EFFECT OF ORGANIC MANURES AND MICROBIAL INOCULANTS ON GROWTH, YIELD AND QUALITY OF GINGER

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DECLARATION

I hereby declare that this thesis entitled **"Effect of organic manures and microbial inoculants on growth, yield and quality of ginger"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **“Effect of organic manures and microbial inoculants on growth, yield and quality of ginger”** is a record of research work done independently by Mrs.Sreekala.G.S. (1999-22-07) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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DEDICATED TO MY PARENTS

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LIST OF ABBREVIATIONS

%	-Percentage
@	-At the rate of
^0C	-Degree Celsius
ADP	-Adenosine diphosphate
AFNOR	-Association Francaise de Normalization
ai	-Active ingredient
AIA	-Acid Insoluble Ash
AMF	-Arbuscular Mycorrihizal fungi
AMS	-Agricultural Marketing Service
ANSI	-American National Standards Institute
AOAC	-Association of Official Agricultural Chemists
ASPS	-Agreement on Phytosanitary measures
ASTA	-American Spice Trade Association
ATBT	-Agreement on Technical Barriers to Trade
ATP	-Adenosine triphosphate
B:C	-Benefit Cost ratio
BIS	-Bureau of Indian Standards
BR	-Bulking rate
C	-Carbon
Ca	-Calcium
CAC	-Codex Alimentarius Commission
cc	-Cubic centimetre
CCP	-Composted Coirpith
CD	-Critical Difference
CGR	-Crop Growth Rate
cm	-Centimetre
CS2	-Carbon disulphide
CTCRI	-Central Tuber Crops Research Institute
Cu	-Copper
cv.	-Cultivar
DAP	-Days After Planting
DMI	-Directorate of Marketing and Inspection
DMP	-Dry Matter Production
eg	-Example
et al.	-and others
ESA	-European Spice Association
EU	-European Union
FAO	-Food and Agriculture Organisation
Fe	-Iron
Fig.	-Figure
FOIS	-Fish Oil Insecticidal Soap
FYM	-Farm Yard Manure
g	-Gram
GDP	-Gross Domestic Product
GMO	-Genetically Modified Organisms
ha	-hectare
HI	-Harvest index
HACCP	-Hazard Analysis Critical Control Points
H_2O	-Water
ICAR	-Indian Council of Agricultural Research
ICRI	-Indian Cardamom Research Institute

List of Abbreviations (cont…)

IFOAM	-International Foundation for Organic Agriculture Movement
IISR	-Indian Institute of Spices Research
ISO	-International Organisation for Standardisation
JAS	-Japan Agricultural Standard
K	-Potassium
KAU	-Kerala Agricultural University
Kg	-Kilogram
l	-Litre
LAD	-Leaf Area Duration
LAI	-Leaf Area Iindex
log	-Logarithm
m	-Metre
m^2	-Square metre
MAP	-Months After Planting
MEA	-Multilateral Environment Agreement
Mg	-Magnesium
ml	-Millilitre
Mn	-Manganese
MOP	-Muriate of Potash
N	-Nitrogen
NAR	-Net Assimilation Rate
NC	-Neem Cake
NOP	-National Organic programme
NVEE	-Non-Volatile Ether Extract
^{0}	-Degree
P	-Phosphorus
OFPA	-Organic Food Production Act
pH	-Power of hydrogen ion concentration
POP	-Package of Practices Recommendations
ppm	-Parts per million
q	-quintal
RBD	-Randomised Block Design
RGR	-Relative Growth Rate
Rs	-Rupees
RS	-Root shoot
S	-Sulphur
SE	-Standard Error
SSP	-Single Super Phosphate
t	-tonne
TNAU	-Tamil Nadu Agricultural University
TRIPS	-Treaty on Intellectual Properties Rights
TSS	-Total Soluble Solids
USA	-United States of America
USFDA	-Unites States Food and Drug Administration
VAM	-Vesicular Arbuscular Mycorrihiza
VC	-Vermicompost
V/O	-Volatile oil
WHO	-World Health Organistaion
WONF	-With Other Natural Flavour
WTO	-World Trade Organisation
Zn	-Zinc

Introduction

1.INTRODUCTION

India having a history of production of spices and trade continues to produce 3.02 million tonnes of spices annually from an area of 2.5 million ha, which accounts for about 2.52 per cent of GDP in agriculture (Singh, 2002). Consumption of spices in the developed countries and some parts of the developing world is also increasing steadily.

India is the largest producer of dry ginger in the world and contributes to 33 per cent of the world production accounting for a foreign exchange earning to the tune of around Rs.30 crores per annum. Kerala occupies the largest area with a production of 42, 699 t dry ginger from an area of 11, 612 ha during 2000-2001 (Selvan and Manojkumar, 2002).

The global demand for dry ginger by 2005 has been estimated to be 0.25 lakh tonnes (Peter, 1997). Considering the demand, the production should also have to be increased. Since Kerala accounts for a major share of ginger production in India, the involvement of Kerala is manifold. Kerala, being the largest producing state of ginger, have capabilities to cater to the requirements of the consuming countries in terms of quality and quantity matching to international standards. One way of increasing the production is by increasing the area of cultivation. In a state like Kerala, where the land is scarce there is limited scope to bring additional area under cultivation. However, there is ample scope for increasing the area under ginger through intercropping. The compatibility and flexibility of ginger crops in coconut cropping system has been well documented by many researchers (Aclan and Quisumbing, 1976, Bai, 1981; Ravisankar and Muthuswamy, 1987 and Jayachandran *et al.*, 1991; Zhao, 1987, 1991;Ancy, 1992; KAU, 1992; George, 1992 and Sreekala, 1999).

The rapid growth of food and food processing industry, world over has led to a significant growth of India's export of value added spices during the last couple of years. With the global food industry increasingly turning towards organic produce the scope for India to earn enormous foreign exchange through aggressive marketing of these organic spices is indeed bright. Of all the concerned implications of the WTO, the growing green sentiments, the Agreement on Phytosanitary measures (ASPS), the Agreement on Technical Barriers to Trade (ATBT) and the Treaty on Intellectual Property Rights (TRIPS) are some of the issues, which may have impact on the global spice trade. Besides the Multilateral Environment Agreements (MEAs), the packaging regulations and the progressive tendency to evaluate environmental impacts of commodities and products from a total life cycle perspective, will have its bearing on trade spices in the coming years. Therefore, it is inevitable to take stock of the situation and plan the strategies, which enhance the capacity to harness the existing competitive advantages (Singh, 2002).

The indiscriminate use of chemicals and tendency of farmers to abandon the use of FYM, green leaves, compost or incorporate crop residue in the soil led to soil degradation also. A global loss of productive cropland due to soil degradation is estimated to be 60 to 70 lakh ha each year (Misra *et al.,* 1999). Thus proper soil management without impairing soil health is a pre requisite for achieving higher productivity from agricultural land. Enhancing and sustaining the productivity of the soil resource is a major challenge before the resource managers as most of our important production system are showing signs of fatigue in high productivity areas due to deterioration of soil fertility, widespread nutrient deficiencies and inadequate and imbalanced supply of plant nutrients. In view of the above soil degradation as well as the hazardous polluting effects of pesticides and fertilizers on environment, there is a growing awareness in the farming community about the alternate agricultural system.

The popularity of organic food is skyrocketing according to Peter Schmich from clear view organic in Australia (John, 2003). Demand is increasing by 30 per cent per year but supply is only increasing by 10 per cent. Our spice farmers can take advantage of this opportunity presently available in the international market by offering organically produced spices and spice products. Considering the world demand for organic food, the improvement of soil health and productivity and the availability of local resources, the organic farming practice can be encouraged.

The uses of organic sources as nutrients are known from the beginning of agriculture (Gowda and Babu, 1999). India has a vast potential of manurial resources - FYM, green manures, crop residues etc. The on-farm recycling of organic wastes and the application of bulky organic manures such as FYM and compost are adopted to sustain good soil health. Apart from these manures, other organic sources like green manure, green leaf manure, vermicompost, neemcake and bioinoculants or biofertilizers are also used.

Guidelines for organic spice production were approved by the National Standards Committee constituted by IFOAM, members during 1998 (Spices Board, 1998a). Quality requirement of spices for export to different countries have been formulated (Spices Board, 1998b). Research programmes on organic farming have commenced since the concept of sustainable farming has caught on in India (Anon, 2000).

Considering the importance of organic agriculture in the present context the investigation was undertaken with the following objectives :

1. To assess the effect of organic manures and microbial inoculants on growth, yield and quality of ginger
2. To assess the effect of organic manures and microbial inoculants in the physical and chemical properties of the soil.
3. To develop a suitable organic farming practice for producing export quality ginger free of pesticide residues.
4. To workout the economics of using different organic manures and microbial inoculants

Review of Literature

2. REVIEW OF LITERATURE

Ginger, grown mainly in states of Kerala, North Eastern States and Tamil Nadu is a high value commercial spice crops compatible with coconut that can be efficiently fitted as inter/mixed crops in areas where coconut is cultivated.

