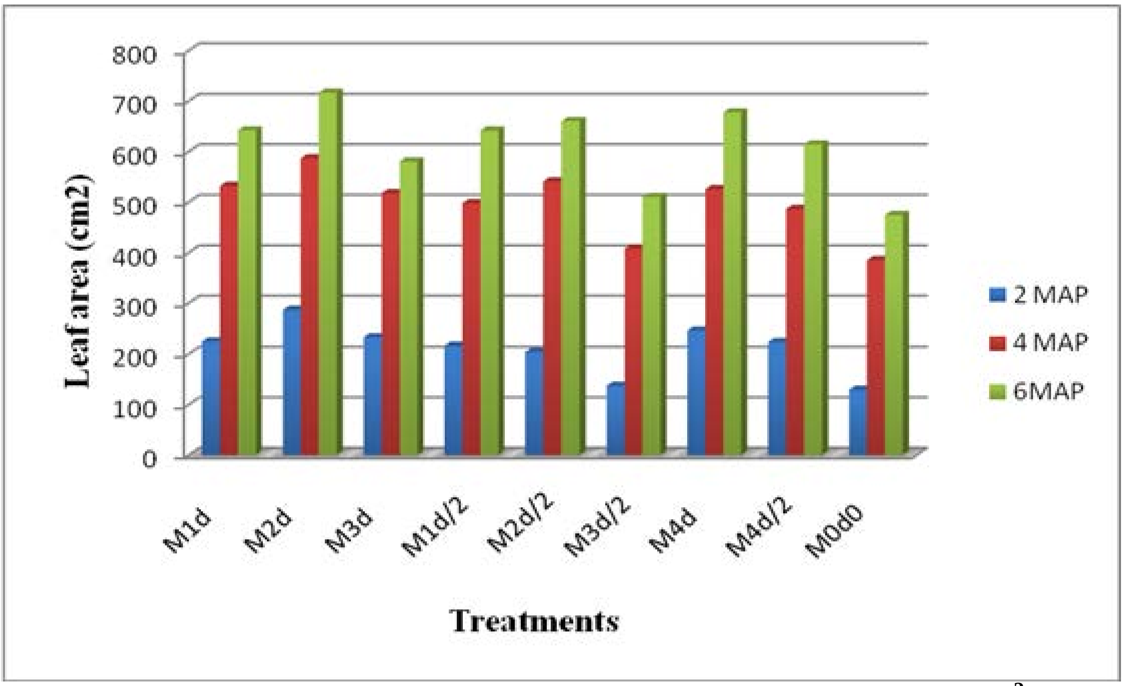


Fig. 4 Effect of organic manures and microbial inoculants on leaf area (cm^2) in *Curcuma aromatica* Salisb.at different growth stages

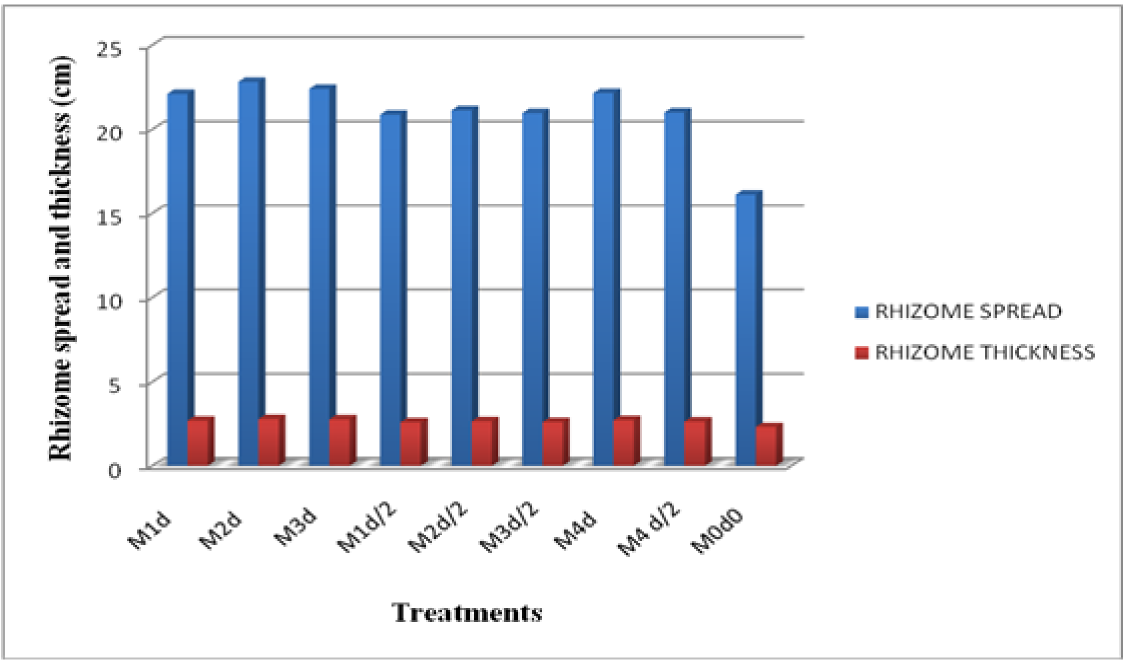


Fig. 5 Effect of organic manures and microbial inoculants on rhizome spread and rhizome thickness (cm) in *Curcuma aromatica* Salisb.

5.1.5. Rhizome spread (cm)

Obviously plants applied with organic manures and microbial inoculants exhibited better rhizome spread than non-treated control plants (M_0 d_0). All treatments except control were found equally effective in giving the better spread of rhizome and the highest value for this character was shown by M_2 d (22.82 cm) (Fig. 5). Vermicompost (M_1) was found to be superior though other manures were also found effective. It is reported that the soils amended with vermicompost have the ability to retain moisture, improve soil structure and cation exchange capacity, have a higher rate of plant growth hormones and humic acids, higher microbial population and activity, and less root pathogens or soil borne diseases (Hoitink, 1980; Tomati *et al*., 1988; Alvarez *et al*., 1995; Domininguez and Edwards, 1999; Subler *et al*., 1998; Muscolo *et al*., 1999; Carpenter-Boggs *et al*., 2000; Atiyeh *et al*., 2002; Arancon *et al*., 2003a; Postma *et al*., 2003; Perner *et al*., 2006) and overall improvement in plant growth and yield (Kale *et al*., 1992; Arancon *et al*., 2003b, 2004).

In the present study it was observed that plants with good vegetative growth produced good sized rhizomes. In kasthuri turmeric, Nirmalatha (2009) also made similar observation. Microbial inoculants were found to have good influence in getting the better rhizome spread in the present study. Nirmalatha (2009) also reported that combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* was significantly superior to all other treatments and produced tallest plants with maximum rhizome spread.

5.1.6. Rhizome thickness (cm)

Organic manures along with microbial inoculants had significant influence on rhizome thickness of kasthuri turmeric. The positive influence was more pronounced in full dose of vermicompost + mi (M_2 d) followed by full dose of neemcake + mi (M_3 d), combined application of organic manures + mi (M_4 d) and full dose of FYM + mi (M_1 d) (Fig. 5). All organic manures tried were found to be equally effective in increasing the rhizome thickness with vermicompost in the top position.

Edwards and Burrows (1988) reported that vermicompost mainly contains more mineral elements which were changed to forms that could be readily taken up by the plants such as nutrients, exchangeable P and soluble potassium, calcium and magnesium which produce better growth and yield in agricultural plants. Similarly, neemcake provide slow and steady nourishment and protect from nematodes and empower the yield and quality of produce (Gaur *et al*., 1992). FYM though not rich source of nutrients, increases organic carbon content of the soil and improves soil physical properties thereby providing better plant growth and yield. Neemcake 1.25 t ha^{-1} along with FYM 12.5 t ha^{-1} and recommended dose of fertilizers recorded the highest thickness of fingers in turmeric (Rao *et al*., 2005).

In present study, it was noticed that when the quantity of organic manures was reduced to half, there was a gradual decrease in rhizome thickness, though not significant, and the least rhizome thickness was noticed in control (M_0 d_0). The finding of Nirmalatha (2009) is also in agreement with this. She reported that vermicompost 25.0 t ha^{-1}, neemcake 6.0 t ha^{-1}, FYM 40 t ha^{-1} recorded maximum rhizome thickness in kasthuri turmeric than their respective lower level of application, and that the combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* was significantly superior to all other treatments with regard to rhizome thickness.

5.1.7. Number of fingers

Significant positive influence of organic manures and microbial inoculants was noticed in the number of fingers produced in kasthuri turmeric. As in case of rhizome thickness, here also, the highest finger number was recorded with full dose of vermicompost + mi (M_2 d) followed by neemcake + mi (M_3 d), combined application of organic manures + mi (M_4 d) and FYM + mi (M_1 d) (Fig. 6). When the dosage of organic manures was reduced to half, a corresponding decrease in finger number was noticed. Corroborative findings were reported by Nirmalatha (2009) in kasthuri turmeric where higher doses of vemicompost, neemcake and FYM produced higher number of fingers than their respective lower dose applications. Similar findings were also reported in turmeric by Gill *et al*. (1999). Though all organic manures were effective, more pronounced effect was recorded for vermicompost. The report of Roy and Hore (2011) that application of vermicompost along with *Azospirillium* and AMF recorded the highest number of fingers in turmeric corroborates the above finding.

In turmeric, rhizome yield was directly correlated with plant height and number of fingers (Panja *et al*., 2002). In the present study also, similar trend was noticed, and plants with maximum height and good vegetative growth produced better rhizome growth with more number of fingers.

5.1.8. Root length (cm)

In the case of root length, full dose of vermicompost, neemcake and FYM and their combined application along with microbial inoculants (M_2 d, M_3 d, M_1 d and M_4 d) were found to have positive influence in producing better root length. Vermicompost was found to be the most effective whereas FYM was not found to be that much effective. Vermicompost originating from plant and animal sources have been reported to contain large amount of humic substances (Senesi *et al*., 1992). Enhanced root elongation, lateral root emergence and plasma membrane H+ ATPase activity of maize roots by humic acid extracts have been reported by Canellas *et al*. (2000).

Vermicomposts contains very rich and diverse microbial populations (Edwards, 1983; 2004). Their application to soils may have added to the indigenous soil microorganism populations, activity and diversity, resulting in much larger richer and diverse soil microbial populations. Beneficial microbes such as rhizobia, diazotrophic bacteria, and mycorrhizae in the rhizosphere improve root growth by fixing atmosphere N_2, suppressing pathogens, producing phytohormones, enhancing root surface area to facilitate uptake of less mobile nutrients such as P and micronutrients, and mobilization and solubilization of unavailable organic/ inorganic nutrients (Baligar *et al.*, 2001). The nutrient content of organic manure coupled with the action of P solubilising bacterial action might have resulted in higher P concentration in soil. Phosphorus plays a key role in the formation of fibrous and strong root system and thereby helping absorption of nutrients from the soil, energy transformation and metabolic processes of plants and thus its ample availability might have resulted in better root growth (Tisdale *et al.*, 1995). Positive influence of combination of AMF and *Trichoderma* in increased root length in wheat has been reported by Kumar *et al.* (1993) and that of *Pseudomonas* and *Trichoderma* in chilli by Rini and Sulochana (2007). Nirmalatha (2009) reported maximum root length in kasthuri turmeric with higher doses of vermicompost and neem cake. Mog (2007) also reported higher root length in carrot with higher doses of vermicompost.

5.1.9. Root spread (cm)

With regard to root spread, similar trend as in the case of root length was observed. Here also, full dose application of vermicompost + mi (M_2 d), neemcake + mi (M_3 d) and FYM + mi (M_1 d) and their combined application + mi (M_4 d) produced significantly superior root spread. The root morphological factors such as length, thickness, surface area, and volume have profound effects on the plant's ability to acquire and absorb nutrients in soil (Baligar and Duncan, 1990; Barber, 1995). Better soil physical condition coupled with increased availability of nutrients due to the application of organic manures and microbial inoculants, might have contributed to the better growth of the root system of the treatment applied plants compared to control (M_0 d_0). This is evident from the fact that the root growth was significantly reduced when the quantity of organic manures applied got reduced and the least root growth was recorded in the control plants where no organic manures and microbial inoculants were applied. The present observation is in agreement with the findings of Nirmalatha (2009). She also reported a significantly superior root spread in the vermicompost 25 t ha^{-1} and neemcake 6 t ha^{-1} applied kasthuri turmeric plants than their lower level applications. She also reported the significant influence of combined application of bioinoculants on the root spread of kasthuri turmeric. Research has revealed that application of vermicompost enhanced plant growth and development, root initiation and root biomass and this was attributed to the organisms essential for maintaining vigorous plant growth capable of withstanding environmental stress (Tomati *et al.*, 1987; Edwards, 1998; Atiyeh *et al.*, 2002; Bachman and Metzger, 2008).

5.1.10. Root weight (g)

Even though no significant difference in the fresh root weight was noticed due to various treatments, their dry weight varied significantly. Highest dry root weight was recorded in full dose of vermicompost + mi (M_2 d) which was on par with all other treatments except control (M_0d_0). Higher dry matter accumulation due to better nutrient uptake brought about by the application of different organic manures and microbial inoculants might have contributed to better dry root weight. Similar findings were recorded by Nirmalatha (2009) also in kasthuri turmeric. The findings of Mog (2007) and that of Rani and Mallareddy (2006) in carrot supports the above finding.

5.2. YIELD AND YIELD COMPONENTS

5.2.1. Fresh and dry rhizome yield (g $plant^{-1}$)

From the data it can be seen that significant increase in the fresh and dry rhizome yield was obtained by the application of different organic manures along with microbial inoculants in kasthuri turmeric. Among the

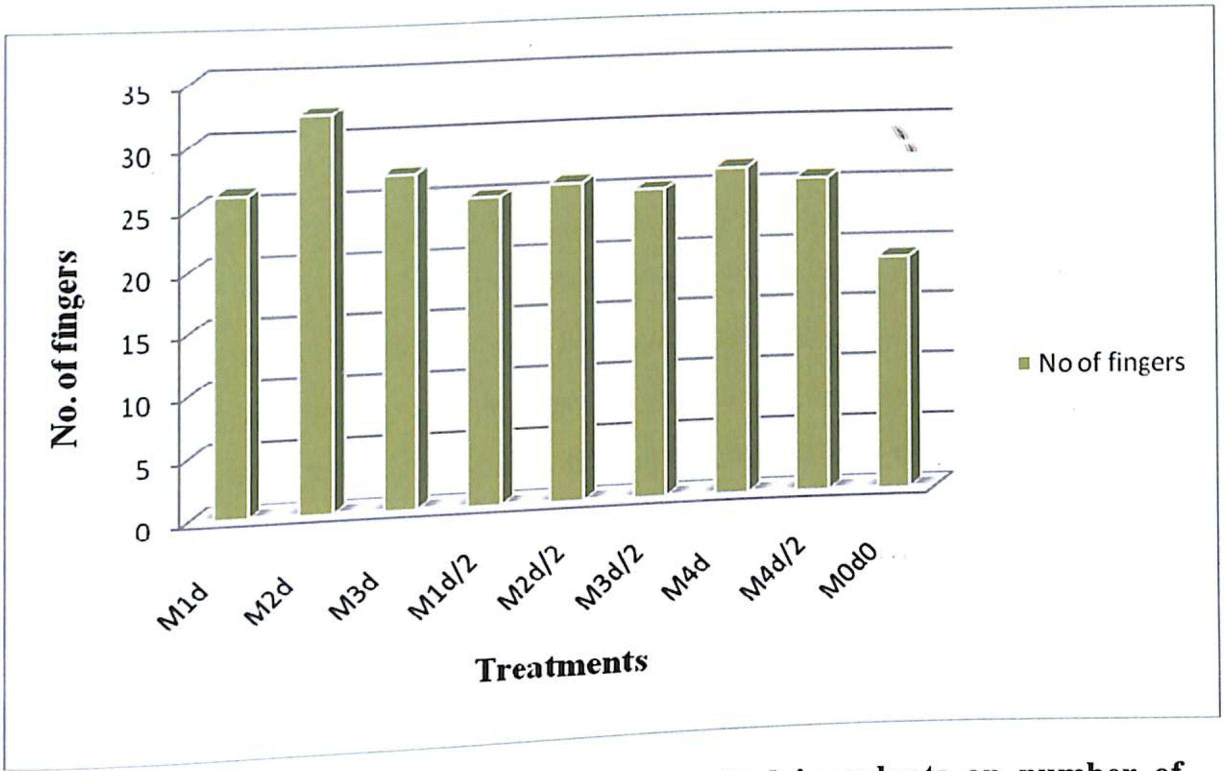


Fig. 6 Effect of organic manures and microbial inoculants on number of fingers in *Curcuma aromatica* Salisb.

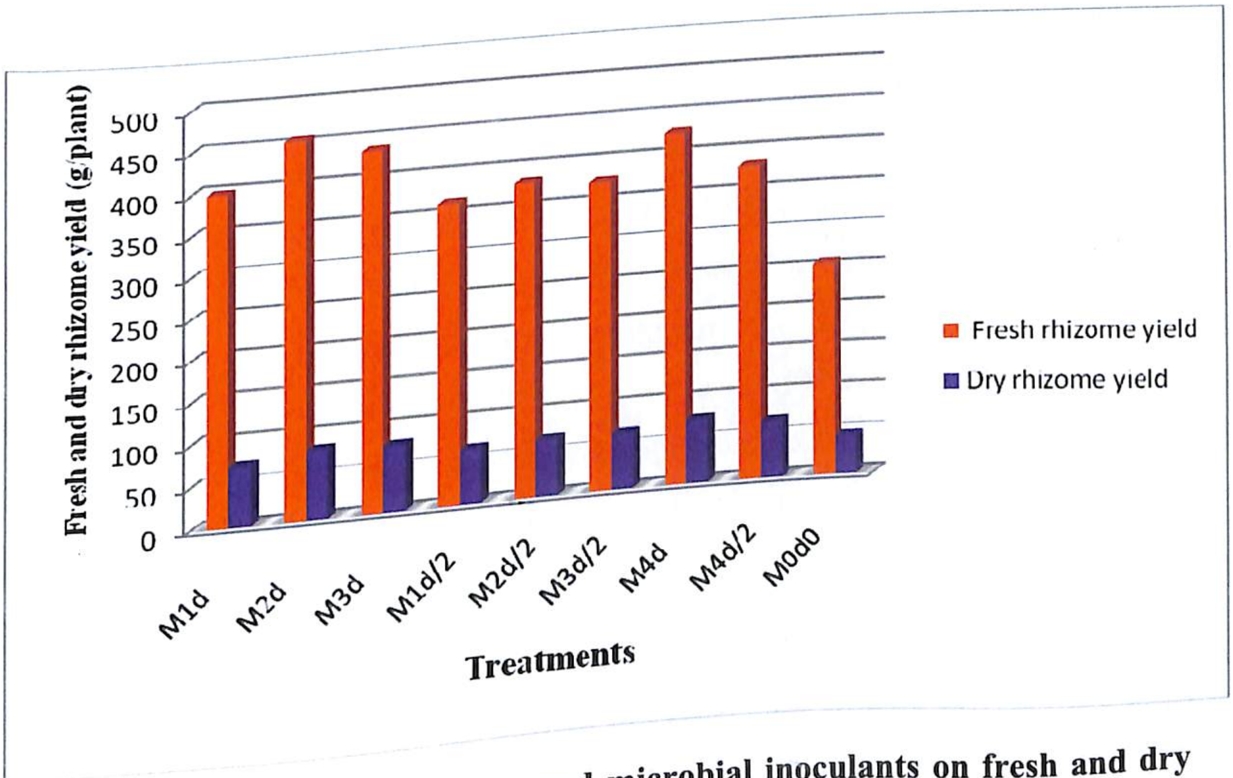


Fig. 7 Effect of organic manures and microbial inoculants on fresh and dry rhizome yield (g plant^{-1}) in *Curcuma aromatica* Salisb.

different organic manures and their combinations tried, vermicompost was found to be most effective followed by neemcake. Accordingly full dose application of vermicompost + mi (M_2 d) turned out to be the best treatment giving a fresh and dry rhizome yield of 456.99 and 82.56 g plant^{-1} respectively (Fig.7). The higher and easily available nutrient content in vermicompost and their better uptake by the plants might be the reason for the highest rhizome yield in this treatment. The reports of Nagavallemma *et al.* (2004) that vermicompost contains a higher percentage of nutrients necessary for plant growth in readily available forms and that of Atiyeh *et al.* (2000) and Zaller (2007) that vermicompost has a potential for improving plant growth and dry matter yield when added to the soil corroborates the present observation. Vermicompost is made up primarily of C, H and O and contains nutrients such as NO_3, PO_4, Ca, K, Mg, S and micronutrients which exhibit similar effects on plant growth and yield as inorganic fertilizers applied to soil (Singh *et al.*, 2008).

Full dose of neemcake application + mi (M_3 d) also produced a comparable fresh and dry rhizome yield of 437.42 and 79.09 g plant^{-1} respectively (Fig. 7). The higher nutrient content in neemcake coupled with their easy and extended availability and better uptake brought about by the microbial action might have resulted in higher yield in this treatment. The statement of Sathianathan (1982) that neemcake reduces leaching loss and extends the period of availability of N to the crop supports this observation. In turmeric, Panigrahi and Pattanayak (1988) observed an increased yield of 53 per cent by neem cake over simple fertilizer treatments. Similar finding have been reported by Sadanandan and Hamza (1998) in ginger and Rao *et al.* (2005) in turmeric. According to them, the highest yield obtained was due to higher uptake of N, P and K leading to production of good vegetative growth resulting in the accumulation of more photosynthates and their further efficient translocation to the rhizome.

An important factor noticed in the present investigation is that when the quantity of organic manures applied was reduced to half a corresponding yield reduction was observed which was most pronounced in the case of neemcake. This shows the significance of optimum quantity of organic manures, to produce maximum yield. The finding of Nirmalatha (2009) that an increased fresh and dry rhizome yield of 396.33 and 72.69 g $plant^{-1}$ in kasthuri turmeric by the application of 25 t ha^{-1} of vermicompost over 15 t ha^{-1} (227.34 and 48.66 g $plant^{-1}$ of fresh and dry rhizome yield respectively) corroborates this observation. Similar findings have been reported by Maheswarappa *et al.* (2000a) in galangal, Preetha *et al.* (2005) in amaranthus, and Singh *et al.* (2010) in strawberry. Khandkar and Nigam (1996) found that the yield of turmeric rhizome increased with an increase in FYM level. They recorded a yield of 33 q ha^{-1} with the application of 6 t ha^{-1} of FYM compared to 3 tonnes of FYM ha^{-1} (29.5 q ha^{-1}). Similar findings have been reported by Gill *et al.* (1999) in turmeric, Singh (2006) in rose, Desuki *et al.* (2010) in pea and (Kushare *et al.*, 2010) in amaranthus.

In present experiment, full dose of FYM + mi (M_1d) application though produced significant fresh and dry yield it was comparatively less than vermicompost and neemcake. This implies the suitability of using vermicompost or neemcake as an alternative to FYM, based on the cost and availability. Report by Sunilkumar (2005) that in coleus, vermicompost 6 t ha^{-1} recorded the highest yield over FYM 30 t ha^{-1} is in agreement with above statement. Mannikeri (2006) also reported similar findings in turmeric.

Combined application of vermicompost, neemcake and FYM in full and half dose + mi (M_4 d and M_4 d/2) also registered good fresh and dry rhizome yield in the present experiment. In these treatments the quantity of FYM used was half and that of vermicompost and neemcake was quarter and 1/8th compared to their sole application. Significant yield recorded in these treatment points to the possibility of using these organic manures in combination particularly when their sufficient availability is a problem.

Plate 4. Effect of organic manures and microbial inoculants on rhizome yield (g plant-[1]) in *Curcuma aromatica* Salisb.

Rhizome with highest fresh weight

Plate 4. Effect of organic manures and microbial inoculants on rhizome yield (g plant $^{-1}$) in *Curcuma aromatica* Salisb. (continued…)

The significant influence of bioinoculants on the rhizome yield of kasthuri turmeric was evident in the present study with the control recording the lowest yield. Nirmalatha (2009) also reported significantly superior fresh and dry rhizome yield by the combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma.* The positive influence of organic manure application along with bioinoculants on the crop yield has been reported by many, in turmeric by Subramanian *et al.* (2003), in ginger, by Sreekala (2004) and by Velmurugan *et al*. (2006c) in turmeric. The application of organic manures alone resulted in lower yield in *Plumbago rosea* compared to combined application of organic manure and microbial inoculants (Nihad, 2005).

5.2.2. Crop duration (days)

It was observed from the experimental data that application of organic manures and microbial inoculants significantly reduced the period of crop maturity in kasthuri turmeric and the control (M_0 d_0) plants took maximum days (235.00) to attain crop maturity (Fig. 8). Half dose of neemcake application + mi (M_3 d/2) (231.67) and control took more days to attain maturity. M_4 d/2 treatment took minimum days and all other treatments were on a par with this treatment with regard to crop maturity. Naturally a plant with good growth is indicative of its efficient photosynthesis and rapid mobilization of assimilates and simultaneous partitioning of photosynthetic towards sink. It was observed that plants with treatments M_1 d, M_1 d/2, M_2 d, M_2 d/2 and M_3 d/2 exhibited maximum vegetative vigour. The rapid mobilization of assimilates from source to sink might have helped these plants to allow crop maturity at an early date compared to control (M_0 d_0) and M_3 d/2 plants which recorded comparatively poor vegetative growth. This finding is in agreement with that of Nirmalatha (2009) who also observed a similar reduction in crop duration in kasthuri turmeric by the application of vermicompost and neemcake.

Vermicompost which is rich in plant nutrients and hormones might have helped in vigorous growth, development and early maturation. The above result is in conformity with the studies of Athani *et al*. (2006) in guava. Combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* also recorded lesser days for crop maturity in kasthuri turmeric (Nirmalatha, 2009).

5.2.3. Top yield (g plant^{-1})

There was no significant difference in dry and fresh top yield from various treatments at harvest. Full dose of vermicompost + mi (M_2 d) recorded the highest fresh and dry top yieldfollowed by full dose of neemcake + mi (M_3 d) whereas, control (M_0 d_0) recorded lowest fresh and dry top yield. Similar findings were reported by Rakhee (2002), in turmeric.

5.3. PHYSIOLOGICAL CHARACTERS

5.3.1. Dry matter production (g plant $^{-1}$)

Dry matter production is a measure of plant productivity in terms of the dry weight of material produced per unit area during a specified time period. A perusal on the data revealed that application of organic manures and microbial inoculants significantly influenced the dry matter production in kasthuri turmeric. Though all treatments, except M_3 d/2 and M_1 d/2 were equally effective in giving better dry matter production than control, full dose vermicompost + mi treatment affected the biomass accumulation most favourably, followed by full dose neem cake + mi, combined application of organic manures + mi and FYM + mi (Fig. 9). This may be due better synchrony of nutrient release and uptake as evidenced by the superior nutrient availability and uptake observed in these treatments. No significant reduction in biomass accumulation was noticed, corresponding to a

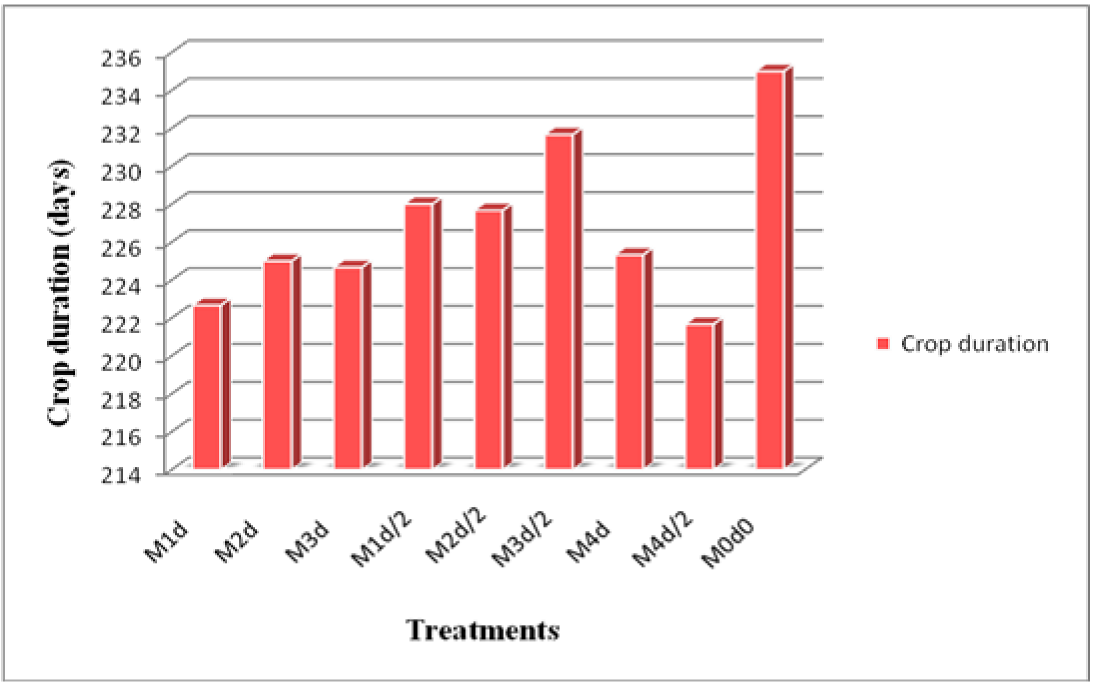


Fig. 8 Effect of organic manures and microbial inoculants on crop duration (days) in *Curcuma aromatica* Salisb.

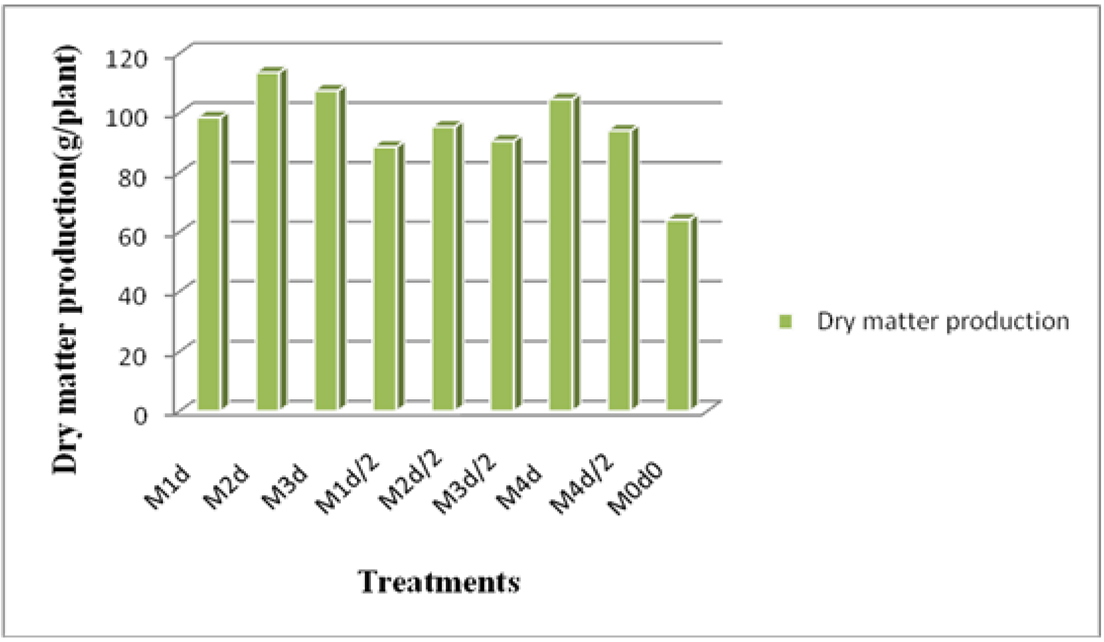


Fig. 9 Effect of organic manures and microbial inoculants on dry matter production (g plant^{-1}) in *Curcuma aromatica* Salisb.at harvest

reduction in the quantity of organic manures as in treatments M_2 d/2 and M_4 d/2. A significant reduction in dry matter production was noticed with neem cake and FYM (M_3 d/2 and M_1 d/2) compared to vermicompost, still they were significantly superior to control.

The positive influence of vermicompost on better vegetative growth and comparatively high DMP has been reported by Pushpa (1996) in tomato, Rajendran *et al*. (2005) in amaranthus, Velmurughan *et al*. (2006a) in cauliflower, Shakila and Prabu (2007) in mint. Nirmalatha (2009) also reported that with regard to dry matter production vermicompost and neemcake was found to be superior to all other treatments in kasthuri turmeric. Vadiraj *et al*. (1993) reported enhanced growth and dry matter yield of cardamom seedlings in vermicompost forest litter compared with that in other growth media tested. Higher doses of vermicompost recorded the highest dry matter production than their lower doses and with increases in doses of vermicompost (doses from 1.25 to 19 t ha^{-1}) there was increasing trend for dry weight $plant^{-1}$ of strawberry as observed by Singh *et al*. (2010), is also in conformity with the present observation.

Neemcake was found to have good influence in getting good dry matter production in the present study. Similar effect of neem cake in chilli has been reported by Sharu (2000). Improvement in the dry matter production by the application of neemcake has also been reported by Naik (2006) in chilli and Sangeetha *et al*. (2010) in rice.

Sreekala (2004) reported that in ginger dry matter production was higher in plots treated with FYM + AMF and FYM + NC + AMF + *Trichoderma* and similar findings have been noticed by Velmurugan *et al*. (2006b) in turmeric and Nihad (2005) in plumbago and these reports are in agreement with the present finding. Nirmalatha (2009) also reported the positive influence of combined application of bioinoculants like *Azospirillum*, AMF, *Pseudomonas* and *Trichoderma* in increasing the DMP in kasthuri turmeric.

5.3.2. Leaf area index

In the case of leaf area index in kasthuri turmeric, combined application of organic manures + mi (M_4 d) was found to have the most significant influence throughout the crop growth period followed by full dose of vermicompost + mi (M_2 d). In all other treatments also significant increase in the leaf area index over control plants (M_0 d_0) were noticed (Fig. 10). The synergistic action of FYM, vermicompost and neemcake in combination with microbial inoculants (M_4 d) resulted in higher uptake of nutrients which might have helped in increasing the leaf area index. Similar findings have been reported in turmeric by Rao *et al*. (2005).