Reducing the cost of production with sustainable high yield and soil health has the relevance at all times. Also, health concerns associated with pesticides residue and related problems demand organically produced products. Organic cultivation of crops without the use of any chemical input comes handy in this regard. Moreover the use of organic manure in soil improves the physical properties of soil and balances the nutrient availability to plants.

Though, there are reports about organic farming practice in spices, so far limited work has been standardized for organic farming practice more specifically in spices like ginger. Literature of different organic manures, microbial inoculants and their integrated effect on growth, yield and quality of ginger are reviewed in this chapter. Wherever information is lacking pertinent literature on other crop has been included.

2.1 ORGANIC MANURE

India having the vast potential of organic sources can effectively utilize this to sustain yield, improve soil aeration, permeability, aggregation, water and nutrient holding capacity, biological properties of soil and soil health.

Farmyard manure (FYM) is the most commonly used traditional organic manure in India being readily available. It consists of a mixture of animal shed wastes containing dung, urine and some straw (Gaur, 1994).

The term vermicomposting means 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 of casting of earthworms are rich in nutrients (N, P, K, Ca and Mg), and also in bacterial and actinomycete population (Gaur and Sadasivam, 1993).

Oil cake is concentrated organic manure and is comparatively richer in NPK. Neemcake is a non-edible oil cake. In addition to nutrients, it contains the alkaloids, nimbin and nimbidin and certain sulphur compounds which effectively inhibit the nitrification process (Reddy and Prasad, 1985; Rajkumar and Sekhon, 1981).

Green manuring is a cheap alternative to the use of fertilizer nitrogen. The process also makes a positive contribution to the maintenance of soil organic mater content at a satisfactory level. Green manuring is a low cost but effective technology in minimizing investment cost on fertilizer and in safeguarding the productive capacity of the soil without any impoverishment (Ramakrishna and Rangarajan, 1993).

2.2 MICROBIAL INOCULANTS

Great emphasis has been laid on development and use of biofertilizers during the last two decades. As a cost effective supplement to chemical fertilizers and renewable energy source biofertilizers can help to economize on the high investment needed for fertilizer use as far as N and P are concerned (Pandey and Kumar, 2002). Biofertilizers save N/P requirement upto 50 per cent in most of the vegetable crops and increase the yield by 18 to 50 per cent in different vegetable crops (Kanaujia and Narayana, 2003).

Vesicular arbuscular mycorrhizae a bio agent are the most ubiquitous fungi able to take up accumulate transfer larger amounts of phosphate to the plants by releasing the nutrients in the root cells containing arbuscles, which draw phosphate more efficiently from the soluble pool than non-mycorrhizal plants. In addition mycorrhial plants have shown greater tolerance to toxic heavy material, drought, high soil temperatures, saline soils, adverse pH, transplant shocks and root pathogens especially nematodes and pathogenic soil fungi than non mycorrhizal plants.

Effects of biofertilizers on various spice crops were evaluated by many workers. In the organic production of turmeric, application of biofertilizers like *Trichoderma viride* (7.5 kg ha^{-1}), *Azospirillum*, (7.5 kg ha^{-1}) and phosphobacteria (7.5 kg ha^{-1}) is recommended.

2.1.1 Effect of organic manures on growth characters

Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches than inorganically grown ones. Addition of organic matter enhanced the growth and biomass of the pepper vines (Sivakumar and Wahid, 1994). The beneficial effect of organic amendments in increasing the growth parameters were reported by Pushpa (1996) in tomato and Anitha (1997) in chilli.

2.1.1.1 Effect of FYM

FYM favourably influence the vegetative mass dry weight, plant height, rate of dry matter increment per unit area in capsicum (Cerna, 1980; Valsikova and Ivanic, 1982). According to Sahota (1993) FYM application increased plant height and number of leaves per plant in potato. According to Arunkumar (2000) highest level of FYM and vermicompost (150 % POP) maintained their superiority at all growth stages regarding plant height, number of leaves and number of branches of amaranthus. In a study on the effect of FYM and N on growth and yield of wheat in Hissar revealed higher plant height with the application of FYM at 20 t ha^{-1} over the control and FYM at 10 t ha^{-1} (Singh and Agarwal, 2001).

Vidyadharan (2000) reported increased plant height, number of leaves per plant, sucker number per hill and dry matter production by the highest level of FYM tried (20 t ha^{-1}) in arrowroot. Application of FYM in turmeric showed its superiority in growth character during the initial stage of growth while during the later stages of growth coirpith compost was superior (Rakhee, 2002).

Influence of organic manures and Azospirillum on growth, yield and quality of ginger was reported (KAU, 1999). The highest dry matter accumulation was reported from treatments, which received FYM alone at the rate of 48 t ha^{-1}.

2.1.1.2 Effect of vermicompost

Kale *et al*. (1987) found that worm cast when used as a manure in place of FYM, significantly influenced vegetative and flowering characters. Shuxin *et al*. (1991) obtained 30-50 per cent increase in plant height, tillering, cane diameter in sugar cane as a result of vermicompost application. They also reported 25 per cent increase in height in soybean plants with the use of vermicompost.

Vadiraj *et al*. (1993) observed that the use of vermicompost as a component of potting mixture in cardamom nursery helped in seedling growth and drymatter production in a short span of time. Krishnakumar *et al*. (1994) reported better growth and development of seedlings in cardamom nursery by the use of vermicompost in potting medium. The effect of vermicompost in turmeric was studied by Vadiraj *et al*. (1996). Varieties Armour and Suroma when treated with vermicompost had 30 per cent increase in plant height and 70 per cent increase in leaf area over control.

2.1.1.3 Effect of Neemcake

Oil cake application resulted in increased plant height in bhindi (Singh and Sitaramaiah, 1963). Different oil cakes were tried by Som *et al*. (1992) to study their effect on growth and yield of brinjal. The maximum plant height was recorded from the treatment receiving neemcake at the rate of 50 q ha^{-1} compared to other oil cakes tried. According to Sharu (2000) in chilli the growth characters like plant height, number of branches and drymatter accumulation as a result of neemcake application was found to be on par with plants received manuring as per the package of practices recommendation of Kerala Agricultural University.

2.1.1.4 Effect of green leaves

Squire (1981) found that a green manure crop of groundnut ploughed in before planting cassava increased cassava root and shoot weight. Nayar *et al*. (1993) emphasized the green manuring *in situ* with cowpea was instrumental in promoting greater dry matter accumulation in the storage roots and sustaining the productivity of cassava.

An experiment on the effect of organic manures and bio-fertilizers on the growth and yield of rabi rice revealed taller plants with more number of tillers per m^2 in green manure + azospirillum treatment plots and it was comparable with FYM + azospirillum (Nagaraju *et al*., 1995).

2.2.1. Effect of microbial inoculants on growth characters

Varma (1995) recorded significantly higher production of new leaves, branches, fresh and dry weight of shoot in bush pepper inoculated with Azospirillum. However, chemical fertilizer had no significant effect on different growth parameters. Preliminary data from the studies carried out at Indian Cardamom Research Institute on the use of bio-fertilizers in cardamom indicate the usefulness of Azospirillum and phosphobacteria for the growth of cardamom (Muthuramalingam *et al.,* 2000). Nath and Korla (2000) studying the effect of bio-fertilizers on growth and yield of ginger revealed better plant start, plant height, number of tillers and leaves per plant over normal dose of NPK and control with no fertilizer or biofertilizers. According to Anith and Manomohandas (2001) application of biocontrol agents was found to have profound effect on the growth parameters of black pepper cuttings.

2.2.1.1 Effect of VAM

VAM increase the rate of growth of plants and also influence of partitioning of phytomass between shoot and root (Smith, 1980). Relatively less of the photosynthates are allocated to the roots and hence the root : shoot ratio is usually lower in VAM plants than in non mycorrhizal counter parts. Lower root shoot ratios with VAM colonization have been reported by Puccini *et al*. (1988) and also by Berta *et al*. (1990) Vetiver plants inoculated with *Glomus* sp. showed higher biomass production compared to control (Ratti *et al*., 2002). The root colonization by VAM fungi, *Glomus mosseae*, *Glomus aggregatum* and *Glomus intraradices* enhanced the growth, number of branches and fresh biomass yield of the periwinkle in comparison to non inoculated control plants. Maximum enhancement in biomass yield was shown by *Glomus mosseae* (33 %). Higher root colonization seems to be a reflection of increased biomass yield of periwinkle plant (Gupta *et al*., 2003).