However, Nirmalatha (2009) reported that in kasthuri turmeric maximum leaf area index was obtained by the application of vermicompost 25 t ha^{-1} without microbial inoculants during the two years of experimentation. Similar observation was also made by Vadiraj *et al*. (1996) in turmeric. Highest leaf area index in mint by the application of vermicompost along with humic acid 0.2 per cent and panchagavya has been reported by Shakila and Prabu (2007).

Also, it was found from the experiment that higher doses of organic manures recorded the higher LAI than their lower doses. Highest leaf area index obtained with the application of highest level of vermicompst compared to lowest its level as reported by Maheswarappa *et al*. (2000b) in galangal and Mog (2007) in chilli also supports the above statement.

In turmeric, Velmurugan *et al*.(2006b) reported that combined application of microbial inoculants like *Azospirillum* + AMF + FYM recorded highest LAI and similar findings have been reported by Sreekala (2004) in ginger and Nihad (2005) in *Plumbago rosea* and Nirmalatha (2009) reported that combined application of bioinoculants like *Azospirillum* + AMF + *Pseudomonas* + *Trichoderma* recorded the highest LAI in kasthuri turmeric.

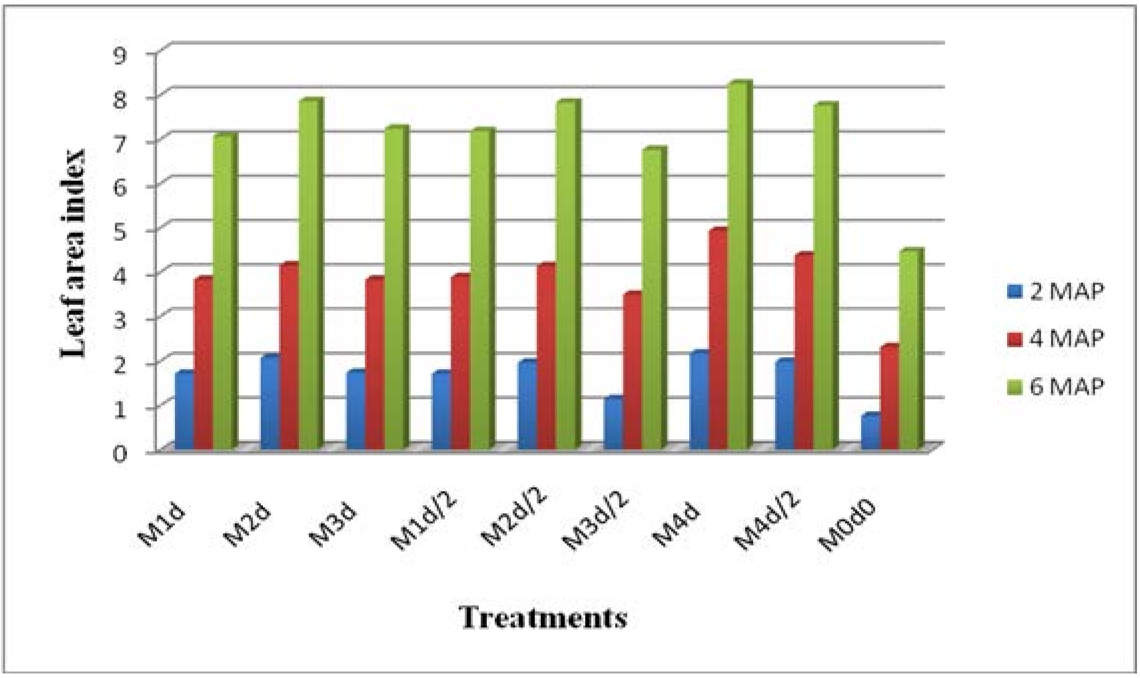


Fig. 10 Effect of organic manures and microbial inoculants on leaf area index in *Curcuma aromatica* Salisb. at different growth stages

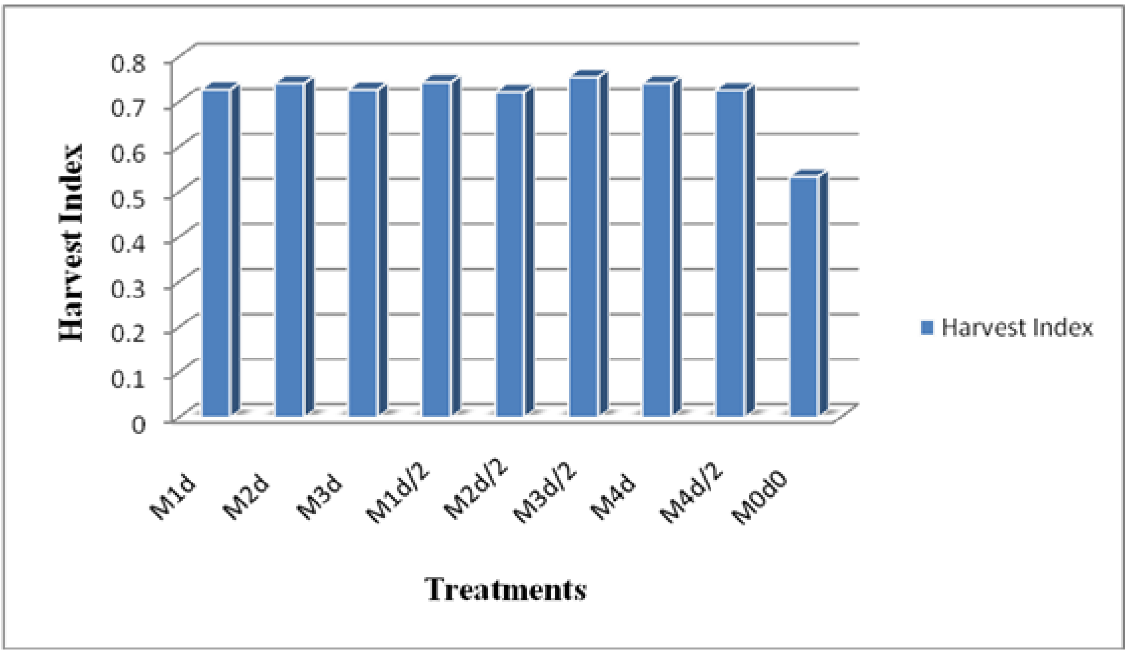


Fig. 11 Effect of organic manures and microbial inoculants on harvest index in *Curcuma aromatica* Salisb.

5.3.3. Harvest index

Harvest index is the ratio of dry rhizome weight to the dry weight of whole plant and in the present study all treatments both full and half doses of organic manures along with microbial inoculants recorded significantly superior harvest index than the control plants (M_0 d_0) (Fig. 11). Reducing the quantity of organic either in sole or combined application didn't have any negative influence on harvest index in kasthuri turmeric. In the study, it was observed that integration of organic manures and microbial inoculants exhibited an increase in yield and yield related attributes of kasthuri turmeric. This could be happened due to mineralization, availability of native and applied macro and micro-nutrients which might have accelerated the synthesis of carbohydrates and its better translocation from sink to source that might have led to an improvement in yield and yield related attributes.

Highest harvest index reported in turmeric by the application of FYM along with biofertilizers by Velmurugan *et al*. (2006b) and in arrow root by Maheswarappa *et al*. (1997) supports the present finding. Nihad (2005) also reported highest harvest index in *Plumbago rosea* in the treatment containing FYM + NC along with microbial inoculants.

5.4. BIOCHEMICAL CHARACTERS

5.4.1. Curcumin content (%)

Generally, curcumin content in kasthuri turmeric rhizomes is less compared to turmeric and the value ranges from 0.05 to 0.10 per cent. In the present study the content ranged from 0.02 to 0.08 and no significant difference among the treatments was noticed. However, full dose of vermicompost and neemcake and combined application of organic manures + mi (M_2 d, M_3 d and M_4 d) recorded highest values whereas the control (M_0d_0) recorded the lowest curcumin content. In turmeric Rakhee (2002) also recorded no significant difference in curcumin content by the application of different organic manures. However, Sadanandan and Hamza (2006) reported highest curcumin recovery in turmeric by the application of neemcake.

5.4.2. Volatile oil content (%)

Volatile oil in kasthuri turmeric was significantly increased by the application of organic manures and microbial inoculants. In this regard all treatments were found significantly superior than the control plants (M_0 d_0). Among the treatments, however full dose of vermicompost (M_2 d) and neemcake (M_3 d) were found to be superior (Fig. 12). Among the different organic manures tested, vermicompost was found to have most significant influence whereas, FYM was found to have the least influence. Similar observation in kasthuri turmeric was also reported by Nirmalatha (2009). An increase in the volatile oil content in turmeric by the application of vermicompost was reported by Rakhee (2002). Combined application of microbial inoculants also increased the volatile oil content in kasthuri turmeric as reported by Nirmalatha (2009).

However, Sadanandan and Hamza (1998) reported that in ginger, application of neem cake 2.5 t ha^{-1} enhanced volatile oil content and similar increase in volatile oil with neemcake application was reported by Sreekala (2004) in ginger.

5.4.3. Non volatile ether extract (%)

The non volatile ether extract of kasthuri turmeric was significantly influenced by the application of organic manures and microbial inoculants. Full dose of vermicompost + mi (M_2 d) was the best treatment followed by neemcake + mi (M_3 d) and combined application of organic manures + mi (M_4 d) (Fig. 12). NVEE content in kasthuri turmeric is an indicative of its quality and quality improvement in kasthuri turmeric by the application of vermicompost, neemcake and also by the combined application of microbial inoculants has been reported by Nirmalatha (2009). Increase in the oleoresin content in turmeric by the application of organic manures has been reported by Nampoothiri (2001). Application of neem cake increased oleoresin content in ginger (Sadanandan and Hamza, 1998; Sreekala 2004). Positive effect of combined application *Azospirillum* and *Azotobacter* increased oleoresin content in turmeric has been reported by Mohan *et al*. (2004).

Higher level application of organic manures recorded higher NVEE than their lower level application and similar findings were reported by, Maheswarappa *et al*. (2000a) in galangal which stated that higher level application of vermicompost (28 t ha^{-1}) and FYM (32 t ha^{-1}) gave the higher oleoresin content than their lower level. Dash *et al.* (2008) reported that application of FYM 20 t ha^{-1} recorded the highest oleoresin content than its lower level in ginger.

5.4.4. Crude fibre (%)

Crude fibre content of kasthuri turmeric rhizome was significantly reduced by the application of organic manures in combination with microbial inoculants. Full dose of vermicompost + mi (M_2 d) was found to be the best treatment followed by neemcake + mi (M_3 d) and combined application of different organic manures + mi (M_4 d) and full dose of FYM + mi (M_1 d) (Fig. 12). When the vermicompost, neemcake and FYM quantity was reduced to half the crude fibre content showed an increase. The control plants (M_0 d_0) recorded the highest crude fibre content in the rhizome. Nirmalatha (2009) also reported similar observation in kasthuri turmeric. Combined application of microbial inoculants also recorded the lowest percentage of crude fibre in kasthuri turmeric as reported by Nirmalatha (2009).

A significant negative correlation between crude fibre content and volatile oil, NVEE content was noticed in ginger by Pruthi (1989) and in present experiment similar correlation was noticed and best treatments were found to have higher volatile oil, non volatile ether extract and least crude fibre. In general, organic manures improves soil structure, physical properties and experts water holding capacity, leading to higher microbial activity which in turn result in better availability and uptake of nutrients leading to better yield and quality.

5.4.5. Starch (%)

Starch content in kasthuri turmeric was significantly increased by the application of organic manures and microbial inoculants and all treatments recorded significantly superior values than control (M_0d_0). Full dose of vermicompost + mi (M_2 d) and full dose of neemcake + mi (M_3 d) were the best treatments (Fig. 12). The property of organic manures along with microbial inoculants in increasing the yield and quality of crops might have lead to the higher starch content in these treatments. The report of Nirmalatha (2009) in kasthuri turmeric also corroborates the present finding. The positive influence of vermicompost in increasing starch content was reported by Sureshkumar (1996) in sweet potato and Sreekala (2004) in ginger.

5.4.6. Chlorophyll content (Chlorophyll a, b and total chlorophyll) (mg g^{-1})

No significant difference was noticed in the chlorophyll a, b and total chlorophyll content in the leaves of kasthuri turmeric by different treatments at 6 MAP. All treatments including control recorded higher values for this character. However, plants treated with full dose of vermicompost and microbial inoculants (M_2 d) recorded the maximum values throughout the growth stages while the control plants (M_0 d_0) recorded the minimum values. Due to the decomposition of different organic manures by the microorganisms, the availability of nutrients

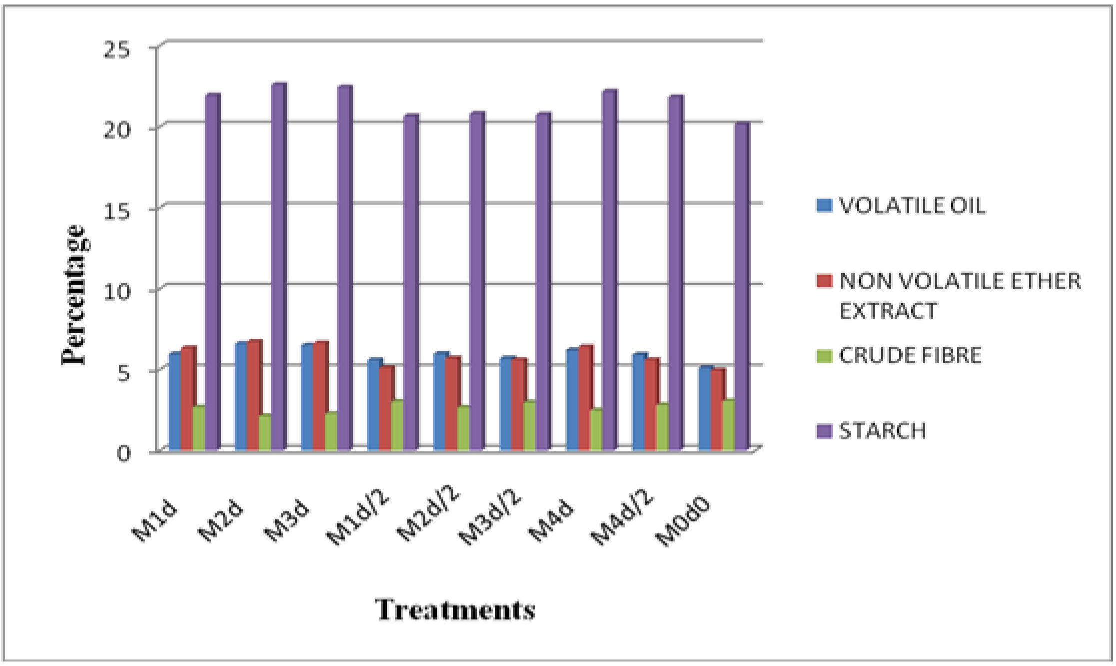


Fig. 12 Effect of organic manures and microbial inoculants on volatile oil, non volatile ether extract, crude fibre and starch content (%) in *Curcuma aromatica* Salisb.

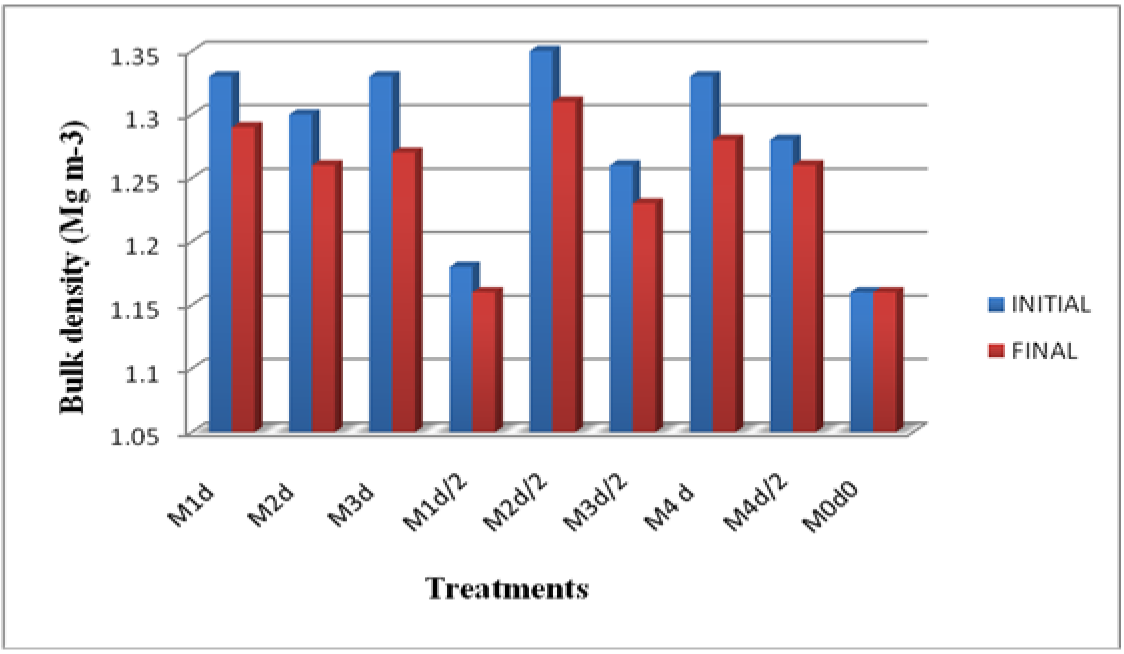


Fig. 13 Effect of organic manures and microbial inoculants on soildensity (Mg m $^{-3}$) before and after the experiment

such as N, P and K and Mg in soil increased resulting in more uptake of nutrients by the plants. The nutrients such as nitrogen and magnesium have a vital role in the formation of the structures of leaf chlorophyll (Evans and Sorger, 1966).