Thomas and Ghai (1988) observed an increase in plant height, number of leaves and shoot dry weight of pepper, Panniyur-1 on inoculation with different AMF. Similar results were reported on inoculation with *Glomus fasciculatum* and *Glomus etunicatum* (Sivaprasad *et al*., 1992). Anandaraj and Sarma (1994) observed that inoculation with AMF enhanced vegetative growth of four different varieties of pepper *viz*., Sreekara, Subhakara, Panniyur-1 and Kottanadan. According to Muthuramalingam *et al*. (2000) application of bio-fertilizers namely VAM, Azospirillum and phosphobacteria improved the growth and development of vanilla and minimized the use of inorganic fertilizers. Increase in vine length, internodal length and number of leaves were significant with the application of bio-fertilizers. The effect of various bio-fertilizers on establishment and growth of pepper cuttings was studied by Ashithraj (2001). Vine length, number of leaves and dry weight were significantly higher in plants inoculated with selected species and strains of AMF and nitrogen fixing bacteria.

According to Sivaprasad (1993) the AMF namely *Glomus multicaule* and *Glomus fasciculatum* significantly enhanced growth of ginger.

Inoculation of VAM at the time of planting in the nursery or field is recommended for improving the growth and tolerance of crop plants against root pathogen particularly black pepper, cardamom, ginger, turmeric, cowpea, rice and transplanted vegetables (KAU, 1996). The response of cardamom cv. Myzore to six promising arbuscular mycorrhizal fungi selected from a primary screening trial and five dominant native mycorrhizal fungi isolated from the local cardamom plantations were tested in a location trial in Idukki district. In general mycorrhizal inoculation was found beneficial in improving the plant growth compared to control (Sreeramulu and Bhagyaraj, 1999). Inoculation with AMF improved the growth of cardamom seedlings to a larger extend compared to uninoculated plant which is in accordance with the findings of Thomas *et al.* (1989) that VAM inoculation improves the growth of cardamom.

2.2.1.2 Effect of Trichoderma

Baker *et al*. (1984) found that *Trichoderma harzianum* can stimulate the growth of plants, including various floricultural and horticultural plants (Chang *et al*., 1986). Pepper seed germinated two days earlier in raw soil containing the fungus than in untreated controls. Flowering of periwinkle was increased and the heights and weights of other plants were greater in earlier steamed or raw soil infested with *Trichoderma harzianum*. Windham *et al*. (1986) reported that addition of *Trichoderma* spp. to autoclaved soil increased root and shoot dry weight of tomato and tobacco. The growth stimulation by *Trichoderma harzianum* could be the result of production by the fungus of plant hormones, increased uptake of nutrients by the plant or the control of one or more sub clinical pathogens (Chet, 1990).

According to Joseph (1997), *Tichoderma viride* was the most effective isolate for suppression of rhizome rot, growth enhancement and yield in ginger.

2.2.1.3 Combination of bio-fertilizers

The combined effect of AMF and antagonists was studied by Kumar *et al*. (1993) in wheat. Mixed cultures of *Glomus epigaeus* and *Trichoderma viride* singly or in combination were tested against three wheat root rot pathogens. The mixed cultures protected wheat plants against the three pathogens as well as resulted in higher plant height, weight and root length. Similar result was also obtained in marigold by the combination of AMF and *Trichoderma* (Calvet *et al*., 1993). In the organic production of turmeric, application of bio-fertilizers like *Trichoderma viride* (7.5 kg ha^{-1}) and phosphobacteria (7.5 kg ha^{-1}) was recommended (Ravikumar, 2002).

2.1.2 Effect of organic manures in root characters

2.1.2.1 Effect of FYM

Farmyard manure serve as a buffer against fluctuations in moisture availability and promoted better root growth (Tandon, 1994). In a trial in bhindi, Isaac (1995) found the highest root spread of 44.05 cm obtained with the application of 6 t of farmyard manure per hectare along with inorganic fertilizers.

The studies on integrated nutrient management in rice-wheat system by Singh *et al*. (2000) revealed that root length, density and drymatter added through root was significantly higher in FYM treated plants than in that of green manure and control.

2.1.2.2 Effect of vermicompost

In turmeric, the root length varied significantly for different organic manure treatments at 6 and 8 MAP, which was on par with plants received organic and inorganic fertilizers as per the package of practices recommendation of Kerala Agricultural University (Rakhee, 2002). The root spread at 8 MAP was highest for coirpith compost and was on par with vermicompost treatment and differed significantly from the package of practices recommendations of Kerala Agricultural University.

2.1.2.3 Effect of green leaves

Green manure crop of groundnut ploughed in before planting cassava increased root weight (Squire, 1981). Nayar *et al.* (1993) emphasized that green manuring *in situ* with cowpea promoted greater dry matter accumulation in the storage roots.

2.2.2 Effect of microbial inoculants on root characters

Experiments conducted to study the effect of bio-fertilizers in root crops revealed increased root length, diameter and yield in carrot and raddish as compared to uninoculated treatments (Kanaujia and Narayan, 2003).

2.2.2.1 Effect of AMF

According to Barea and Azcon (1982) mycorrhizal fungi are capable of elaborating small quantities of growth hormones including auxins, which may help in inducing root production. Kothari *et al.* (1990) found that mycorrhizal inoculation with *Glomus mossea* reduced the total root length and root dry weight of maize plants compared with non-mycorrhizal phosphorus fertilized controls. Osonubi (1994) observed that root length and root dry weight of maize were significantly increased by mycorrhizal infection. But in sorghum total length was increased where as the root dry weight was not influenced by VAM inoculation. The effect of green manure and nitrogen levels and nutrient uptake of rice and wheat and rice wheat sequence was studied by Nair and Gupta (1999). Application of 50 kg P_2O_5 per hectare alone and along with VAM augmented the root length by 47.8 per cent and 50.7 per cent respectively over the control.

Anandaraj and Sarma (1994) observed enhanced rooting in *Glomus fasciculantum* inoculated pepper cuttings. They attributed this effect to increased level of endogenous hormones. According to Ashithraj (2001) AMF inoculation had positive significant difference on root length where as nitrogen fixing bacteria did not show any significant effect in black pepper.

2.2.2.2 Effect of Trichoderma

According to Kumar *et al*. (1993) combination of AMF and *Trichoderma* resulted in higher root length in wheat. 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).

2.1.3 Effect of organic manures on physiological characters

The organic as well as bio-fertilizers greatly influence the growth of plants and thereby various physiological parameters. The effect of different organic manures and biofertilizers on growth and yield of rabi rice revealed higher LAI and DMP at harvest for green manure + Azospirillum treatment and was comparable with FYM + Azospirillum (Nagaraju *et al*., 1995). Rekha (1999) reported highest LAI, RGR and CGR for brinjal plants treated with organic manure and chemical fertilizers in 1:1 ratio. The influence of organic manures on leaf number, LAI, DMP was superior over inorganic fertilizer application (Subbarao and Ravisankar, 2001). Similar results were obtained by Sharma and Mitra (1990) and Kuppuswamy *et al*. (1992).

An experiment on galangal as the intercrop in coconut revealed increase in dry matter accumulation in rhizomes at harvest due to FYM and vermicompost. FYM + NPK and NPK treatment could be attributed to efficient translocation of drymatter into rhizomes (Maheswarappa *et al*., 2000). Nutrient management schedule for white yam under intercropping situation in coconut garden using three sources of organic manures (FYM, coirpith compost, *in situ* green manuring using sun hemp) in main plots and combination of three levels each of N and K (40, 80, 120 kg ha^{-1}) and

n_0k_0 control revealed maximum LAI, NAR, CGR values from plants treated with coirpith compost.

The integrated nutrient management studied in chilli revealed highest RGR, CGR and NAR for vermicompost-applied plots (Sharu, 2000). The effect of different organic manures on growth, yield and quality of turmeric revealed that application of FYM and vermicompost resulted in higher CGR and RGR. NAR was maximum for treatments like vermicompost, green leaves and NPK alone. DMP, LAI, LAD as well as root shoot ratio was highest for FYM and coirpith compost treatment (Rakhee, 2002). Velmurugan *et al*. (2002) tried different treatments like FYM, vermicompost, digested coirpith compost and 50 per cent of recommended dose of fertilizer (62.5 : 30: 45 kg NPK per ha) as main plot treatment and Azospirillum, phosphobacteria, VAM, Azospirillum + phosphobacteria, Azospirillum + VAM, phosphobacteria + VAM, Azospirillum + phosphobacteria + VAM as sub plot and with control (without any inoculation) in turmeric. The application of FYM + Azospirillum + phosphobacteria + VAM recorded larger leaf area, leaf area index, photosynthetic rate, specific leaf weight, DMP, harvest index and yield over other treatments.