The decomposition of organic matter in the soil due to the microbial inoculants liberates CO_2, CH_4 etc. which were taken up by the plants very easily for their growth. Due to biological activities of the bioinoculants, the uptake of N and P increases which might have helped in building up of more chlorophyll in the organic manures and microbial inoculants applied plants. Mulching with the plant materials has got significant influence on the chlorophyll content of turmeric leaves as reported by Sanyal and Dhar (2008). In the present experiment the control plots were also provided with green mulching at 2 MAP and 4 MAP. The favorable effect of green mulching and regular after cultivation practices followed might have resulted in better chlorophyll build up and consequent yield maintains in the control plots also.

5.5. SOIL ANALYSIS

5.5.1. Soil physical properties

5.5.1.1. Bulk density (Mg m^{-3})

After the experiment, a reduction in the soil bulk density was recorded in all plots except control (M_0d_0) where the bulk density remained the same (Fig. 13). However, no significant difference in soil bulk density was noticed among the treatments before and after the experiment. Application of organic manures and microbial inoculants generally contributes to improvement in the physico-chemical and biological characteristics of the field soils that favour better plant growth.

Positive influence of organic manures on soil bulk density has been reported by many researchers. Havangi and Mann (1970) reported that a continuous application of FYM decreased the bulk density of soil. Maheswarappa *et al*., (1999) reported that in East Indian galangal cultivation the bulk density of soil decreased by the application FYM 32 t ha^{-1} from the initial value. According to Singh *et al*. (2000) in rice application of FYM significantly brought down the bulk density of both surface and subsurface soils in comparison with the control. However, Nirmalatha (2009) reported that vermicompost was most effective compared to neem cake and FYM, for improving the soil physical characters like bulk density in kasthuri turmeric.

As explained by Brady (1996), organic matter stimulates the formation and stabilization of granular and crumb type aggregates, facilitates greater pore space and lowers the specific gravity of soils. It is important to note that the extent of physical improvements in the soil brought about by the various organic manures and microbial inoculants evaluated in this experiment was not significant though there was a change in final values from the initial soil values. Sreekala (2004) reported that microbial inoculants either singly or in combination with organic manures did not influence the bulk density either after first year or even after two years of experimentation in ginger.

5.5.1.2. Water holding capacity (%)

In general, there was an increase in the water holding capacity of the soil after the experiment, though a significant difference was not noticed among the treatments. Higher doses of organic manure application along with microbial inoculants had a corresponding increase in the water holding capacity and vice versa (Fig. 14). These observations are in conformity with the reports of Whalen *et al*. (2000, 2003) and Seobi *et al*. (2005) which revealed that organic manures increases pH and water holding capacity and decreases the bulk density in soil. In the present study a slight increase in the water holding capacity in the control (M_0 d_0) was noticed. This may be due to the effect of mulching, timely and regular cultivation practices followed in the control which improved the general soil condition. Similar findings were obtained by Rakhee (2002) in nutrient management of turmeric through organic manures. Sreekala (2004) also reported that use of different microbial inoculants as well as their combination with organic manures could not influence the WHC after second year of experimentation in ginger.

5.5.2. Soil chemical properties

5.5.2.1. pH

The soils of the experimental plot were slightly acidic with pH ranging from 6.39 to 6.59. After the experiment also pH range remained somewhat unchanged (6.38-6.59) (Fig. 15). However, the effect of different treatments on soil pH after the experiment was found to be quite different. Full dose of application of FYM increased the soil pH (M_1d) while the half dose application (M_1 d/2) showed reduction. In the case of vermicompost no change in the pH was noticed in full dose application (M_2 d) while an increase in pH was noticed when the quantity was reduced to half (M_2 d/2). In the case of neemcake, a reduction was noticed in both cases (M_3 d and M_3 d/2). Combined application of organic manures in lower dose (M_4 d/2) leads to an increase in the soil pH (Fig. 15). A reduction in soil pH indicates enhanced microbial activity leading to the production of organic acids (Rengel and Marschner, 2005). According to Luizao *et al.* (2007) the increase in the soil pH is related to the availability of soil nutrients. An increase in the available organic carbon, nitrogen and phosphorus content in the FYM applied treatments, substantiates the above statement.

Hedge *et al.* (1998) reported that when FYM or vermicompost was applied soil pH changed to neutrality. Srikanth *et al.* (1999) reported that application of vermicompost alone maintained the pH of soil at neutral

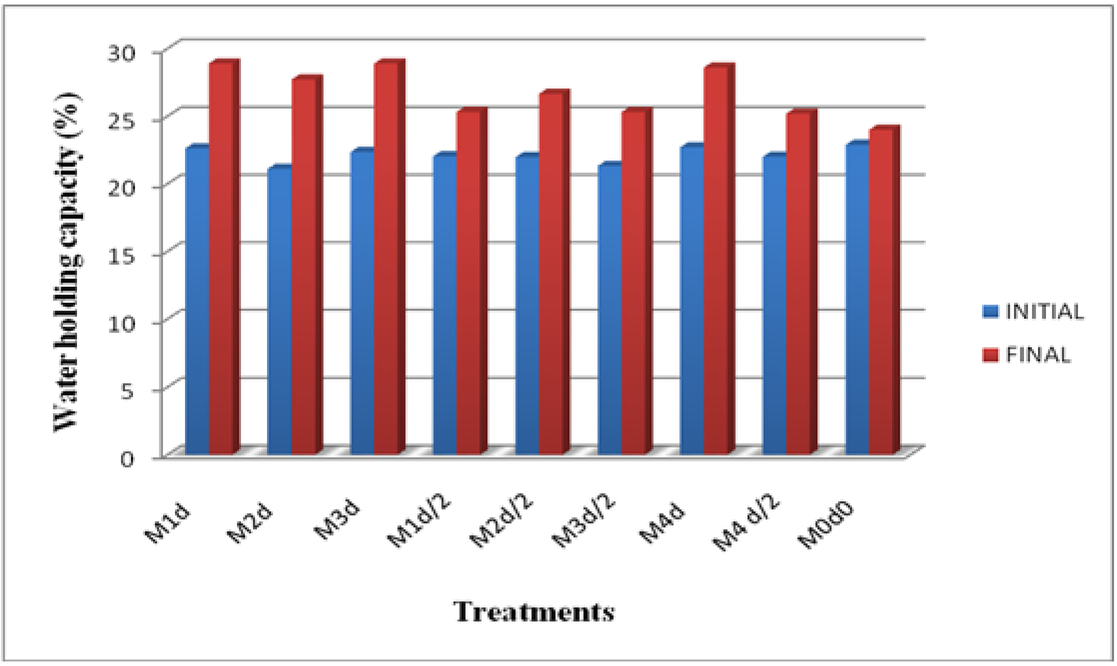


Fig. 14 Effect of organic manures and microbial inoculants on water holding capacity (%) before and after the experiment

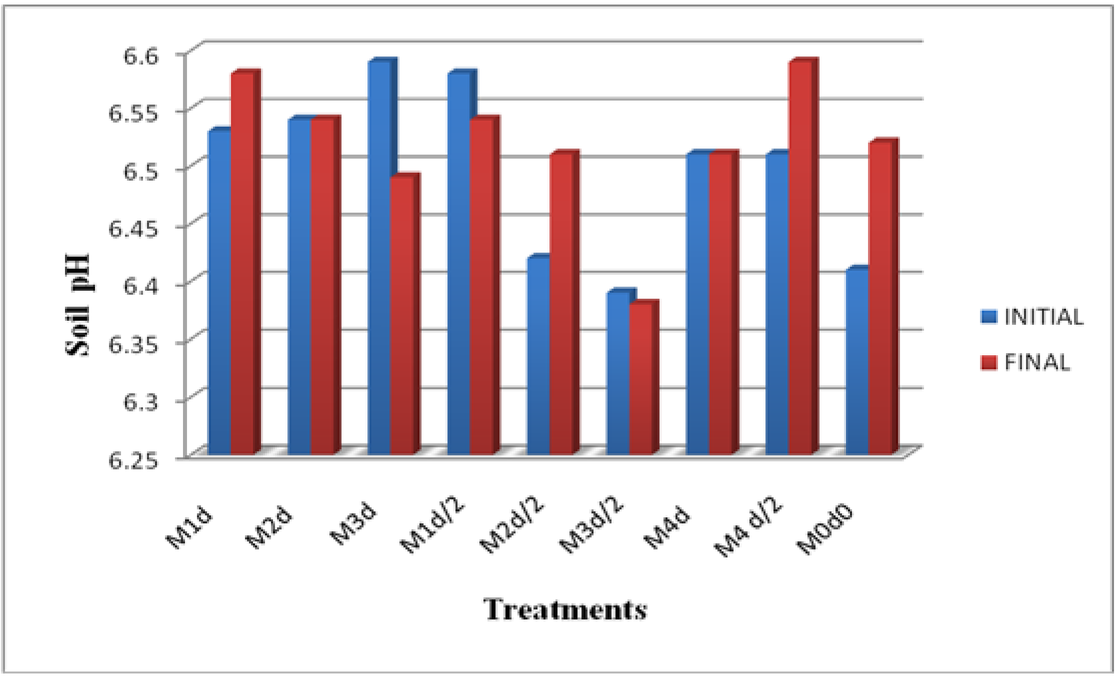


Fig. 15 Effect of organic manures and microbial inoculants on soil pH before and after the experiment

condition as compared to inorganic fertilizers. Nirmalatha (2009) found that application of vermicompost 25.0 t ha^{-1} recorded the maximum reduction in soil pH in kasthuri turmeric.

However, Rakhee (2002) reported no significant change in soil pH by the application organic manures in turmeric. Similarly, Sreekala (2004) also found no significant influence on the soil pH in ginger by organic manures, microbial inoculants and their interactions.

5.5.2.2. EC (d S m^{-1})

An increase in the electrical conductivity was noticed in all the treatments. The electrical conductivity representing salt content increased in all the treatments after the experiment. Substantial increase in EC was noticed in vermicompost applied treatments (M_2 d and M_2 d/2) followed by combined application of organic manures in higher and lower dose (M_4 d and M_4 d/2) (Fig. 16). This may be due to the fact that most of the mineral nitrogen in vermicompost is usually in the nitrate form (Atiyesh *et al*., 2001; Orozco *et al*., 1996). Similar increase in EC by the application of vermicompost 25 t ha^{-1} has been reported by Nirmalatha (2009) also in kasthuri turmeric.

Bioinoculants also found influence in increasing the electrical conductivity of soil. Sumathi *et al*. (2011) reported that combined application of *A.lipoferum* + *B. megaterium* recorded the highestelectrical conductivity in turmeric.

5.5.2.3. Organic carbon (%)

An increase in organic carbon was noticed in all treatments including control (M_0 d_0) after the experiment. Substantial increase in organic carbon was noticed when full dose of FYM along with microbial inoculants was applied (M_1 d) followed by vermicompost full dose application (M_2 d) and least increase

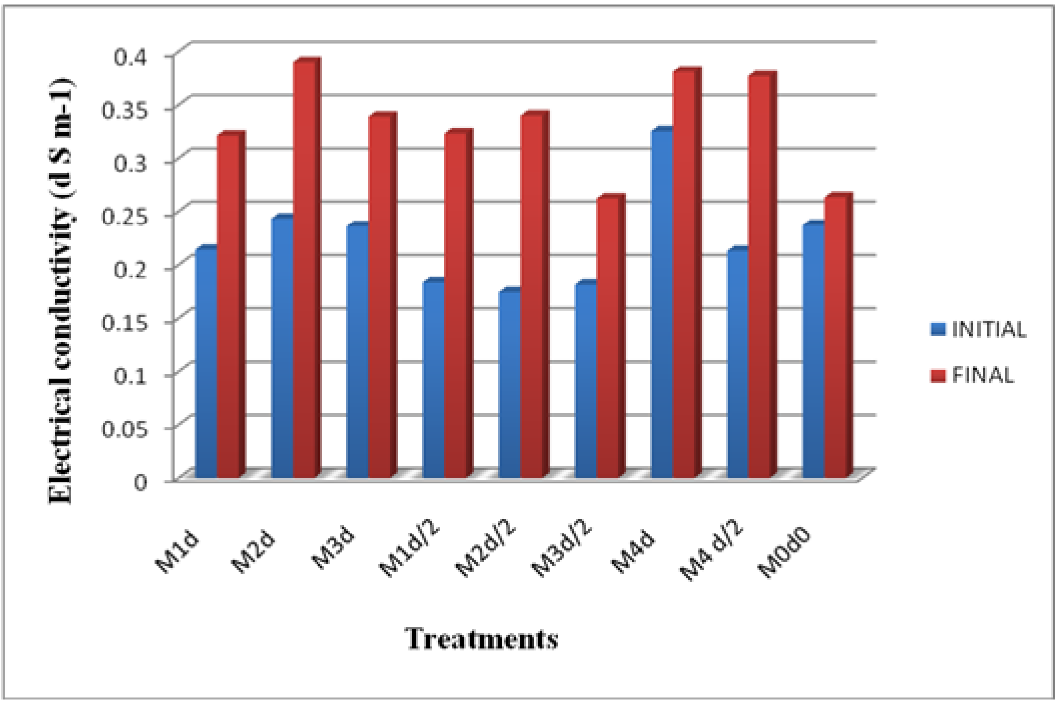


Fig. 16 Effect of organic manures and microbial inoculants on electrical conductivity (d S m^{-1}) before and after the experiment

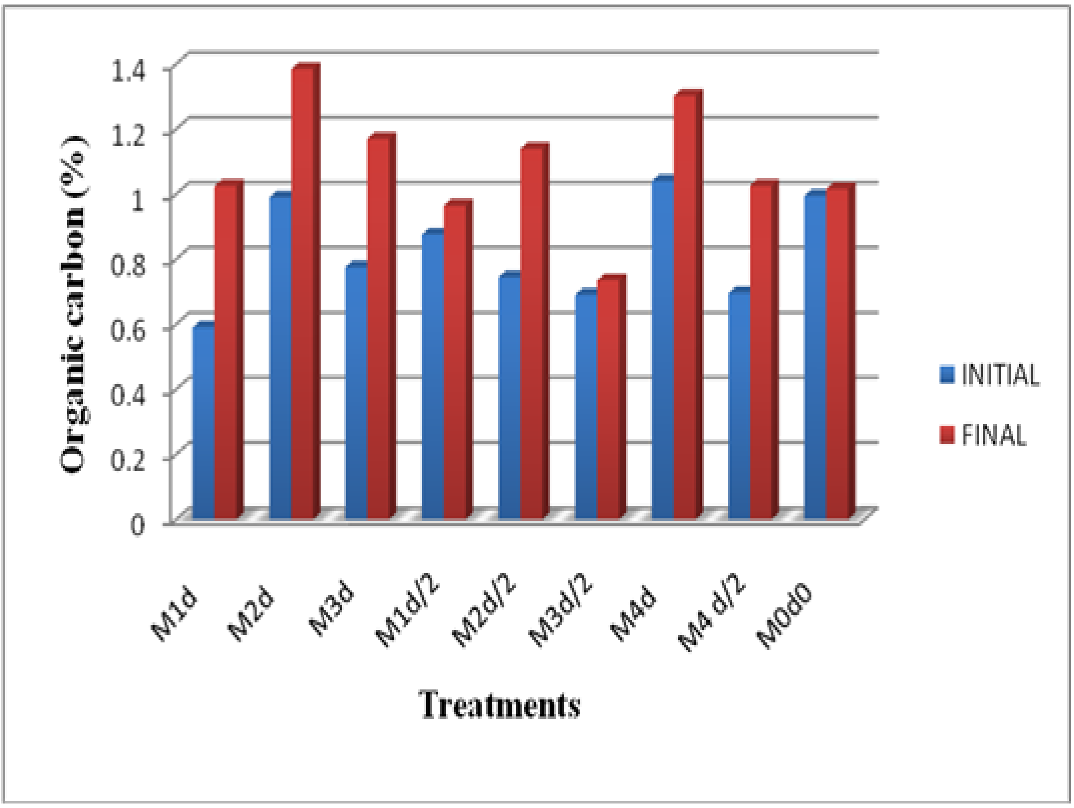


Fig. 17 Effect of organic manures and microbial inoculants on organic carbon (%) before and after the experiment

was noticed in the control (M_0 d_0) (Fig. 17). Improvement in organic carbon content of soil, availability in soil nitrogen, phosphate and potash, release of nutrients like B, Cu, Fe, Mn, Mo, Zn and Co due to application of organic manures has been reported by many scientists (Johnkutty and Menon, 1981; Jenkinson *et al*., 1985).

Kabeerathumma *et al*. (1990) in a long term manurial experiment in cassava, after thirteen years of continuous cropping observed an increase in organic carbon with the inclusion of FYM and application of respective nutrients to the soil. Hedge *et al*. (1998) reported that organic carbon doubled when FYM or vermicompost was applied in soil. According to Maheswarappa *et al*. (1998) organic carbon content was the highest in vermicompost treated plot compared to other treatments.

Bioinoculants were also found to have influence in increasing the organic carbon of soil in present study which is in corroboration with the findings of Sumathi *et al*. (2011) in turmeric.

5.5.2.4.1. Available N (kg ha^{-1})

Initially no significance difference in the available N content was noticed in the experimental plots. However, after the experiment a significant increase in soil N has been recorded by different treatments over control (M_0 d_0). Highly significant effect was brought about by full dose application of neemcake + mi (M_3 d) and full dose of FYM + mi (M_1 d) (Fig. 18). Lower dose of organic manures led to a lesser increment in available soil N. Increase in N availability in neemcake treated plots may be due to higher N content and its gradual mineralization process. Improvement in the bioavailability of N, P and K in soil by the combined application of neemcake along with microbial inoculants has been reported by Murugan *et al*. (2011) in black gram. FYM along with microbial inoculants (M_1 d) also play a vital role in increasing the N, P and K availability in the soil by direct contribution as well as indirectly by influencing chemical transformation reaction and microbial activity as reported by Senthil Kumar *et al*. (2004).

Improvement in the soil available N by the application of neemcake and FYM has been reported by many scientists. Sathianathan (1982) found that neem cake reduced leaching loss and extended the period of availability of N to the crop. Neem cake has the capacity of releasing nitrogen over a stipulated period of crop growth (Hulagur, 1996). Neem cake application @ 6.0 t ha^{-1} recorded the maximum available N content in soil (Nirmalatha, 2009). Similarly importance of higher level application of FYM in turmeric in improving soil N has been previously reported by Venkatesh *et al*. (2003) in ginger. Combined application of microbial inoculants like *A. lipoferum* + *T. viridae* + *B. megaterium* + *A. fluorescens* + AM fungi recorded the highest available nitrogen content in soil as reported by Sumathi *et al*. (2011).

5.5.2.4.2. Available P and K (Kg ha^{-1})

No significant difference in the available P and K content was noticed among the treatments before and after the experiment. However, after the experiment an increase in P and K content was there in all treatments including control (M_0d_0) after the experiment. Substantial increase in soil P and K content was made by vermicompost and neemcake + mi (M_2 d and M_3 d). Combined application of organic manures + mi (M_4 d) also increased the P and K availability in the soil (Fig. 19 and 20 respectively). Higher P content in vermicompost due to increased phosphatase activity from the direct action of gut enzymes and indirectly by the stimulation of microorganisms has been reported by Edward and Burrows (1988). They also reported that in vermicompost P usually occurs in the form of exchangeable phosphorus. Neemcake along with phosphorus

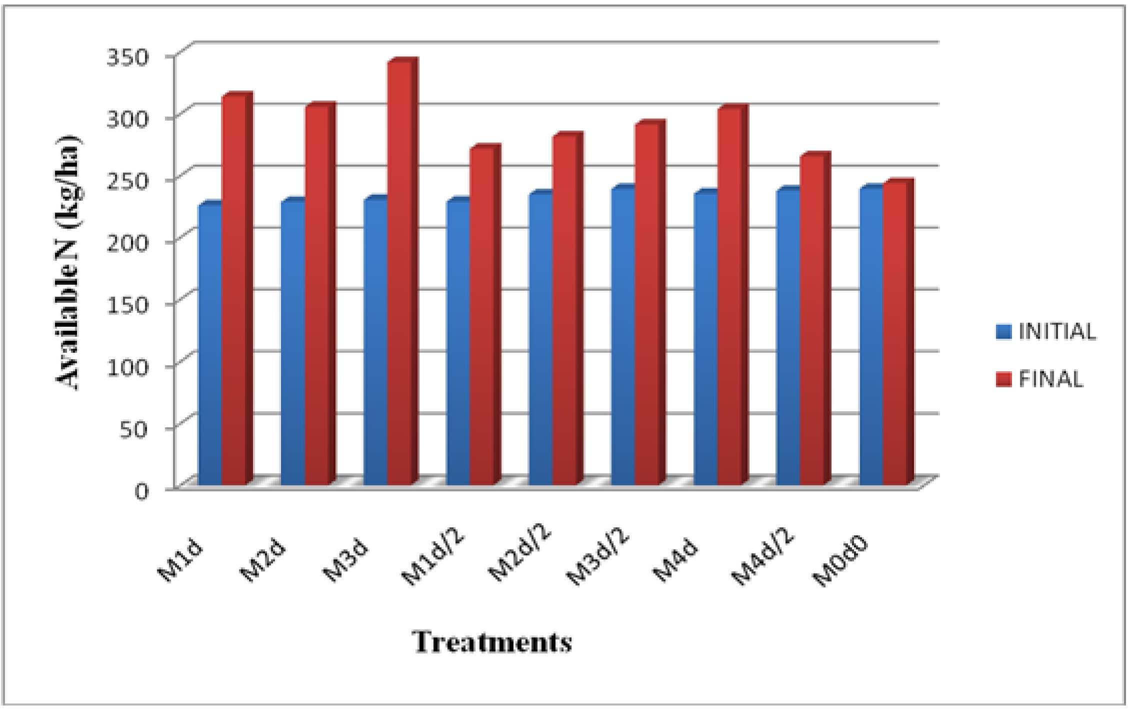


Fig. 18 Effect of organic manures and microbial inoculants on available nitrogen content (kg ha^{-1}) before and after the experiment

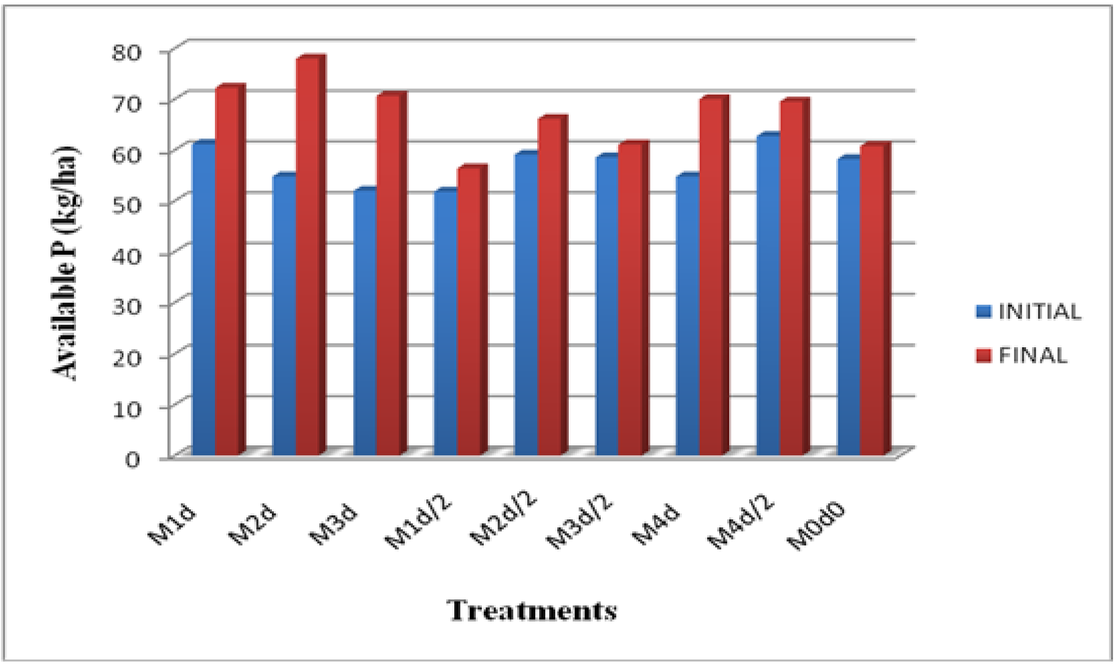


Fig. 19 Effect of organic manures and microbial inoculants on available phosphorus content (kg ha^{-1}) before and after the experiment

solubilising bacteria is very effective in improving the bioavailability of N, P and K in soil as reported by Murugan *et al.* (2011). Available P, K, Ca, Mg of the rhizosphere soil almost doubled in cardamom when vermicompost was applied for over two years (Hegde *et al.*, 1998). Increase in available P content of the soil is attributed to the decomposition of organic manures which could have enhanced the labile P in the soil by complexing calcium, magnesium and aluminium (Subramanium and Kumarswamy, 1989) and solubilization of phosphate rich organic compounds through release of organic acids upon decomposition of organic matter and chelation of organic anions with iron and aluminium resulting into effective solubilization of inorganic phosphates into soil (Subba Rao, 1999). The increased availability of nitrogen and phosphorus has synergistic effect on potassium uptake as reported by Tandon (1933). Nirmalatha (2009) reported that in kasthuri turmeric available soil P and K content was significantly superior when vermicompost 25.0 t ha^{-1} was applied. Also importance of combined application of microbial inoculants like *T. viridae* + *A. fluorescens* + AM fungi for improving the available P in turmeric has been reported by Sumathi *et al*. (2011).

The timely and regular cultural practices including mulching might have contributed to an increased N, P and K content in the control plots also, though the increase is not substantial.

5.5.3. Soil biological properties

5.5.3.1. Microbial load

5.5.3.1.1. Bacterial count

Maximum reduction of phytopathogenic bacterial population was recorded in M_3 d where neemcake @ 6 t ha^{-1} along with microbial inoculants were applied (Fig. 21). The same trend was observed in M_2 d/2 where vermicompost was applied @ 12.5 t ha^{-1} with microbial inoculants. This clearly indicates the

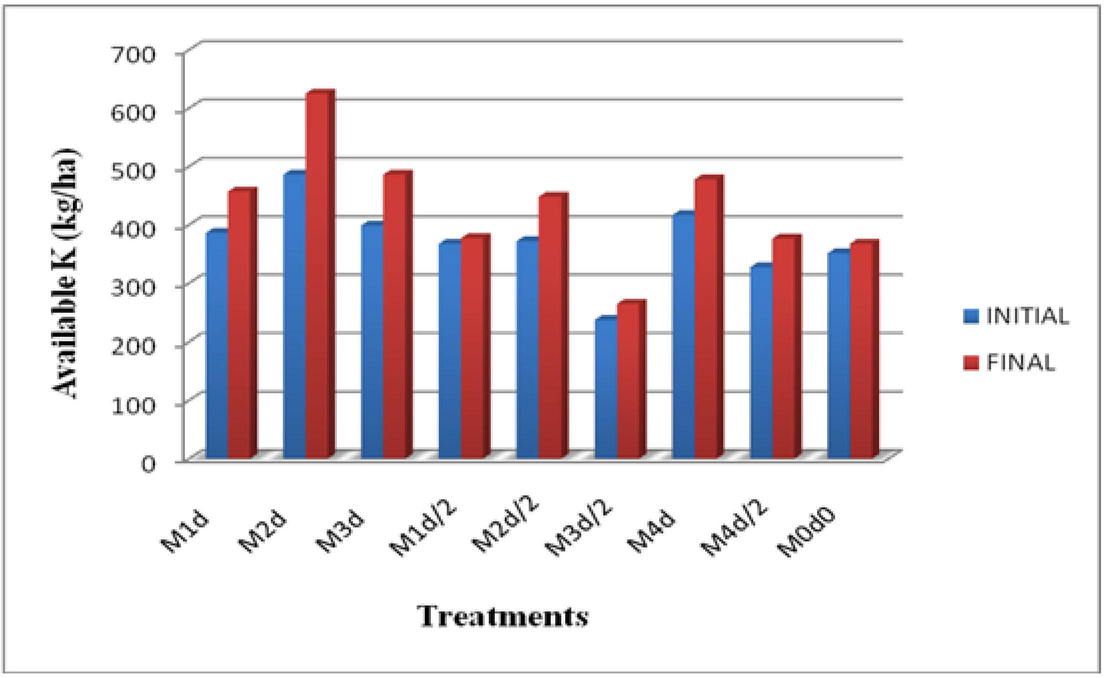


Fig. 20 Effect of organic manures and microbial inoculants on available potassium content (kg ha^{-1}) before and after the experiment

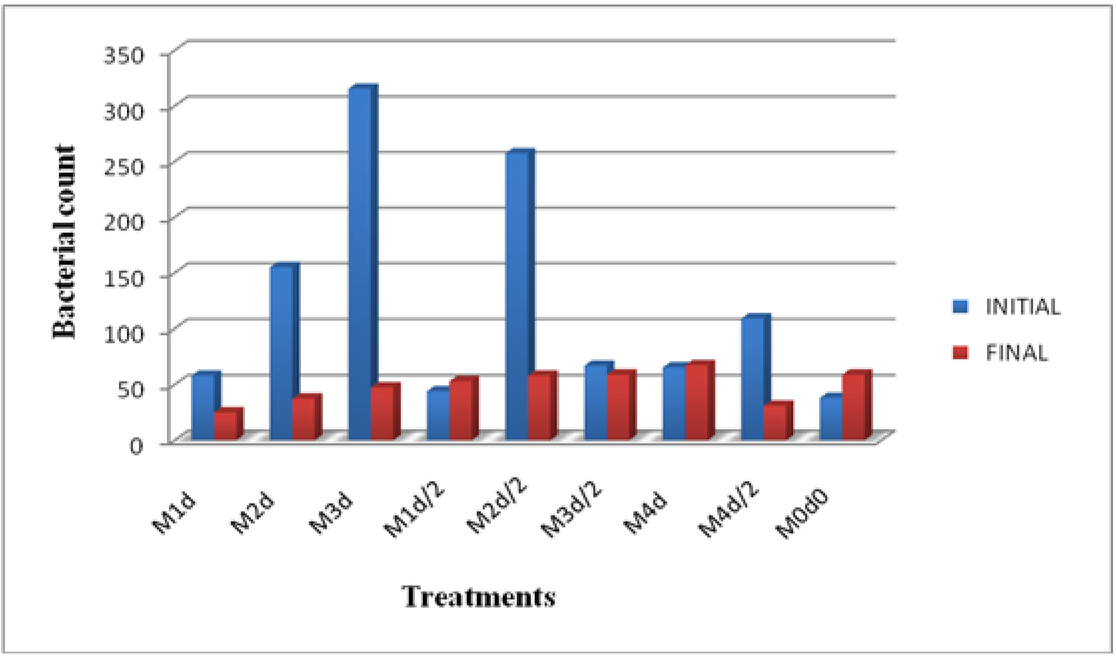


Fig. 21 Effect of organic manures and microbial inoculants on bacterial count before and after the experiment

importance of the application of organic manures like neemcake and vermicompost. At higher dose of FYM (40 t ha^{-1}) the bacterial population was found decreasing, but when the quantity was reduced to half, there was an increase in number of bacterial population in M_1 d/2 and M_4 d. The similar trend was recorded by Rajasree (1999) and she found that in bitter gourd application of fertilizers sources along with FYM as organic source (1:2 N substitution ratio) resulted in lower bacterial population of 14.13 ($1x10^8$) compared to other treatments and bacterial population was affected by ratios of N substitutions and general reduction in the count was noticed as compare to the initial population of 13.1 ($1x\ 10^8$).

5.5.3.1.2. Fungal count

In the case of fungal propagules, the full dose of organic manures showed an increase in the count (M_1 d, M_2 d and M_3 d), but as the dose was reduced to half a reverse trend was noticed. The fungal propagules were found decreasing (Fig. 22). This indicates the importance of reducing the quantity of FYM, vermicompost and neemcake. In control (M_0 d_0) also the population was increased to 42.5×10^4 from 10×10^4. The increasing trend was noticed in the group analysis study (M_1 and M_2).

Similar findings were reported by Rajasree (1999). She reported that in standardization of organic manuring in bittergourd, levels of N from 200 to 250 and 300 kg ha^{-1} increased the fungal population from 76.96 (1×10^4) to 78.21 (1×10^4) and then to 83.45 (1×10^4) respectively and nitrogen nutrition was found to promote the soil fungal population which was maximum with the application of full dose of N. Biedenbek *et al*. (1996) observed that the soil fungal population increased with increase in the nitrogen level. Also, Brady (1996) suggested the possibilities of an intense inter microbial rivalry for food in soil which may dominate or suppress certain microorganisms.

Sheraz *et al*. (2010) reported that antagonistic microorganism already present in soil competes with microbial inoculants and many times do not allow their effective establishment by outcompeting the inoculated population, this could also be a reason to obtain an increase in the phytopathogenic fungal population in M_1 d, M_2 d and M_3 d treatments. Leka (2011) recorded that when Enteroplantin-K-Planticola SL 09- based biofertilizer was applied along with five other treatments including solid well rotten FYM @ 30 t ha^{-1} in potato, the fungal count was found decreasing. All these reports are in agreement with present finding.

5.5.3.1.3. Actinomycetes count

Changing results were obtained in the case of actinomycetes with varying organic manures at different doses. The actinomycetes count in the soil was found increasing when full dose and half dose of FYM were applied (M_1 d and M_1d/2) (Fig. 23). The excess dose might have influenced the actinomycetes population in a negative manner, thereby increasing the population. Similar finding was recorded by Rajasree (1999), that actinomycetes population was higher with 2:1 ratio of N substitution using FYM as an organic source. Nambiar (1994) reported that when nitrogen was applied through organic sources of FYM in higher doses, hike in the actinomycetes population was noticed.