2.2.3 Effect of microbial inoculants on physiological parameters

In amaranthus the physiological parameters were influenced by dual inoculation of Azospirillum and AMF with higher dose of chemical fertilizer (Niranjana, 1998). Bio-fertilizers significantly and favourably influenced the parameters LAI, NAR, RGR and HI in peas (Vimala and Natarajan, 2002), which could be attributed to physiological changes in plant on exposure to the action of growth promoting substances (Thimman, 1974) like auxin and gibberillins (Naumova *et al*., 1962, Broadbent *et al*. 1977, Barea *et al*., 1976) synthesized by inoculated microorganisms.

2.1.4 Effect of organic manures on yield and yield components.

2.1.4.1 Effect of FYM

Farmyard manure serves as a good source of almost all plant nutrients. The results of the permanent manurial experiments conducted at Coimbatore since 1909 revealed that the effect of farmyard manure on the first 36 crops was inferior to that of complete mineral fertilizers (NPK) whereas the yields from the 37th crop onwards indicated a relatively better performance of FYM. The same situation in favour of FYM over NPK existed till the 82nd crop (Krishnamoorthy and Ravikumar, 1973). In the long-term field experiment for seven years at Jalandhar, Sharma *et al.* (1988) revealed that FYM was more effective in increasing tuber yield to potato than green manuring with daincha. The results of a long term fertilizer experiment conducted at Tamil Nadu Agricultural University, Coimbatore, in a mixed red and medium black soil for a period of sixteen years revealed significant differences in the yield of finger millet maize and cowpea due to FYM application (Muthuswamy *et al.*, 1990).

An experiment conducted at Karnataka revealed 30.6 per cent yield increase over control in sweet potato and 11.8 per cent yield increase in cassava over control due to FYM application (Gaur *et al.*, 1984). According to Joseph (1998) yield attributing characters like length, weight and number of fruits per plant were highest for snakegourd in plants applied with FYM and FYM to substitute NPK. Application of FYM alone resulted in higher yield in yam (Mohankumar and Nair, 1979) in amorphophallus (Patel and Mehta, 1987) in turmeric (Balashanmugham *et al.*, 1989) in arrowroot (Vidhyadharan, 2000).

The performance of kacholam under varying levels of N, P_2O_5 and K_2O with and without organic manure was tried (Bai and Augustin, 1998) for two crop years. The results showed that during 1994-95, application of FYM @ 20 t ha^{-1} could increase the yield of rhizomes by 2.03 times as compared to that of absolute control. Application of N, P_2O_5 and K_2O @ 40: 20: 20 kg ha^{-1} over a basal incorporation of FYM @ 20 t ha^{-1} during

1994-95 resulted in getting the highest yield of 2597 kg ha^{-1} were as during 1995-96 it was with the application of 80:40:40 kg ha^{-1} of N, P_2O_5 and K_2O respectively along with FYM @ 20 t ha^{-1}. Application of varying levels of N fertilizers did not affect the yield of Kacholam during both the year of experimentation. The effect of organics and inorganics in betelvine (Arulmozhiyan *et al.*, 2002) revealed highest yield attribute by the application of FYM at 200 kg N/ha. According to Rakhee (2002) the rhizome spread of turmeric was influenced by organic manures only at 8 MAP and was maximum for coirpith compost treatment, which was on par with FYM.

Increase in yield due to combined application of FYM and inorganic fertilizer was reported in ginger by Pawar and Patil (1987). Field experiments were conducted at ICAR, Research Complex Farm, Umiam, Meghalaya during kharif 1999 and 2000 to study the response of ginger to phosphorus sources (rock phosphate and SSP), FYM and mother rhizome removal. Maximum rhizome yield of 19.5 to ha^{-1} was noticed with the application of rock phosphate + FYM without mother rhizome removal which was at par with SSP + FYM. Addition of FYM also significantly increased the rhizome yield irrespective of mother rhizome removal and the interaction of phosphorus x FYM was also significant on rhizome yield (Venkatesh *et al*., 2003).

2.1.4.2 Effect of vermicompost

Vermicompost is a potential organic manure and is rich source of major and minor nutrients to the plants. According to Phule (1993) vermiculture in sugarcane resulted in significantly higher yield. Barve (1993) found an increase in fruit yield with the application of vermicompost to grapes. Dharmalingam *et al*. (1995) studied the effect of vermicompost pelleted soybean seeds and reported 16 per cent increase in yield over non-pelleted seeds. An experiment conducted at College of Agriculture, Vellayani to find out the effect of different sources and levels of organic manures on yield and quality of amaranthus, revealed maximum yield for vermicompost treatment @ 25 t ha^{-1} during all the harvest except the third harvest where it was second to FYM @ 93.75 t ha^{-1}. Higher levels of two manures were always superior to package of practices recommendations of Kerala Agricultural University (Arunkumar, 2000).

Rajalekshmi *et al*. (1997) in their studies on various organic manures in combination with chemical fertilizers, NPK @ 75:40:25 kg ha^{-1}, on chillies found that the yield was the highest (8.36 t ha^{-1}) in the treatment receiving vermicompost + NPK fertilizers and the lowest in vermiculture alone. Combined use of organic and inorganic fertilizers with the objective to find out the benefits of vermicompost, neem cake and FYM along with biofertilizers in improving the yielding ability of chilli cultivars, K_2 and Sindhur was studied (Ankarao and Haripriya, 2003). Among the various organic manures incorporation of vermicompost (5 t ha^{-1}) was considered as the best in improving all the characters. Application of recommended dose of fertilizers ranked second for *per se* performance of both varieties. Application of neemcake ranked next to plots treated with recommended dose of fertilizers.

Vadiraj *et al*. (1996) reported that vermicompost application alone or in combination with inorganic fertilizers was found to increase the yield of turmeric. Among organic manures tested by Maheswarappa *et al*. (1997) in arrowroot intercropped in coconut garden, vermicompost recorded highest rhizome yield compared to composted coirpith.

2.1.4.3 Effect of Neemcake

Islam and Haque (1992) considered oilcake as a good organic manure to be applied during land preparation of brinjal, chilli and bhindi for getting higher yield. Som *et al*. (1992) who observed highest fruit yield in brinjal plants treated with neem cake @ 50 q ha^{-1} compared to other oil cakes. A study conducted at Kerala Agricultural University, Vellanikkara, revealed that the optimum ratio of organic manure to inorganic N for banana was 25:75 and the best source of organic manure was neemcake containing 5.2 per cent N (950 g plant^{-1}) followed by FYM containing 0.4 per cent N (12.5 kg plant^{-1}) (KAU, 1993).

Kadam *et al*. (1993) compared the effect of organic and inorganic sources on the yield of betelvine. Among various sources tried namely, neemcake, karanj cake, neemcake + urea and urea alone, application of N through neem cake produced significant response in increasing the yield.

Application of neemcake @ 1 t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990). According to Sadanandan and Hamza (1998) application of organic cakes increased the yield in ginger.

2.1.4.4 Effect of green leaves

The effect of green manure crops incorporated at 60 days after sowing on the yield of the succeeding rice crop and on nitrogen status of the soil was evaluated at Coimbatore. Plots incorporated with green manure crops had about 200 per cent higher grain yield than non manured plots (Sanyasi Raju, 1952).

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

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

The experiment conducted to develop a nutrient management schedule for white yam under intercropping situations revealed that application of FYM, coirpith compost and *in situ* green manuring using sun hemp produced similar effects in promoting tuber weight, length and girth of tubers (Suja, 2001).

2.2.4 Effect of microbial inoculants on yield and yield characters

The effect of bio-fertilizers on yield characters of ginger as revealed by Nath and Korla (2000) revealed maximum yield from azofert treated bio plants compared to all other treatments.

A two year experiment conducted on pea revealed that combined application of Rhizobium inoculation with phosphorus and potassium fertilizers increased yield by 122.7 per cent as compared to control. Rhizobium and fertilizer inoculation of *Pseudomonas striata* to pea seed also increased green pod yield by 25.66 per cent over uninoculated (Kanaujia and Narayan, 2003).

2.2.4.1 Effect of AMF

The yield of peppermint was found to be significantly increased compared to control through inoculation of VAM fungi (Khaliq *et al*., 2001). Experiments were conducted on Azotobacter, Azospirillum alone and their combined effect with phosphobacteria (VAM) and it was found that combined application of Azotobacter and nitrogen application increased yield by 18 per cent more than applying nitrogen fertilizer alone. In another trial combined application of Azospirillum and phosphobacteria increased yield by 18.3 per cent as well as saved 25 per cent of inorganic fertilizer and thereby reduced cost of cultivation in onion. In the case of chilli plants inoculated with mycorrhiza biofertilizers (without phosphorus) more number of fruit and fruit yield resulted as compared to uninoculated plants which received 75 kg phosphorus per hectare (Kanaujia and Narayan, 2003). Research trial was conducted on integrated nutrient management on five year old vanilla during 2001-2002 consisting of 25 g each of VAM, Azospirillum and phosphobacteria and four levels of NPK namely 25, 50, 75 and 100 g per vine per year. Biometric observation on number of fruits per vine, bean length, bean girth, single bean weight, and bean weight per vine indicated maximum values for 25 g each of VAM, Azospirillum and phosphobacteria per vine per year combined with 100 kg NPK per vine per year (Parthiban and Easwaran, 2003).