Neemcake and the vermicompost application positively influenced the actinomycetes population thereby the propagules were reduced (M_2 d and M_3 d) (Fig. 23). But as the doses are reduced to half and 1/4th, again a positive trend could be observed indicating that the quantity of organic manure can be reduced, so that with minimum economics the cultivation of kasthuri turmeric can be carried out. Several animals and plant pathogenic fungi, bacteria, actinomycetes, viral, protozoan and helminthes are sensitive to neem preparations, with antiseptic properties (Kabeh and Jalingo, 2007).

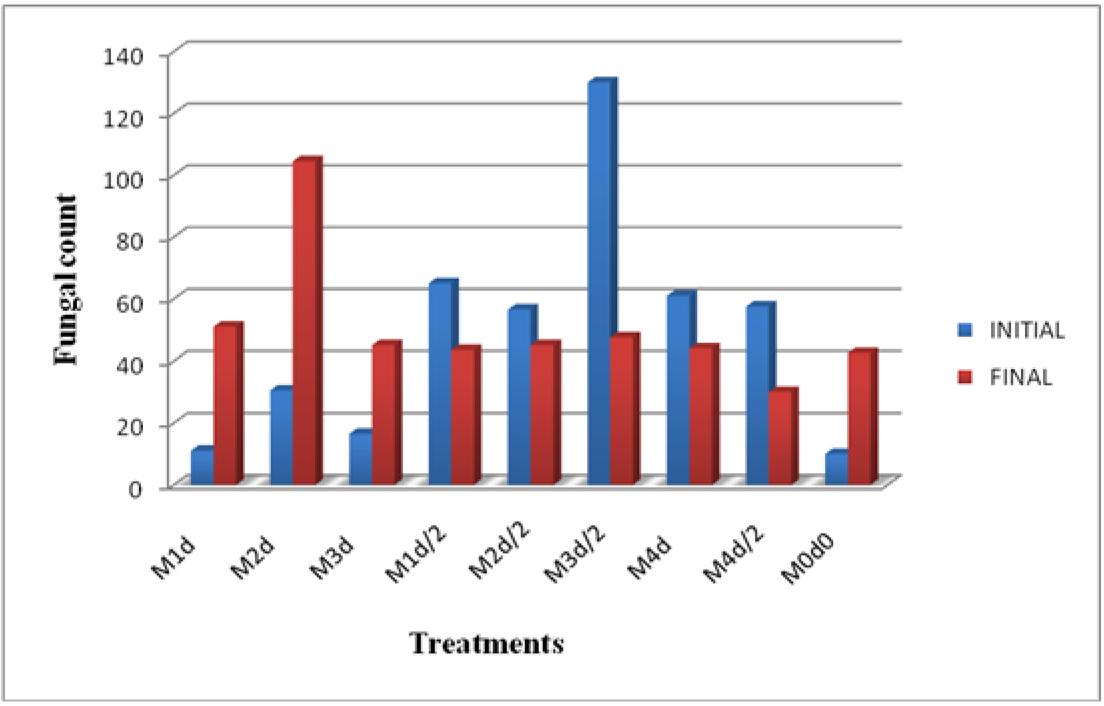


Fig. 22 Effect of organic manures and microbial inoculants on fungal count before and after the experiment

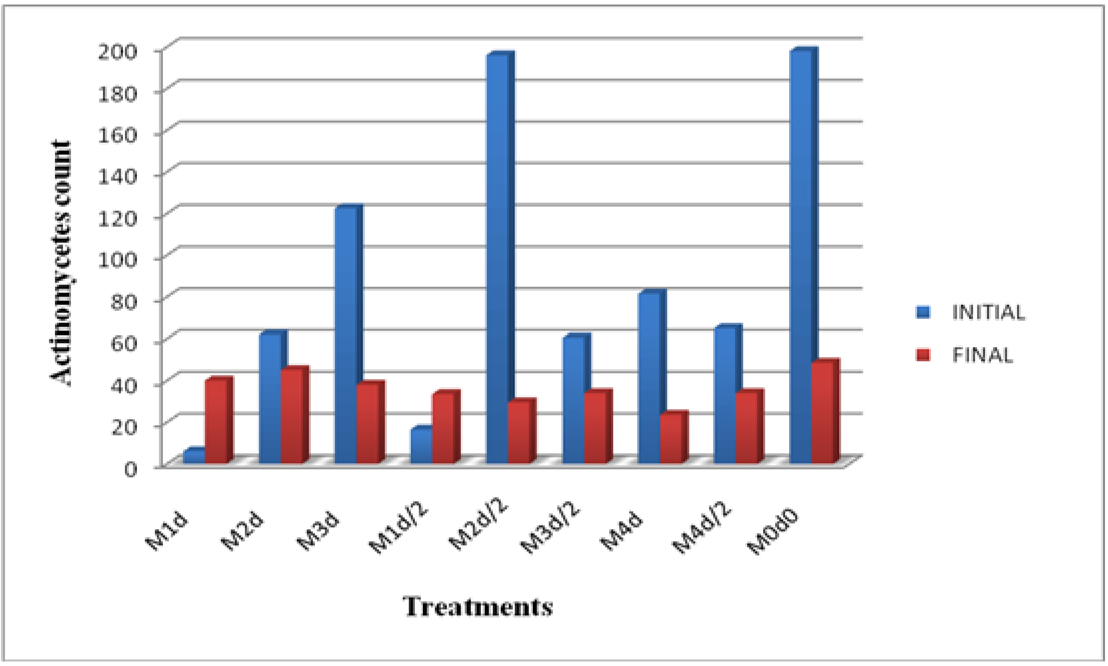


Fig. 23 Effect of organic manures and microbial inoculants on actinomycetes count before and after the experiment

In group analysis, vermicompost application (M_2) was found to reduce the actinomycetes count from an initial population of 129.00 x 10^6 to 37.25 x 10^6. Higher doses of farm yard manure (M_1) increased the actinomycetes count in the soil from 11.25 x 10^6 to 36.75 x 10^6. Singh *et al*. (1998) reported that N application at moderate levels improved the bacterial and fungal population in the soil while higher levels of N application reduced the actinomycetes population in the soil.

The study shows the importance of the use of organic manures in crop plants and reducing the quantity of those manures which adversely affect the microbial population in the soil, which in turn will help to build up the beneficial flora present in the soil. The fact is that the correct dose of the various manures to be applied have to be standardized and appropriate dosage should be given at proper time.

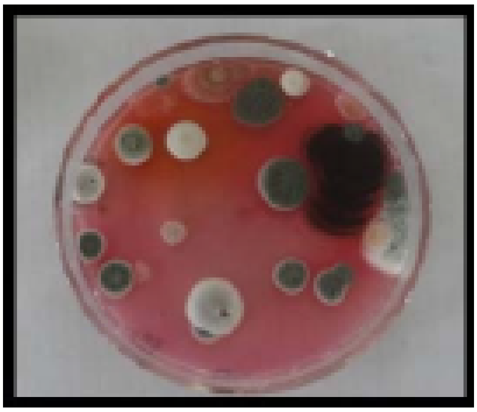
5.5.3.2. Mycorrhizal colonization (%)

Application of organic manures and microbial inoculants had a positive trend towards the colonization percentage in kasthuri turmeric (Fig. 24). The maximum colonization percentage was recorded at 4 MAP with 40 t ha^{-1} FYM + mi (M_1 d), But as the dose reduced to half (M_1 d/2) it was 9.67 per cent at 4 MAP.

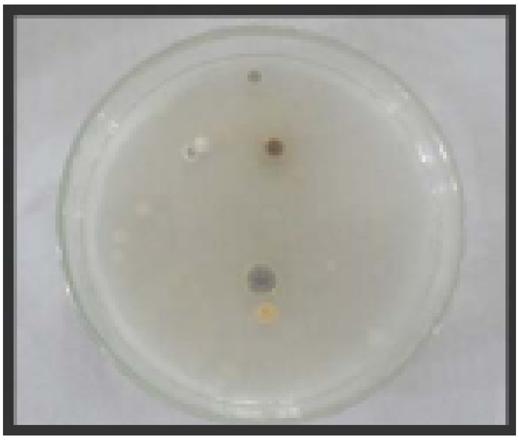
With vermicompost maximum colonization percentage was at 4 MAP (36 per cent) and with neemcake maximum colonization was at 4 MAP (28 per cent). As the dose decreased the colonization percentage also was found decreasing at 4 MAP, but at 6 MAP it slightly increased. The mycorrhizal inoculation is advantageous in improving plant growth and plants inoculated with different species of VAM fungi recorded a significant increase in growth compared to uninoculated plants (Kumar, 2004).

In cowpea dual inoculation of AMF + PSB with 15 kg P_2O_5 ha^{-1} along with 25 t ha^{-1} of FYM is ideal for getting maximum AMF root colonization per

bacterial population in M_3 d



Pathogenic fungal propagules in M_3 d /2



Actinomycetes count in M_2 d/2

Plate 5. Effect of organic manures and microbial inoculants on microbial load

cent with maximum pod and haulm yield and higher doses of manures recorded the higher mycorrhizal colonization (Meena and Shahul, 2002). AMF application recorded the maximum AMF colonization percentage in rice and recorded the higher yield (Jayakiran, 2004). AMF colonization was found to be higher when applied with phosphate solubilising bacteria compare to control, or when it applied singly it increases the nutrient content of pod in vegetable cowpea (Meena, 1999). Kavitha (1996) repored that, in maize highest value of mycorrhizal colonization in VAM applied plots. VAM gives good results with Rhizobium + 50% recommended dose of N in *Stylosanthes guianensis* cv. Schofield for herbage production (Sreedurga, 1993). Rice straw vermicompost 5 t ha^{-1} along with AMF recorded the maximum root volume and root colonization in sorghum (Hameeda *et al*., 2007). Microbial inoculations significantly improved the root colonization over control in chrysanthemum and mixed AMF strain gave the maximum root colonization at 90 DAP in chrysanthemum (Kanwar *et al*., 2008).

5.6. PLANT UPTAKE

The uptake of nutrients is primarily a function of total biomass production and nutrient content at cellular level. In the present experiment, the positive influence of organic manures and microbial inoculants was quite visible in the uptake of nutrients in kasthuri turmeric.

5.6.1. Uptake of N (kg ha^{-1})

Highest N uptake was observed with full dose application of vermicompost, neem cake and combination application (M_2 d, M_3 d and M_4 d) (Fig. 25). Increase in the soil N availability due to the application of organic manures and microbial inoculants might have led to higher N uptake. The improvement in soil environment with organic manures addition probably encouraged root proliferation to draw more nitrogen. The higher root length and root spread recorded in the above treatments (Table 8 and 9) corroborates this fact. Improvement in major and minor nutrient content in the soil by the use of organic manures has been reported by many scientists (Johnkutty and Menon, 1981; Jenkinson *et al*., 1985). Significant increase in soil N by the incorporation of vermicompost into soils has been reported by Sreenivas *et al*. (2000). The ability of microbial inoculants to mobilize soil nutrient is well documented. In the present study combined application of *Pseudomonas*, *Azospirillum*, *Trichoderma* and AMF was adopted in all treatments. Increase in total N in soil by the combined application of *Azospirillum, Trichoderma* and *Pseudomonas* has been reported by Parmar and Dadarwal (1999). According to them the biological N-fixation carried out by *Azospirillum* was responsible for increase in total N content. They also reported the possibility of increased N-fixation by *Azospirillum* sp. with the aid of other agriculturally important microorganisms when inoculated combined. According to them some PGPB secrete some molecules acting as inducers/signals to help the process of N- fixation. Full dose FYM was not as effective as neem cake and vermicompost probably due to comparatively lesser nutrient content and difference in the nutrient release pattern.

When the organic manure quantity was reduced to half a reduction in N uptake was noticed probably due to lesser availability of nitrogen compared to higher dose. Increased uptake of N with higher dose of organic manure has been reported by several workers, Mishra and Sharma (1997), Sudha and Chandani (2002), Preetha *et al*. (2005) and Hulagar (1996).

5.6.2. Uptake of P (kg ha^{-1})

Significantly superior P uptake was noticed with full dose application of organic manures (M_1d, M_2 d, M_3 d and M_4 d) with the combined application recording the highest value (M_4 d). Lower dose of organic manures though with microbial inoculants, recorded lower uptake of P (Fig. 25). The organic acids produced from the degradation of organic materials might have resulted in the solubility and release of native P to result in higher P uptake. Increased uptake of

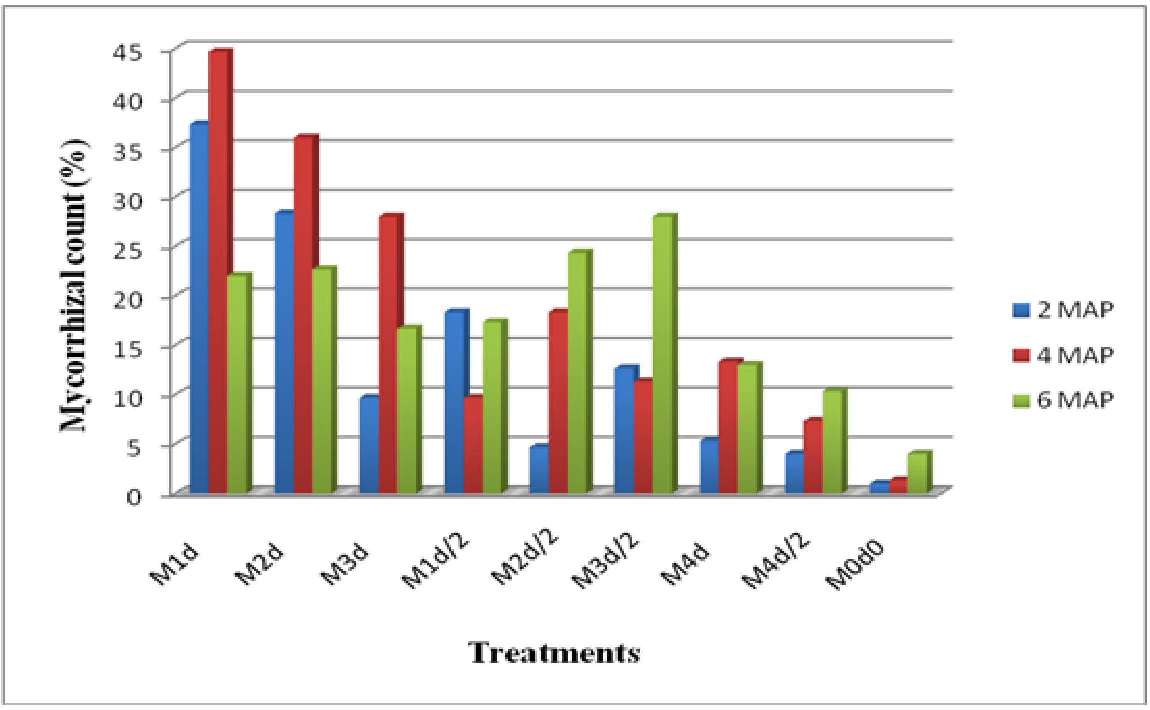


Fig. 24 Effect of organic manures and microbial inoculants on mycorrhizal colonization (%) in *Curcuma aromatica* Salisb. at different growth stages

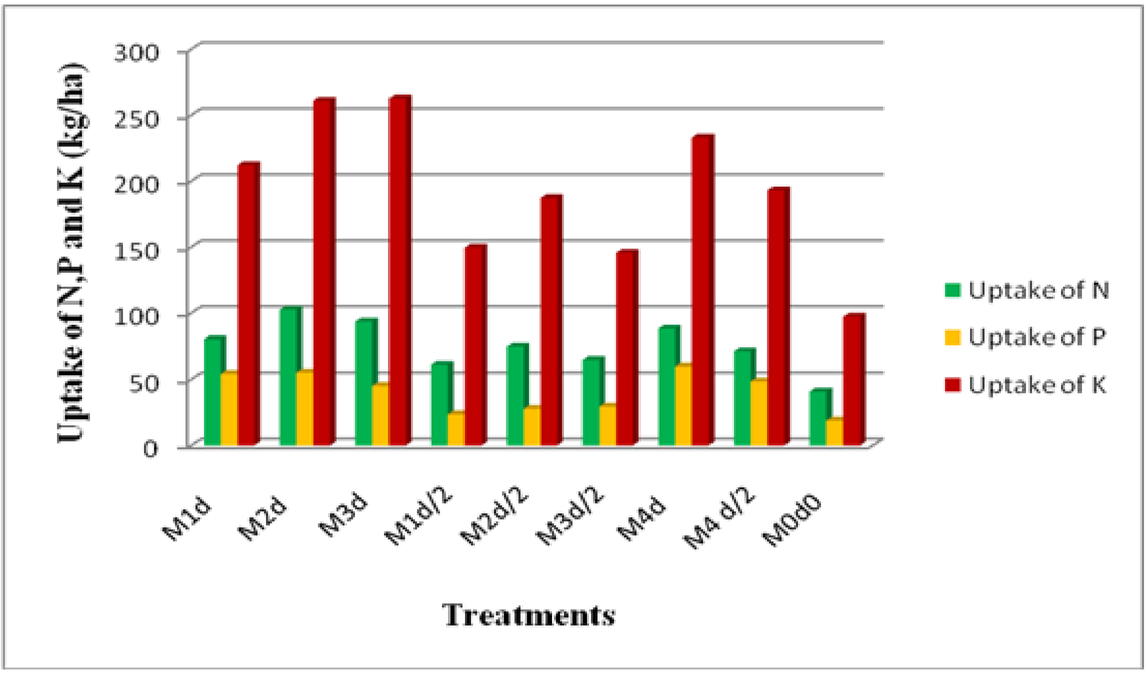


Fig. 25 Effect of organic manures and microbial inoculants on uptake of N, P and K (kg ha^{-1}) in *Curcuma aromatica* Salisb.

P and K with the higher doses of organic manures has been reported by Sharma and Mittra (1991), Gill *et al*. (2004) in turmeric and Singh (1999) in wheat. High P uptake is also attributable to the increased P mobilization by the action of microbial inoculants. The combination of *Trichoderma*, *Pseudomonas* and AMF can strongly influence the soil phosphorus content and *Pseudomonas* sp. is an efficient solubilizer of complex phosphates releasing inorganic phosphates as reported by Sumathi *et al*. (2011) in turmeric.

In the present study, combined application of organic manures, in lower doses along with microbial inoculants (M_4 d/2) also recorded a significant P uptake. Highest uptake of P and K in sweet potato with combined application of lime + FYM + neemcake + green manure has been reported by Laxminarayana *et al*. (2011).

5.6.3. Uptake of K (kg ha^{-1})

Application of organic manures like neemcake and vermicompost along with microbial inoculants either singly or in combination (M_1 d, M_2 d, M_3 d and M_4 d) had significant influence on the uptake of K as observed from the present study. Highest response was seen with neemcake, vermicompost and combined application (Fig. 25). The effect of vermicompost on plants are not solely attributed to the quantity of mineral nutrition provided but also to its other growth regulating components such as plant growth hormones and humic acids (Arancon and Edwards, 2005). According to Samson and Visser (1989), humic acid induced increase in the permeability of biomembranes for electrolytes accounted for increased uptake of potassium. Humic substances modify membrane bound ATPase activity and the relation between membrane ATPase activity, H+ extrusion and the ion uptake suggested that humic substance influence active uptake of potassium by interfering with specific ion carrier. The increase in K availability and uptake in full dose of neemcake applied plants may be due to the action of microbial inoculants particularly *Pseudomonas sp*. Improved bioavailability of N, P and K in soil by the application of neemcake and microbial inoculants has been reported by Murugan *et al*. (2011) in black gram.

Full dose application of organic manures registered comparatively higher K uptake than lower doses. Reduced quantity recorded lesser uptake. As in the case of N and P, the increased uptake of K is also related to its increased availability. In the study, it was noticed that full dose application of organic manures along with microbial inoculants registered higher available K and reduction in the quantity showed a corresponding reduction in the soil available K. Similar trend noticed in the uptake also, is in agreement with the above observation. Sharma and Mittra (1991) reported increased K uptake with higher doses of organic manure.

5.7. INCIDENCE OF PESTS AND DISEASES

Pest and disease incidence were found very less during the crop growth. Plant protection measures were carried out for stem borer (*Conogethes punctiferalis*), lema beetle (*Lema* spp.) and for leaf blight disease (*Colletotrichum capsici*).

Application of organic manures and microbial inoculants might have reduced the pest and disease infestation in the present study. Effectiveness of organic ammendments microbial inoculants in the control of pests and diseases have been reported by many; Alam and Khan (1974) observed that neemcake, mahuacake and mustard cake controlled phytonematodes in the field. Several other authors also reported that effectiveness of organic amendments (oil seed cake) for management of nematodes in various crops (Abid *et al*., 1995; Sheela *et al*., 1995; Rajani *et al*., 1998). For control of sclerotium rot, root knot, soft rot of turmeric and ginger application of neemcake is very useful (Rajpurohit and Dubal, 2009).

The positive effect of AMF against pests and diseases was reported in pepper (Shivaprasad *et al*., 2000) and kacholam (KAU, 2003). Application of *Trichoderma* is very useful for the control of phyllosticta leaf spot, soft rot in turmeric and ginger (Rajpurohit and Dubal, 2009). *Trichoderma* sp. useful against rhizome rot, storage rot in turmeric and soft rot, ginger yellows in ginger (Thomas, 2003). Soil drenching with *Trichoderma* and *Pseudomonas* checks leaf spot and rhizome rot in turmeric (Mishra and Gopalakrishnan, 2006).

5.8. ECONOMICS OF CULTIVATION/ B: C RATIO

The application of organic manures and microbial inoculants considerably increased the gross income over the control (M_0 d_0), where no manures or microbial inoculants were used. Highest rhizome yield and consequently highest gross income was recorded for full dose vermicompost + mi (M_2 d) followed by neemcake + mi (M_3 d) and combined application of all organic manures + mi (M_4 d). Treatments where organic manures were applied in lower doses (M_1 d/2, M_2 d/2 M_3 d/2 and M_4 d/2) either singly or combined, along with microbial inoculants, also produced better yields and gross income than control.

However, highest net profit (Rs. 4, 67,935 /-) was recorded in M_3 d (neemcake 6 t ha^{-1} + mi) pushing M_2 d (vermicompost 25 t ha^{-1} + mi) to the second position (Rs. 4,16,796 /-). This was due to the lesser quantity of neemcake required and comparable cost of vermicompost and neemcake. Highest cost of cultivation (Rs. 3, 04,954 /-) was incurred for the treatment M_2 d (full dose vermicompost + mi). This was due to the higher cost of readymade vermicompost used for the experiment. M_4 d (combined application in higher dose + mi) recorded the third highest net profit (Rs. 4, 05,390 /-). Better net returns over control were also obtained from the treatments in which lower doses of organic manures were used.

An important observation in the economic analysis was that the treatment which registered the highest yield (M_2 d) recorded the lowest B: C ratio (2.37) except control. It happened so because of higher cost of cultivation incurred for the purchase of readymade vermicompost. Among all treatments, the highest benefit cost ratio (3.05) was for the treatment M_3 d (neemcake 6 t ha^{-1} + mi) (Fig. 26) because of the highest net profit. The superiority of neemcake and vermicompost in increasing yield and net returns in kasthuri turmeric has already been reported by Nirmalatha (2009). In the present experiment, along with microbial inoculants neemcake was found to be more cost effective than vermicompost. Treatment M_3 d/2 (Neemcake 3 t ha^{-1} + mi) recorded the next highest B: C ratio (2.92). Vermicompost application in higher and lower doses + mi (M_2 d and M_2 d/2) though produced highest yield and substantial gross income, the benefit: cost ratio was found to be lowered (2.37 and 2.43 respectively) compared to other treatments, due to higher quantity required and higher cost. Lower dose of vermicompost (M_2 d/2) was found to be more cost effective than higher dose (M_2 d) due to lower cost of cultivation. In the treatments involving vermicompost, the cost cultivation can be reduced substantially if the farmers resort to producing the vermicompost by themselves using available organic wastes/plant residues rather than purchasing the readymade vermicompost. If so, these treatments can turn out to be the most cost effective ones.

Combined application of organic manures both at higher and lower doses (M_4 d and M_4 d/2) recorded better B: C ratios (2.53 and 2.57 respectively) and B: C ratio was slightly higher with lower dose, because of lesser yield difference and lower cost of cultivation. FYM application @ 40 t ha^{-1} or 20 t ha^{-1} along with microbial inoculants (M_1 d and M_1 d/2) also produced better yield and monetary returns in kasthuri turmeric. The B: C ratio was also promising (2.49 and 2.55 respectively) and slightly higher ratio was with 20 t ha^{-1} FYM + mi (M_1 d/2) also because of reduction in cost of cultivation.

The control plot recorded a B: C ratio of 1.77. This may be due to the fact that experimental site was moderately fertile as can be seen from the nutrient status (Appendix-II) and due to the systematic and timely after cultivation

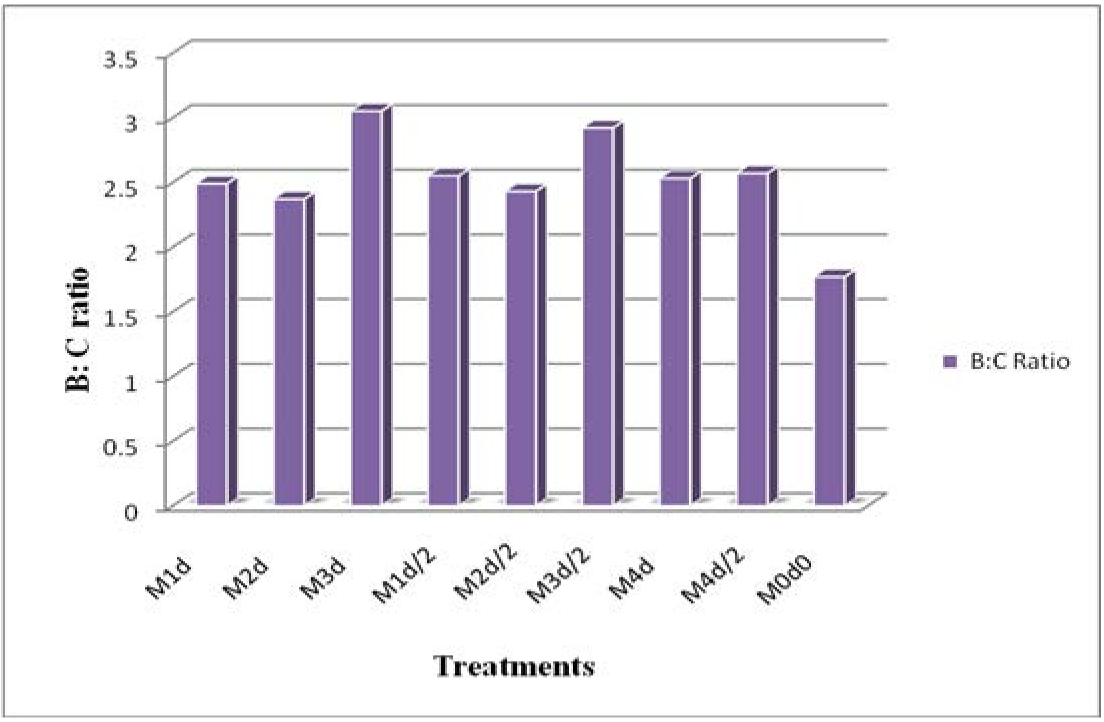


Fig.26 Effect of organic manures and microbial inoculants on B: C ratio in *Curcuma aromatica* Salisb.

practices like mulching, interculture, weeding, earthing up etc. followed in the control plot also.

Among the nine treatments tried, treatment M_3 d (Neemcake 6.0 t ha^{-1} along with microbial inoculants *Azospirillum*, AMF, *Trichoderma* and *Pseudomonas*) which recorded a fresh rhizome yield of 27.84 t ha^{-1} and the highest B: C ratio of 3.05 can be considered as the best cost effective organic manurial recommendation for kasthuri turmeric cultivation. Treatment M_3 d/2 (Neemcake 3.0 t ha^{-1} + mi) was found to be the next best treatment which recorded a fresh rhizome yield of 23.21 t ha^{-1} and a B: C ratio of 2.92.

Since, kasthuri turmeric is a cosmetic cum medicinal plant, apart from yield, quality of rhizomes also assumes significant importance. The quality of any crop is determined by the biochemical constituents present in the economic part. In the present study, vermicompost + mi (M_2 d) produced best quality rhizomes with highest volatile oil, starch and NVEE and with less fibre content.

SUMMARY

6. SUMMARY

An experiment entitled "Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram, during 2010-2011. The main objective of the study was to formulate a low cost organic manurial recommendation for commercial cultivation of kasthuri turmeric which has high cosmetic value, which is a medicinal and aromatic plant with multiple uses.

The salient findings of the above studies are summarized in this chapter.

1. The effect of organic manures and microbial inoculants on plant height of kasthuri turmeric was significantly higher to control and was most prominent in vermicompost + mi (M_2 d) treated plots. Combined application of the three organic manures (FYM, VC and NC) in full and half dose + mi (M_4 d and M_4 d/2), full dose of neemcake + mi (M_3 d), full dose of FYM + mi (M_1 d) also were equally effective treatments for producing significantly superior plant heights. Neemcake and FYM in half dose + mi (M_3 d/2 and M_1 d/2) were found to be less effective in producing better plant height especially during the later stages of crop growth.

2. No significant difference in tiller production was noticed among the treatments.

3. In the case of number of leaves, organic manures and microbial inoculants applied plants produced significantly more number of leaves compared to control (M_0 d_0). Among the treatments, half dose of neemcake + mi (M_3 d/2) produced the highest number of leaves followed by full dose of FYM + mi (M_1 d) and half dose of vermicompost + mi (M_2 d/2). Neemcake and FYM along with microbial inoculants recorded significantly superior leaf production than vermicompost. Organic manures applied singly along with microbial inoculants have more

influence on kasthuri turmeric leaf production than combined application of organic manures + mi (M_4 d and M_4 d/2).

4. With regard to leaf area, vermicompost full and half dose + mi (M_2 d and M_2 d/2) were found to be the best followed by the combined application of organic manures + mi (M_4 d) and FYM full and half dose + mi (M_1 d and M_1 d/2). Neemcake application either full or half dose + mi (M_3 d and M_3 d/2) didn't have much influence on leaf area. However, when it was applied along with other organic manures (M_4 d) significant leaf area increase was noticed.

5. All treatments except control were found equally effective in giving the better spread of rhizome and the highest value for this character was shown by M_2 d (22.82 cm). Vermicompost (M_1) was found to be superior though other manures were also found effective.

6. Rhizome thickness in kasthuri turmeric was significantly influenced by the application of organic manures and microbial inoculants and the highest value was recorded with full dose of vermicompost + mi (M_2 d) which was on par with that of full dose of neemcake + mi (M_3 d), combined application of organic manures + mi (M_4 d) and full dose of FYM + mi (M_1 d). All organic manures tried were found to be equally effective in increasing the rhizome thickness with vermicompost in the top position. When the quantity of organic manures was reduced to half, there was a gradual decrease in rhizome thickness though not significant and the least rhizome thickness was noticed in control (M_0 d_0).

7. The highest finger number was recorded with full dose of vermicompost + mi (M_2 d) followed by neemcake + mi (M_3 d), combined application of organic manures + mi (M_4 d) and FYM + mi (M_1 d). When the dosage of organic manures was reduced to half, a corresponding decrease in finger number was noticed. Though all organic manures were effective, more pronounced effect was recorded for vermicompost in case of number of fingers.

8. In the case of root length, full dose of vermicompost, neemcake and FYM and their combined application along with microbial inoculants (M_2 d, M_3 d, M_1 d and M_4 d) were found to have positive influence in producing better root length. Vermicompost was found to be the most effective whereas, FYM was not found to be that much effective.

9. Full dose vermicompost + mi (M_2 d), neemcake + mi (M_3 d) and FYM + mi (M_1 d) and their combined application + mi (M_4 d) produced significantly superior root spread. The root growth was significantly reduced when the quantity of organic manures applied got reduced.

10. No significant difference in the fresh root weight was noticed due to various treatments, but their dry weight varied significantly. Highest dry root weight was recorded in full dose of vermicompost + mi (M_2 d) which was on par with all other treatments except control (M_0d_0).

11. Fresh and dry rhizome yield in kasthuri turmeric was significantly influenced by the application of organic manures and microbial inoculants and full dose vermicompost + mi (M_2 d) was the best treatment giving a fresh and dry rhizome yield of 456.99 and 82.56 g plant^{-1} respectively. Full dose of neemcake application + mi (M_3 d) also produced a comparable fresh and dry rhizome yield of 437.42 and 79.09 g plant^{-1} respectively. When the quantity of organic manures applied was reduced to half a corresponding yield reduction was observed which was most pronounced in the case of neemcake. Full dose of FYM + mi (M_1 d) application though produced significant fresh and dry rhizome yield it was comparatively less than vermicompost and neemcake. Combined application of vermicompost, neemcake and FYM in full and half dose + mi (M_4 d and M_4 d/2) also registered good rhizome yield.

12. Application of organic manures and microbial inoculants significantly reduced the period of crop maturity in kasthuri turmeric and the control (M_0 d_0) plants took

maximum days (235.00) to attain crop maturity which was on par with half dose of neemcake application + mi(M_3 d/2). M_4 d/2 treatment took minimum days (221.67) and all other treatments were on par with this treatment.

13. There was no significant difference in dry and fresh top yield from various treatments at harvest.

14. All treatments, except M_3 d/2 and M_1 d/2 were equally effective in giving better dry matter production than control. Full dose vermicompost treatment (M_2 d) affected the biomass accumulation most favourably, followed by full dose neem cake + mi (M_3 d), combined application of organic manures + mi (M_4 d) and FYM + mi (M_1 d). A significant reduction in dry matter production was noticed with neem cake and FYM (M_3 d/2 and M_1 d/2) compared to vermicompost, but they were significantly superior to control.

15. In the case of leaf area index, combined application of organic manures and microbial inoculants (M_4 d) was found to have the most significant influence throughout the crop growth period followed by full dose of vermicompost application (M_2 d). In all other treatments also significant increase in the leaf area index over control plants (M_0 d_0) were noticed. Higher doses of organic manures recorded the higher LAI than their lower doses.

16. All treatments both full and half doses of organic manures along with microbial inoculants recorded significantly superior harvest index than the control plants (M_0d_0). Reducing the quantity of organic either in sole or combined application didn't have any negative influence on harvest index.