2.2.4.2 Effect of Trichoderma

Joseph (1997) recorded maximum rhizome yield in ginger plants inoculated with *Trichoderma viride* and AMF.

The combined application of neemcake (150 kg ha^{-1}) along with seed treatment using *Trichoderma viride* recorded maximum yield in fenugreek (IISR, 1998).

2.1.5 Effect of organic manures in quality aspects

Productions of quality spice and value addition to the produce are at paramount importance in the present scenario of globalization leading to free trade. The growth trend in the exports of value added spices such as spice oils and oleoresins indicate that these items would take over the top lot in spices exports. With the global food industry increasingly turning towards oils and oleoresins that have a natural flavour, the scope of India to earn enormous foreign exchange through aggressive marketing of these value added spices is indeed bright (Manojkumar and Sivaraman, 2002).

Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds were reported by the application of organic manures (Rani *et al*., 1997). According to Arunkumar (2000) quality of amaranthus like vitamin C, fibre and protein content improved with various organic manures.

Performance of kacholam under varying levels of organic and inorganic fertilizers were studied by Bai and Augustin (1998). An increase in oil yield from 18.9 to 28.4 l ha^{-1} was noticed by the use of organic manures. In turmeric application of organic matter favoured increase in curcumin and oleoresin contents (Nampoothiri, 2001). The effect of organics *viz.,* goat manure, chicken manure, pig manure, Farmyard manure and chemical fertilizers and untreated control on black pepper was studied. Among the organic sources pig manure though influenced oleoresin and piperine in pepper marginally, the difference were not significant statistically (Sadanandan and Hamza, 2002).

2.1.5.1 Effect of FYM

Kansal *et al*. (1981) opined that application of 20 t of farmyard manure per hectare increased the ascorbic acid content in spinach leaves. Ravindran and Balanambisan (1987) observed that the quality of tubers in sweet potato was not much affected by different doses of FYM. Application of FYM @ 12.5 t ha^{-1} enhanced the quality of cassava tubers as reported by Mohankumar *et al*. (1976) and Pillai *et al*. (1987). According to Vidhyadharan (2000) highest protein content in arrowroot was recorded by highest level of FYM (20 t ha^{-1}) and N (120 kg ha^{-1}).

2.1.5.2 Effect of vermicompost

Vermicompost applied alone or in combination with organic and inorganic fertilizers resulted in better yield and quality of different crops (Gavrilov, 1962; Tomati *et al*., 1983;Bano *et al*., 1987). Considerable scientific data were generated to testify that the produce obtained with the use of vermicompost is nutritionally superior, tastes good, has good texture and have better keeping qualities (Lampkin, 1990). In sugarcane, the quality of produce was increased when vermiculture was adopted. Vermicompost has a definite advantage over other organic manures in respect of quality and shelf life to the produce (Khankar, 1993). Barve (1993) reported the superiority of vermiculture farming in grape cultivation when compared to chemical farming.

2.1.5.3 Effect of Neemcake

According to Sadanandan and Hamza (1996) neemcake application was found to be superior with regard to curcumin recovery in turmeric.

2.1.5.4 Effect of green leaves

The quality of rice was found to be improved by the application of green manures. More protein, phosphoric acid and potash were reported from green-manured rice (Murthy, 1978). Thampan (1993) also reported improved quality of food grains and fruits as a result of green manure application.

2.2.5 Effect of microbial inoculants on the quality aspects

Inoculation with Azospirillum increased capsaicin and ascorbic acid contents in chilli (Balakrishnan, 1988). Amrithalingam (1988) recorded highest ascorbic acid and capsaicin content in Azospirillum treatment. Chattoo *et al.* (1997) observed that in Knol Khol, Azospirillum increased yield and quality attributes over control. Niranjana (1998) observed least fibre content in treatment which received Azospirillum inoculation with 75 per cent of package of practices recommendations of Kerala Agricultural University in amaranthus.

The field trial with three levels of nitrogen (0, 30 and 60 kg ha^{-1}) and each level integrated with both single and combined inoculation of Azotobacter and Azospirillum revealed that inoculation increased the curcumin and protein content in turmeric and dual inoculated treatments showed better curcumin content combined to single inoculated and uninoculated treatment at the respective nitrogen levels. The investigation suggested dual inoculation of Azotobacter and Azospirillum along with fertilizer nitrogen (30 kg ha^{-1}) for quality improvement in turmeric (Jena and Das, 1997).

The influence of different organic manures and Azospirillum on growth, yield and quality of ginger was reported from KAU (1999). The results revealed 15 per cent increase in essential oil content where 25 per cent of N were substituted through Azospirillum and was on par with FYM alone treatment. The oleoresin content as well as the dry recovery was not significantly influenced by the treatment.

2.2.5.1 Effect of AMF

Green chillies having higher ascorbic acid content were obtained when plants were inoculated with AMF (Bagyaraj and Sreeramulu, 1982). 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* or *Cymbopogon winterianus* Jowitt have more essential oil than in control plants (Ratti and Janardhan, 1996). AMF inoculation was also found to enhance major derivatives of the oil. In geranium the cumulative herbage yield (103.32 t ha^{-1}) and essential oil yield (172.36 kg ha^{-1}) were significantly higher under fertigation with 80 per cent NPK + Azotobacter + Azospirillum + VAM biofertilizers in all the three seasons (Pasha *et al*., 2003)

2.2.5.2 Effect of Trichoderma

The total protein content produced by *Trichoderma* sp. treated chickpea was significantly higher compared to the untreated chickpea roots (Srivastava *et al*. 2002).

2.3 Soil characters

2.3.1 Soil physical properties

2.3.1.1 Effect of organic manures on soil physical properties

Soil is one of the land resources and a component of the terrestrial ecosystem. In the modern farming systems developed in India since the mid sixties, the objective has been to maximize production at any cost. Increasing quantities of external inputs such as fertilizers, plant protection chemicals and irrigation water have been used with little reliance on the maintenance of soil organic matter. Consequently the traditional agronomic practices such as green manuring, use of farm wastes either as such or after composting and other soil ameliorative measures have not become part of the farming systems. This has resulted in a slow but steady decline in the productive and recuperative capacity of the soil.

Organic matter, though seldom exceeds one per cent in Indian agricultural soils, regulates the physical, physico-chemical, chemical and biological environment of the soil at levels favourable for crop production. The organic residues that are added to the soil undergo microbial decomposition. In the process, various organic acids and other products of decay are released which act as strong binding agents in the formation of large and stable soil aggregates. The action of gum compounds, polysaccharides and fulvic acid component of organic matter is considered important in this respect. As a result, the soil structure is improved which is reflected in low bulk density values and better water conducting properties of the soil (Manickam, 1993).

Muthuvel *et al*. (1982) reported a decrease in the bulk density with increase in organic matter content due to better aggregation. Loganathan (1990) reported that application of organic amendments namely sawdust, groundnut shell powder, coir dust and FYM each @ 2.5 and 5 t ha^{-1} improved the soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of red soil with hardpan. Gaur (1994) reported that aggregation is quite often improved by organic manure application, which is attributed to the action of gum compounds of organic matter. The water holding capacity of the soil was increased under all the organic manure treatments, whereas there was no change in the WHC values under NPK alone and control treatments. The WHC increased upto 33.2 per cent from the initial values of 28 per cent under organic manure treatments.

In the All India Coordinated long-term fertilizer experiments, application of inorganic nitrogen continuously for 15 years increased bulk density and reduced the soil water retention at different locations (Nambiar, 1994).

2.3.1.1.1 Effect of FYM

The favourable effect of farmyard manure application on the structural properties of the soil were observed by several investigations (Biswas *et al*., 1969 and Muthuvel *et al*., 1982). Havanagi and Mann (1970) reported that a continuous application of FYM decreased the bulk density of soil. Aravind (1987) observed that when farmyard manure was applied as an organic source of nitrogen, bulk density of soil lowered from 1.30 to 1.06 g cc^{-1} compared to the poultry manure application, which lowered the same from 1.30 to 1.10 g cc^{-1}. Maheswarappa *et al*. (1998) found a decrease in bulk density due to recycling FYM and poultry waste in coconut based mixed farming systems. Maheswarappa (1999a) studied the influence of planting material, plant population and organic manures on yield of East Indian galangal as well as the change in soil physico-chemical and biological properties. The bulk density of soil decreased from 1.38 g cc^{-1} in FYM @ 32 t ha^{-1} from the initial value of 1.55 g cc^{-1}. There was no change in the bulk density under NPK alone and control. According to Singh *et al*. (2000) application of FYM significantly brought down the bulk density of both surface and subsurface soils in comparison with the control. However application of different levels of fertilizer did not affect the bulk density.