17. With regard to curcumin content,no significant difference was noticed among the treatments.

18. In case of volatile oil, all treatments were significantly superior to the control plants (M_0 d_0). Full dose of vermicompost (M_2 d) and neemcake (M_3 d) were

found to be superior. Among the different organic manures tested, vermicompost was found to have most significant influence whereas, FYM was found to have the least influence.

19. Full dose of vermicompost + mi (M_2 d) was the best treatment for NVEE followed by neemcake + mi (M_3 d) and combined application of organic manures + mi (M_4 d). Higher level application of organic manures recorded higher NVEE than their lower level application.

20. With regard to crude fibre content in the rhizomes, full dose of vermicompost + mi (M_2 d) was found to be the best followed by neemcake (M_3 d) and combined application of different organic manures + mi (M_4 d) and FYM (M_1 d). When the vermicompost, neemcake and FYM quantity was reduced to half the crude fibre content showed an increase. The control plants (M_0 d_0) recorded the highest crude fibre content.

21. All treatments recorded significantly superior values than control (M_0d_0) in case of starch content. Full dose of vermicompost (M_2 d) and neemcake (M_3 d) recorded higher starch content in the rhizomes.

22. No significant difference was noticed in the chlorophyll a, b and total chlorophyll content in the leaves of kasthuri turmeric by different treatments. All treatments including control recorded higher values for this character.

23. After the experiment, a reduction in the soil bulk density was recorded in all plots except control (M_0d_0) where the bulk density remained the same. However, no significant difference in soil bulk density was noticed among the treatments before and after the experiment.

24. In general, there was an increase in the water holding capacity of the soil after the experiment, though a significant difference was not noticed among the

treatments. Higher doses of organic manure application along with microbial inoculants had a corresponding increase in the water holding capacity and vice versa.

25. The soils of the experimental plot were slightly acidic with pH ranging from 6.39 to 6.59. After the experiment also pH range remained somewhat unchanged (6.38-6.59). Full dose of application of FYM (M_1 d) increased the soil pH while the half dose application (M_1 d/2) showed reduction. In the case of vermicompost no change in the pH was noticed in full dose application (M_2 d), while an increase in pH was noticed when the quantity was reduced to half (M_2 d/2). In the case of neemcake, a reduction was noticed in both cases (M_3 d and M_3 d/2). Combined application of organic manures in lower dose (M_4 d/2) led to an increase in the soil pH.

26. An increase in soil electrical conductivity was noticed in all treatments after the experiment. Substantial increase in EC was noticed in vermicompost applied treatments (M_2 d and M_2 d/2) followed by combined application of organic manures in higher and lower dose (M_4 d and M_4 d/2).

27. An increase in organic carbon was noticed in all treatments including control (M_0 d_0) after the experiment. Substantial increase in organic carbon was noticed when full dose of FYM + mi was applied (M_1 d) followed by vermicompost full dose application (M_2 d) and least increase was noticed in the control (M_0 d_0).

28. Before the experiment no significance difference in the available N content was noticed in the plots. However, after the experiment a significant increase in soil N has been recorded by different treatments over control (M_0 d_0). Highly significant effect was brought about by full dose application of neemcake (M_3 d) and FYM (M_1 d) along with microbial inoculants. Lower dose of organic manures led to a lesser increment in available soil N.

29. No significant difference in the available P and K content was noticed among the treatments before and after the experiment. However, after the experiment an increase in P and K content was there in all treatments including control (M_0d_0). Substantial increase in soil P content was made by vermicompost and neemcake + mi (M_2 d and M_3 d). Combined application of organic manures + mi (M_4 d) also increased the P availability in the soil.

30. Maximum reduction of phytopathogenic bacterial population was recorded in M_3 d where neemcake 6 t ha^{-1} + microbial inoculants were applied. The same trend was observed in M_2 d/2, where vermicompost 12.5 t ha^{-1} + microbial inoculants applied. At higher dose of FYM (40 t ha^{-1}) the bacterial population was found decreasing, but when the quantity was reduced to half, there was an increase in number of bacterial population in M_1 d/2 and M_4 d.

31. In the case of fungal propagules the full dose of organic manures showed an increase in the count (M_1 d, M_2 d and M_3 d), but as the dose was reduced to half (M_1 d/2, M_2 d/2, M_3 d/2, M_4 d and M_4 d/2) a reverse trend was noticed. The fungal propagules were found decreasing.

32. The actinomycetes count in the soil was found increasing when full dose and half dose of FYM were applied (M_1 d and M_1 d/2). Neemcake and vermicompost application (M_2 d and M_3 d) positively influenced the actinomycetes population.

33. Application of organic manures and microbial inoculants had a positive influence towards the mycorrhizal colonization percentage in kasthuri turmeric. The maximum colonization percentage was recorded at 4 MAP with 40 t ha^{-1} FYM + mi (M_1 d). With vermicompost (M_2 d), maximum colonization percentage was at 4 MAP and with neemcake (M_3 d) at 4 MAP. As the dose decreased the colonization percentage also was found decreasing at 4 MAP, but at 6 MAP it slightly increased.

34. Highest N uptake was observed with full dose application of vermicompost, neem cake and combination application (M_2 d, M_3 d and M_4 d). Full dose FYM (M_1 d) was not as effective as neem cake and vermicompost. When the organic manure quantity was reduced to half a reduction in N uptake was noticed.

35. Significantly superior P uptake was noticed with full dose application of organic manures (M_1 d, M_3 d and M_3 d) and with the combined application (M_4 d) recording the highest value. Lower dose of organic manures though with microbial inoculants, recorded lower uptake of P. Combined application of organic manures, in lower doses along with microbial inoculants (M_4 d/2) also recorded a significant P uptake.

36. Application of organic manures like neemcake and vermicompost along with microbial inoculants either singly or in combination (M_1 d, M_2 d, M_3 d and M_4 d) had significant influence on the uptake of K. Highest response was seen with neemcake, vermicompost and combined application. Full dose application of organic manures along with microbial inoculants registered higher uptake of K and reduction in the quantity showed a corresponding reduction.

37. Pest and disease incidence were found very less during the crop growth.

38. In the economic analysis, highest rhizome yield and consequently highest gross income was recorded for full dose vermicompost + mi (M_2 d) followed by neemcake + mi (M_3 d) and combined application of all organic manures + mi (M_4 d). Treatments where organic manures were applied in lower doses (M_1 d/2 M_2 d/2 M_3 d/2 and M_4 d/2) either singly or combined, along with microbial inoculants, also produced better yields and gross income than control.

Highest net profit (Rs. 4,67,935 /-) was recorded in M_3 d (neemcake 6 t ha^{-1} + mi) followed by M_2 d (Rs. 4,16,796 /-). M_4 d recorded the third highest net profit (Rs. 4,05,390 /-). Better net returns over control were also obtained from the treatments in which lower doses of organic manures were used. Highest cost of cultivation (Rs. 3,04,954 /-) was incurred for the treatment M_2 d (full dose vermicompost + mi).

Among all treatments, the highest benefit cost ratio (3.05) was for the treatment M_3 d. Treatment M_3 d/2 recorded the next highest B: C ratio (2.92). Vermicompost application in higher and lower doses + mi (M_2 d and M_2 d/2) recorded the B: C ratio was 2.37 and 2.43 respectively. Combined application of organic manures both at higher and lower doses (M_4 d and M_4 d/2) recorded better B: C ratios (2.53 and 2.57 respectively). FYM application @ 40 t ha^{-1} or 20 t ha^{-1} along with microbial inoculants (M_1 d and M_1 d/2) produced better yield and the B: C ratio was also promising (2.49 and 2.55 respectively). The control plot (M_0 d_0) recorded the lowest B: C ratio of 1.77.

Conclusion:

The salient research findings from the study entitled "Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)" can be concluded as follows:

1. Among the nine treatments tried, treatment M_3 d (Neemcake 6.0 t ha^{-1} along with microbial inoculants *Azospirillum*, AMF, *Trichoderma* and *Pseudomonas*) which recorded a fresh rhizome yield of 27.84 t ha^{-1} and the highest B: C ratio of 3.05 can be considered as the best cost effective organic manurial recommendation for kasthuri turmeric cultivation. Treatment M_3 d/2 (Neemcake 3.0 t ha^{-1} + mi) was found to be the next best treatment which recorded a fresh rhizome yield of 23.21 t ha^{-1} and a B: C ratio of 2.92.

2. In the case of qualitative characters like volatile oil, non volatile ether extract and starch M_2 d (vermicompost 25 t ha^{-1} + mi) recorded the highest values followed by M_3 d (Neemcake 6.0 t ha^{-1}+ mi) and M_4 d (FYM 20.0 t ha^{-1} + VC 6.25 t ha^{-1} + NC 1.5 t ha^{-1} + mi) and same treatments recorded lower crude fibre content also.

3. Much improvement in soil physical, chemical and biological properties can be achieved through organic manuring in kasthuri turmeric using FYM, vermicompost and neemcake along with microbial inoculants like *Azospirillum* + AMF + *Trichoderma* + *Pseudomonas*.

4. Pests and diseases incidence in kasthuri turmeric can be reduced considerably by organic manuring using FYM, vermicompost and neemcake along with microbial inoculants like *Azospirillum* + AMF + *Trichoderma* + *Pseudomonas*.

Future line of study:

1. Best treatments from present research may be subjected to farm trials and multilocation trials for studying their effectiveness in farmer's fields and under different agro-ecological conditions.

2. The feasibility of other sources of organic manures and microbial inoculants and their combination has to be investigated.

3. The residual effect of organic manure-microbial inoculants combination is to be studied.

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ABSTRACT

STANDARDIZATION OF ORGANIC MANURING IN KASTHURI TURMERIC (*Curcuma aromatica* Salisb.)

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8. ABSTRACT

A study entitled "Standardization of organic manuring in kasthuri turmeric (*Curcuma aromatica* Salisb.)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram, during 2010-2011 to formulate a cost effective organic manurial recommendation for commercial cultivation of kasthuri turmeric.

The experiment was laid out in RBD with nine treatments and three replications. The treatments consisted of different doses and combinations of three organic manures *viz.*, FYM, vermicompost and neemcake plus a combination of microbial inoculants *viz.*, *Azospirillum*, Arbuscular Mycorrhizal fungi (AMF), *Trichoderma* and *Pseudomonas.* The treatments were M_1 d (T_1) - FYM 40.0 t ha^{-1} + mi, M_2 d (T_2) - Vermicompost (VC) 25.0 t ha^{-1} + mi, M_3 d (T_3) - Neemcake (NC) 6.0 t ha^{-1} + mi, M_1 d/2 (T_4) - FYM 20.0 t ha^{-1} + mi, M_2 d/2 (T_5) - Vermicompost 12.5 t ha^{-1} + mi, M_3 d/2 (T_6) - Neemcake 3.0 t ha^{-1} + mi, M_4 d (T_7) - FYM 20.0 t ha^{-1} + VC 6.25 t ha^{-1} + NC 1.5 t ha^{-1} + mi, M_4 d/2 (T_8) - FYM 20.0 t ha^{-1} + VC 3.125 t ha^{-1} + NC 0.75 t ha^{-1} + mi and M_0 d_0 (T_9) - Absolute control with no organic manures and microbial inoculants.

The results revealed that application of different organic manures along with microbial inoculants significantly influenced the morphological characters, biochemical and physiological parameters, nutrient uptake, dry matter production and ultimately the yield and yield attributes in kasthuri turmeric. A general improvement in the soil physical, chemical and biological properties was noticed in the experimental plots, after the experiment.

Treatment M_2 d recorded significantly superior values for plant height, leaf area, rhizome and root characters followed by M_3 d and M_4 d and M_1 d. No significant difference in tiller production was noticed by the treatments but highest number of leaves was recorded in M_3 d/2.

Highest fresh and dry rhizome yield was produced by M_2 d. Equivalent yield was also obtained from M_3 d. Significantly superior yields compared to control were also registered by M_4 d, M_1 d, M_2 d/2 and M_4 d/2. All these treatments recorded significantly lesser crop duration than control.

All treatments except M_3 d/2 and M_1 d/2 were equally effective in giving better dry matter production than control. M_2 d affected the biomass accumulation most favourably, followed by M_3 d, and M_4 d.In the case of leaf area index, M_4 d was found to have the most significant influence throughout the crop growth period followed by M_2 d. In all other treatments also significant increase in the leaf area index over control (M_0 d_0) was noticed. All treatments recorded significantly superior harvest index than control.

In the case of biochemical characters like volatile oil, non volatile ether extract and starch M_2 drecorded the highest values followed by M_3 d and M_4 d and same treatments recorded lower crude fibre content also. However, no significant difference in leaf chlorophyll and rhizome curcumin content was noticed among the treatments.

After the experiment an improvement in the soil physical and chemical properties was recorded in all plots. A general reduction in soil bulk density and an increase in the water holding capacity of the soil was recorded in all plots after the experiment. However, a significant difference among the treatments was not noticed. Soil pH range of the experimental field remained same after the experiment (6.38-6.59), while an increase in the electrical conductivity was noticed in all the treatments.An increase in organic carbon was noticed in all treatments including control (M_0 d_0) after the experiment. General increase in available N, P and K was noticed in all plots with highest values in higher doses of organic manures (M_3 d, M_2 d, M_1d and M_4 d) applied plots.

Highest N uptake was observed with full dose application of vermicompost, neem cake and combination application (M_2 d, M_3 d and M_4 d). Significantly superior P uptake was noticed with full dose application of organic manures (M_1 d, M_2 d and M_3 d) with the combined application recording the highest value (M_4 d). Lower dose of organic manures though with microbial inoculants, recorded lower uptake of P. Application of organic manures like neemcake and vermicompost along with microbial inoculants either singly or in combination (M_1 d, M_2 d, M_3 d and M_4 d) had significant influence on the uptake of K, as observed from the present study. Pest and disease incidence was observed very less in present experiment.

The treatment M_3 d was found the best treatment for reducing the phytopathogenic bacterial population in the soil. Maximum reduction of pathogenic fungal population was found in the treatment M_3 d/2 whereas, in the case of actinomycetes it was observed in the treatment M_2 d/2. Throughout the growth stages, all treatments recorded significantly superior root colonization than control. At 2 and 4 MAP, M_1 d recorded significantly superior root colonization, but at 6 MAP, M_3 d/2 recorded significantly superior value.

In the cost benefit analysis, highest net income was obtained from M_3 d (Rs. 4, 67,935 /-) followed by M_2 d (Rs. 4, 16,796 /-) and M_4 d (Rs. 4, 05,390 /-). Treatment M_3 d recorded the highest B: C ratio (3.05) followed by M_3 d/2 (2.92). Better B: C ratios were also observed with treatments M_4 d/2, M_1 d/2, M_4 d, M_1 d and M_2 d/2 (2.57, 2.55, 2.53, 2.49 and 2.43 respectively). M_2 d recorded a B: C ratio of 2.37.

Economic analysis revealed that, treatments M_3 d, M_3 d/2 and M_4 d/2 recorded the higher B: C ratios. Hence, treatment M_3 d (Neemcake 6.0 t ha^{-1} + mi) can be considered as the best cost effective organic manurial recommendation for kasthuri turmeric cultivation.

APPENDICES

APPENDIX - I

Weather data during the crop period

Period (Month)	Maximum Temperature (^0C)	Rainfall (mm)	Relative Humidity (%)	Evaporation (mm)
May	32.60	278.90	86.80	3.80
June	30.10	245.20	89.40	3.10
July	30.29	199.99	84.63	3.36
August	30.37	91.63	84.96	3.46
September	30.62	134.40	82.79	3.38
October	30.33	504.98	83.74	3.17
November	30.33	289.80	83.71	3.02
December	29.75	105.98	85.77	3.89
January	30.48	7.35	86.09	3.18

APPENDIX - II

Soil characteristics of the experimental site

A. Physical properties

Parameters	Mean value	Method
Bulk density, (Mg m^3)	1.280	Core method (Gupta and Dakshinamoorthy, 1980).
Water holding Capacity, (%)	22.110	Undisturbed core sample method (Gupta and Dakshinamoorthy, 1980).

B. Chemical properties

pH	6.500	pH meter with electrodes (Jackson, 1973).
EC (d S m^{-1})	0.223	Electrical conductivity meter.
Organic Carbon (%)	0.820	Walkley and Black's rapid titration method (Jackson, 1973).

Available N (kg ha^{-1})	233.350	Alkaline permanganate method by titrimetric method (Subbiah and Asija, 1956).
Available P(kg ha^{-1})	57.010	Bray No.1 Method using spectro-photometer (Jackson 1973).
Available K (kg ha^{-1})	371.280	Neutral normal ammonium acetate and available K was read in Flame photometer (Jackson, 1973).

C. Biological properties

Bacterial count	123.28×10^6	Serial dilution plate technique (Johnson and Curl, 1972).
Fungal count	48.67×10^4	Serial dilution plate technique (Johnson and Curl, 1972).
Actinomycetes count	89.78×10^6	Serial dilution plate technique (Johnson and Curl, 1972).

APPENDIX - III

Nutrient content of organic manures used for the experiment

Sl. No.	Organic manures	Nutrient content (%)		
		N	P	K
1.	FYM	0.9	0.4	1.2
2.	Vermicompost	1.4	0.8	1.2
3.	Neemcake	2.1	0.4	1.5