Increase in soil moisture retention due to addition of FYM was observed by Salter and Williams (1963). Biswas *et al*. (1969) observed that application of farmyard manure in a rice fallow rotation for ten years improved the water retention characteristics of an alluvial sandy loam soil. Loganathan (1990) reported an increase in total soil porosity from 42.6 to 44.0 per cent when the rate of application of farmyard manure was raised from 2.5 t ha^{-1} to 5 t ha^{-1}. Shinde and Gawade (1992) reported that application of 100 kg N per ha as FYM increased the structural index (32.3) over the application of NPK (28.5), NP (29.0) and N alone (25.4).

FYM is beneficial in increasing the water stable aggregates in the soil (Kanwar and Prihar, 1982). Nambiar and Ghosh (1984) while reviewing the results of long term fertilizer experiments, have observed marked increase in the water stable aggregates and mean weight diameter due to farmyard manure application in red and black soils of Hyderabad, Coimbatore and Jabalpur.

2.3.1.1.2 Effect of vermicompost

Kala and Krishnamoorthy (1981) described the role of earthworms in the degradation of organic wastes and in improving the physio-chemical properties of soil. 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). Vijayalekshmi (1993) reported that soil physical properties such as porosity, soil aggregation, soil transmission and conductivity of wormcast applied soil was higher when compared to no wormcast amended soil in paddy. Maheswarappa *et al.* (1999b) studied the effect of organic manures on soil physical properties and reported that vermicompost application decreased the bulk density of the soil to a greater extent.

2.3.1.1.3 Effect of neemcake

Biswas *et al*. (1969) found that application of groundnut cake in a rice fallow rotation for ten years improved the water retention characteristics of an alluvial sandy loam soil.

Sadanandan and Hamza (1998) reported improved physical condition of the soil as a result of organic cake application in ginger.

2.3.1.1.4 Effect of green leaves

Continuous use of green manures decreased the bulk density of soil (Havanagi and Mann, 1970) The effect of glyricidia pruning on soil properties and their performance on white yam was study by Otu and Agboola (1991) and reported 14 per cent decrease in soil bulk density. Ramakrishnan and Rangarajan (1993) reported that green manuring has a positive influence on the physical and chemical properties of the soil.

2.3.1.2 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. In this context, the production and use of biofertilizers in agriculture assume considerable importance (Verma, 1993).

Aggregation and aggregate stability are of fundamental importance in determining agricultural capacity of the soil (Bryan, 1969). Microorganisms have been shown to promote soil aggregation and thus indirectly influence root environment and plant growth. Polysaccharides have an important role in soil aggregate formation and stability and these 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 hyphae, 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 (1978) observed improved soil texture due to arbuscular mycorrhizal associations. Tisdale and Oades (1982) observed that under plants macro aggregates were stabilized mainly by roots and VAM hyphae.

The foregoing review reiterates the need for enriching agricultural lands with crop residues and other sources of organic matter as well as biofertilizers so as to improve the soil physical conditions and productivity.

2.3.2 Soil nutrient status

2.3.2.1 Effect of organic manures on soil nutrient status

Organic manures and fertilizers greatly influence the nutrient status of the soil namely available N, P, K organic carbon and soil pH. There are many reports in this effect. Soils high in organic matter are considered to be fertile ones. This is mainly due to the gradual release of nutrients from organic matter on mineralisation eventhough the quantum of nutrients released from organic matter may be low as compared to that from inorganics, the overall fertility status of cultivated soils is influenced by the organic fraction through exchange reactions, chelations and buffering. In fact most of the nitrogen and a higher proportion of the phosphorus and sulphur present in the soil are held in organic combinations which, become available to the crop on mineralisation (Manickam, 1993).

The intensive and exploitive agriculture practiced for long has caused a rapid decline in the organic matter content of the soils. The organic carbon content in unfertilized and unmanured soils has been found to be reduced by half within ten years of cultivation. Nitrogen alone through fertilizer has also caused a decrease of organic carbon. However, when fertilizer was combined with farmyard manure, the organic carbon content could be maintained at the original level, though not increased. The decline in soil organic matter content is followed by a corresponding decline in the fertility and productive capacity of the soil. This declining trend could be arrested by the adoption of appropriate soil resource management (Manickam, 1993).

Increases in the available nitrogen content of soil and increased nitrogen recovery due to organic sources of nitrogen have been reported by several workers (Muthuvel *et al*., 1977 and Srivastava, 1985). Besides available nitrogen, organic carbon and total nitrogen concentration (Muthuvel *et al*., 1979; Subramanian, 1986) and the enzyme activity are also favourably influenced by organic sources of nitrogen (Damodaran, 1987).

Phosphorus is present in the soil in both inorganic and organic forms. Inosital phosphates, the major constituent of organic phosphorus in the soil, have to undergo microbial decomposition before becoming available to crops. As in the case of nitrogen, the organic phosphates on appearance are also appropriated by the microbial population causing temporary immobilization of the nutrient. The most important contribution of organic matter in the phosphorus nutrition of plants is the release of phosphates from the soil minerals. The organic acids and humus formed in the course of decomposition of organic substances form complexes with iron and aluminium compounds in the soil and consequently reduce inorganic phosphate fixation in the soil. The beneficial effects of organic on the mobilization of soil phosphorus have been reported by Sivasamy (1982).

Organics also serve as a source of potassium. The soil organic matter because of its high absorptive capacity usually carries substantial amounts of exchangeable potassium. Muthuvel *et al*. (1977) while studying the physico-chemical properties of soil in the permanent manurial experiments have also observed the favourable influence of organic manures in enhancing the available potassium content of soils.

Increase in organic carbon content of soil due to combined application of inorganic and organics continuously for a period of ten years was observed in the long term fertilizer experiment being conducted under the co-ordinated programme of the Indian Council of Agricultural Research (Nambiar and Ghosh, 1984). Carbon content of soil increased from 0.91 to 1.58 per cent by the continuous application of organic manures (Udayasooriam *et al*., 1988).

Yang *et al*. (1994) reported from Taiwan that soil pH was increased by the application of organic manures like pig and chicken faeces, animal and plant residues and municipal residues. On the other hand, the Japanese scientists Kitamura and Nakane (1994) observed that application of conventional organic fertilizers reduced soil pH and increases soil electrical conductivity. According to Igbokwe *et al*. (1996) pH was highest with the organic farming system. The soil samples taken at the end of an organic farming trial indicated an increase in pH in plots applied with compost (Roe *et al*., 1997).

2.3.2.1.1 Effect of FYM on available N, P, K organic carbon and soil pH

Higher efficiency of FYM in producing higher yield and improving chemical properties of soil compared to castor oilcake and urea was reported by Gomes *et al*. (1993).

Kabeerathumma *et al*. (1990) and Susan *et al*. (1998) in a long term manurial experiment after thirteen years of continuous cropping observed increased nutrients like N, P, K and organic carbon with the inclusion of FYM and application of respective nutrients to the soil.

The results of the study carried out at Central Research Institute for Dry land Agriculture, Hyderabad during 1994 to evaluate the releasing pattern and availability of P from different soil types of Ranga Reddy district of Andra Pradesh shows that increasing levels of FYM and applied P increased the available P in all types of soils. The P availability was increased at 30 days of incubation as compared to 15 days with FYM whereas without FYM it increased with increase in the incubation (Saravanapandian, 1998).

Increased availability of potassium due to the combined application of FYM with 100 per cent recommended quantity of NPK in the long term fertilizer experiments was reported by Aravind (1987).

The role of FYM application in increasing organic carbon level has been reported by many workers (Biswas *et al*., 1969; Bijay Singh *et al*., 1983; Prasad *et al*., 1983). Kanwar and Prihar (1982) reported that continuous application of farmyard manure increased the organic carbon as well as nitrogen contents of the soil. According to Maheswarappa *et al*. (1998) an increase in the organic carbon and pH of the soil under different treatments except NPK alone and control was reported. Among organic manures, the organic carbon content was increased to 0.380 – 0.381 per cent under FYM and under NPK alone (0.198 per cent) during 1996 – 1997 from the initial value of 0.21 per cent. The organic carbon observed under control plot and NPK alone decreased year after year marginally. Hedge *et al*. (1998) reported that the nutrient (P, K, Mg and Ca) and the organic carbon content of the rhizosphere soil almost doubled when it was supplied with FYM or vermicompost for over two seasons. The soil pH changed to neutrality. However there was negligible difference between vemicompost and FYM with respect to nutrients and organic carbon. In an experiment conducted at KAU (1999) to study the influence of organic manures and Azospirillum on the growth, yield and quality of ginger, the organic carbon content in the soil after the harvest of crop was the maximum in plots supplied with farmyard manure alone (48 t ha^{-1}). The response of ginger to phosphorus sources (rock phosphate and SSP), FYM and mother rhizome removal in acid alfisol at Meghalaya was studied. Available phosphorus content in post harvest soil was the maximum in rock phosphate + FYM treatment where as the other properties *viz.,* pH, organic carbon, and exchangeable cation were at par due to rock phosphate and SSP application (Venkatesh *et al*., 2003).

2.3.2.1.2 Effect of vermicompost on available N, P, K organic carbon and soil pH

The earthworm casts or vermicompost are higher in bacteria, organic matter, total and nitrate N, available P and K (Gaur, 1982 and Brady, 1994). Curry and Boyle (1987) reported enhanced plant growth in the presence of earthworms due to the increased supply of readily available plant nutrients and better soil physical conditions. Scheu (1987) found large amounts of mineralized N in the presence of large earthworm biomass. Increased availability of N in earthworm casts compared to non ingested soil had been reported by several workers (Tomati *et al*., 1988; Tiwari *et al*.,1989; Romero and Chamooro, 1993; Parkin and Berry, 1994 and Rao *et al*., 1996).

Haimi and Huhta (1990) reported that earthworms increase the proportion of mineral N available for plants at any given time although N was clearly immobilized in the initial stage. Reddy and Mahesh (1995) reported an increased availability of N and K in soil by the application of vermicompost compared to FYM. Vasanthi and Kumaraswamy (1996) observed an increase in soil nutrient status due to the application of vermicompost.

Increased concentration of available and exchangeable K content in casts were reported by Lal and Vleeschauwer (1982) and Tiwari *et al*. (1989). According to Maheswarappa *et al*. (1998) organic carbon content was the highest in the vermicompost treated plot (0.39 per cent) compared to FYM, NPK alone and control plot during 1996-97 from the initial value of 0.21 per cent. A perceptible increase in pH was also recorded with the application of vermicompost, FYM and CCP. There was no change in pH under NPK and control treatment.

2.3.2.1.3 Effect of neemcake on available N, P, K, Organic carbon and soil pH

Most of the non-edible oil cakes contain alkaloid contents, which inhibit the nitrification process of nitrogen transformation in soils. Neemcakes contains the alkaloids, nimbin and nimbidin, which effectively inhibit the nitrification (Saharwat and Pamer, 1975; Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981). The application of neemcake added organic carbon and potash to the soil and increased the ginger yield (Sadanandan and Iyer, 1986).

The neem, mahua, karanja and castor oil cakes have great value as means of immobilizers, thus conserving the applied and soil nitrogen and mineralizing steadily over a longer period. They could aid in metered supply of nitrogen over a stipulating period of crop growth (Hulagur, 1993).

Neemcake @ 15 kg per plant along with 600:300:600 g NPK per plant could maintain available NPK status of the soil at the highest level (Borah *et al*., 2001).

2.3.2.1.4 Effect of green leaves on available N, P, K, Organic carbon and soil pH

Prabhakar and Nair (1987) noted that incorporation of green manure cowpea in a cassava field could improve the nitrogen status of the soil from the initial level of 0.075 per cent to 0.083 per cent. Enhancement in the available N, P, K and organic carbon contents of soil due to green manuring *in situ* was also noted by Nayar *et al*. (1993). According to Hedge *et al*. (1995) green manuring can aid in recycling of nutrients from the deeper profiles into the root zone of cardamom.

Integrated management of green leaf compost, crop residues and inorganic fertilizers in rice-rice system were studied by Raju and Reddy (2000). The organic carbon status of soil increased substantial in most of the treatments compared with its initial level. Supply of NPK through chemical form caused heavy depletion in a long run.

The experiment conducted by Hemalatha *et al*. (2000) revealed that use of different organic sources like daincha, sun hemp, FYM and control significantly improved the soil fertility status and it was pronounced by the daincha incorporation by increasing available soil N, P, K and organic carbon at post harvest stage. According to Suja (2001), green manuring enhanced the available N, P and K status of the soil profoundly.

2.3.2.2 Effect of microbial inoculants on available N, P, K, organic carbon and soil pH

Microorganisms induce many biochemical transformations in the soil. These include mineralisation of organically bound forms of nutrients, exchange reactions, fixation of atmospheric nitrogen and various other changes leading to better availability of nutrients already present in the soil. The group of microorganisms responsible for nitrogen fixation, phosphorus solubilisation and compost decomposition are being put to beneficial use in the form of biofertilizers. There are some microorganisms capable of solubilizing insoluble soil phosphorus while some collect available phosphorus from remote places out of reach of plant root hairs by sending elongated filaments (eg: Vesicular Arbuscular Mycorrhiza). Few of the heterotropic organisms decompose cellulose rapidly. Such beneficial organisms are domesticated in suitable carriers which on application to soil augment crop growth and yield. These carriers are slangishly called biofertilizers or approximately called bio inoculants (Verma and Bhattacharyya, 1992) or microbial inoculants (Subba Rao, 1988) or microbial fertilizers (Tilak, 1991).

Inadequate phosphorus is one of the major factors limiting plant growth in many soils. Application of P fertilizers can be both expensive and ineffective because of high capacity of soil to adsorb or fix P in forms unavailable to plants (Menge *et al.*, 1983). VAM fungi have been proposed as a low input solution to this problem. In phosphate deficient soils immobile phosphate ions develop a phosphate depletion zone around the roots. The hyphae reach beyond this zone and directly translocate nutrients from the soil to the cortex (Hayman, 1983).

VA mycorrhizal hyphae obtain their extra phosphate from liable pool rather than dissolving soluble phosphate. Sparingly soluble rock phosphate is better utilized by the hyphae by close physical contact with the ions dissociating at the particle surface (Raj *et al.*, 1981). Subbiah (1990) reported that when adequate amount of farmyard manure added to the soil with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of soil.

Tilak and Dwivedi (1990) reported improved assimilation due to VAM. The VAM inoculated papaya varieties showed significant increase in the N, P, K content compared the control (Kennedy and Rangarajan, 2001). Effect of four species of VAM fungi and P on leaf and soil mineral nutrient status of apple seedling was studied by Sharma *et al.* (2002). 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 convert the unavailable nutrient content from the rhizosphere soil to available form resulting in increased contents of P, Zn, Cu, Mn and Fe.

2.4 PLANT ANALYSIS

2.4.1 Effect of organic manures on uptake of N, P, K

Sureshlal and Mathur (1989) while studying on crop yield under varied conditions reported that continuous use of inorganic fertilizers alone has detrimental effect on crop production whereas their combination with FYM can regulate the nutrient uptake from the soil besides improving the quality and quantity of crop produce. Deiz (1989) reported that nitrogen uptake by wheat was much greater in the manure, compost or peat treatments than in the inorganic control.

Susan *et al*. (1998) reported that inclusion of FYM favour the uptake of N and Zn in cassava. The experiment of organic manures and Azospirillum on growth, yield and quality of ginger revealed that the treatment involving farmyard manure alone at 48 t ha^{-1} substituting 50 per cent N and 25 per cent N through Azospirillum recorded higher total uptake of N, P and K at 180 DAP (KAU, 1999). The response of ginger to phosphorus sources (rock phosphate and SSP), FYM and mother rhizome removal revealed significantly increased N, P and K uptake by rhizomes due to application of P sources and FYM (Venkatesh *et al*., 2003).

Kale *et al*. (1992) found significantly higher levels of uptake of N and P in rice treated with vermicompost. According to Anina (1995) application of Eudrillus compost increased the uptake of nutrients by plants. According to Reddy and Mahesh (1995) application of vermicompost increased the N and P uptake in green gram compared to FYM. Increased uptake of nutrients and higher yield in tomato (Pushpa, 1996) and chilli (Rajalekshmi, 1996) were reported by the application of vermicompost.

In rye grass, neemcake and karanja cake improved the uptake of nitrogen especially at higher level of application (Hulagur, 1993).

Nayar and Potty (1996) observed higher uptake of N and K in cassava under green manuring. Pellet and Elsharkawy (1997) was of the view that the unfertilized cassava plant removes 40 kg ha^{-1} where as the fertilized could accumulate more than 100 to 120 kg ha^{-1} of K. Nair and Gupta (1999) reported that the total N uptake by rice was not significantly influenced by green manuring. However, the different N level significantly influenced total N uptake in the second year. The total P uptake was significantly influenced by green manuring in the first year only. The green manuring however did not significantly influence the total K uptake on both years.

2.4.2 Effect of microbial inoculants on N, P, K uptake

There is well-documented evidence that VAM mycorrhizae have important effects on plant P uptake. Greater soil exploration by mycorrhizal roots as a means of increasing phosphate uptake was well established. Mosse (1973) reported an increased uptake of relatively immobile element especially P, Zn, Cu, S, Mn and Fe in AMF inoculated plants than uninoculated plants. Gaddeda *et al*. (1984) reported that P concentration in apple leaves increased from 0.04 to 0.19 per cent by inoculation with *Glomus fasciculatum* in park dale soil with an exchangeable P content of 13 ppm. Higher uptake of N, K, Ca, Mg, Zn and 20 per cent increase in P content was observed in mycorrhizal papaya seedlings than non mycorrhizal. Shivasankar *et al*. (1988) reported that mycorrhizal plants showed a significant increase in tissue N, P and leaf nitrate reductase activity when compared with control. The higher uptake of soil nutrients, particularly less mobile nutrients by AMF was attributed to greater volume of soil explored by the external AMF hyphae (Marschner and Dell, 1994; Jacobson, 1995). Combined inoculation of *Glomus faciculatum*, *Azospirillum braziliens*, Phosphobacteria and digested organic supplements resulted in better growth and nutrient uptake in tea (Rajagopal and

Ramaretinam, 1997). Increased uptake of P, Cu and Mn by AMF inoculated plants has been reported Wang *et al.* (1997) in tea.

Integrated nutrient management studies in betel vine by Mozhiyan and Thamburaj (1998) revealed highest uptake of N, P, K, Ca and Mg with the application of Azospirillum along with FYM and nitrogen through inorganic way. 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. The symbiotic association of mycorrhizal fungi enhanced the mineral nutrients especially P, K and Zn acquisition in the peppermint (Khaliq *et al*., 2001). The effect of Azospirillum and graded levels of nitrogenous fertilizers on the growth and yield of turmeric indicated that the application of Azospirillum reduced 50 per cent of the recommended nitrogenous fertilizer besides increasing the fresh rhizome weight 20.68 per cent over recommended dose of fertilizer (Subramanian *et al.,* 2003).

AMF inoculated black pepper cuttings showed increased P and Zn contents against uninoculated plants (Thomas and Ghai, 1988 and Sivaprasad *et al.,* 1992). The effect of various biofertilizers like AMF, N_2 fixing bacteria on establishment and growth of pepper cuttings were studied by Ashithraj (2001). The N and P content increased significantly. However K content was not at all affected by the microbial colonization.

AMF inoculation in cardamom increased P uptake (Thomas *et al*., 1994). An increased uptake of P was also reported by Sreeramulu and Bagyaraj (1999) in cardamom seedlings inoculated with *Glomus monosporium*.

According to Joseph (1997) the combined use of AMF and *Trichoderma* in ginger increased K uptake.

2.5 EFFECT OF ORGANIC MANURES ON PEST AND DISEASE INCIDENCE

The constant use of chemical pesticides and fungicides may bring about many environmental and ecological problems, which are of serious concern to most of us. Ginger being an export oriented crop, the residual toxicity and connected problems are matters of major concern. The increasing awareness about the environmental consequences of fungicide applications and the growing interest for pesticide free agricultural produce promoted many to think of organic farming.

Various amendments like composted cattle manure, poultry manure, sewage sludge and composted wool waste were found to suppress the club root disease caused by *Plasmodiophora brassicae* in field grown Chinese cabbage (Kinoshita *et al*., 1984).

2.5.1 Effect of FYM on pest and disease incidence

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

2.5.2 Effect of vermicompost on pest and disease incidence

Earthworms dispensed *Pseudomonas coirugata* strain 2140 R a biocontrol agent for take all disease (Ryder and Ravira, 1993). The activity of *Apporrectodea trapeziodes,* the larger 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 the influence of earthworms on *Rhizobium* populations. Jiji (1997) reported that vermicompost produced with *Eudrillus euginiae* was significantly superior over control with respect to the count of fungi and bacteria.

2.5.3 Effect of neemcake on pest and disease incidence

Alam and khan (1974) observed that neemcake, mahua cake and mustard cake controlled phytonematodes in the field almost as effective as DD and nemagon. A study on the integrated nutrition management of chilly by Sharu (2000) revealed lowest incidence of bacterial wilt when chemical fertilizers and neemcake were applied in the ratio 3:1 where as highest incidence was noted in plot where package of practices recommendation of Kerala Agricultural University was followed.

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 neemcake alone @ 3.8 t ha^{-1} (KAU 1999). Arulmozhiyan *et al*. (2002) studied the effect of organics and inorganic in betelvine and recorded lowest disease incidence of phytophthora foot rot in vines which received neemcake.

2.5.4 Effect of green leaves on pest and disease incidence

Effect of solar energy and green manures on the control of southern blight of tomato was observed by Tu *et al*. (1987). They found that the green manure gave increased control of the disease compared to plastic covering alone.

2.6 EFFECT OF ORGANIC MANURES ON NEMATODE POPULATION IN THE SOIL

The beneficial effects of organic amendments and plant residues in reducing plant parasitic nematode populations have long been known (Singh and Sitaramaiah, 1973). The productivity of horticultural crops is very much limited by phytonematodes and the loss incurred by these nematodes is magnified when associated with other soil biota in causing complex diseases. The economic loss caused by these nematodes in these crops is ranged from 30 per cent to total failure of crops occasionally. A set of package of practices has been developed to contain the nematodes through chemical and non-chemical methods. Now a days the use of bioagents is considered as one of the best alternative approaches for the management of nematodes as it is safe to environment, no health hazards to human beings and economically viable to farmers (Rajendran *et al*., 2001).

In spices cultivation root knot nematodes are unique since almost all spice crops are infested by these nematodes. Biological control assumes a greater role in the management of plant parasitic nematodes particularly in the export oriented crops like spices (Ramana, 2003).

A study by Vats *et al*. (1998) revealed that application of organic manures like neemcake, poultry manure, spent compost, FYM and biogas slurry improved plant growth of cotton and led to reduction in root knot nematode populations. In the standardization of organic and inorganic fertilizer requirement in banana variety Nendran different organic sources of nitrogen namely FYM, neemcake and FYM + neemcake were tried. The nematode population in soil and root mat was found to be minimum in neemcake treatment and maximum in treatment with nitrogen alone (KAU, 1998).

Vemana *et al.* (1999) observed that among the organic amendments, the highest reduction in the nematode population was in sawdust (25 q ha $^{-1}$) treatments supplemented with nitrogen (30 kg ha^{-1}), phosphorus (40 kg ha^{-1}) and potassium (50 kg ha^{-1}) followed by neemcake (10 q ha^{-1}) poultry manure (50 q ha^{-1}), farmyard manure (100 q ha^{-1}), press mud (25 q ha^{-1}) and caster cake (10 q ha^{-1}) in ground nut. The investigation to find out the effect of biodynamic treatments on the cyst nematodes and yield of potato cv. 'Kufri jyoti' revealed that the treatments involving green manuring with lupin, spraying with horn manure application of decomposed farm yard manure @ 30 t ha^{-1}, biodynamic compost @ 2 t ha^{-1}, application of neemcake @ 12.5 t ha^{-1}, tuber treatment with cowpat pit @ 30 g in 10 l water and intercropping with mustard has reduced the cyst population in the soil (Devrajan *et al*., 2001).

According to Ryder and Ravira (1993) earthworms dispersed *Pseudomonas coirugata* strain 2140 R, a biocontrol agent for 'Take-all diseases'. The activity of *Apporrectodea trapezoids* the larger earthworm, can substantially decrease the symptoms caused by Rhizoctonia in wheat seedlings as reported by Stephen *et al*. (1993). Doube *et al*. (1994) evaluated the control of fungal root diseases of cereal crops using earthworms and bio-control agents and the influence of earthworms on Rhizobium populations.

Neemcake applied @ 1 t ha^{-1} in drenches near the root zone of betelvine at the time of planting of vines was most effective in controlling the root knot nematode and increased the yield of betelvine (Acharya and Padhi, 1988). Sundararaju and Sudha (1993) observed the effectiveness of neem oilcake @ 1 kg palm^{-1} year^{-1} in reducing the nematode population and increasing the yield significantly in arecanut, banana and black pepper under arecanut based farming system. Rao *et al*. (1997) reported that use of aqueous extract of neemcake for seed treatment and soil drenching under field conditions were found effective as application of carbofuran at 2 kg ai ha^{-1} or neemcake at 2 t ha^{-1} for the management of *Meloidogyne. incognita* on okra. Rajani (1998) investigated the effectiveness of neemcake @ 200 g m^{-2} for managing root knot nematode in kacholam. Among neem based formulations (achook, neemark, nimbecidine), achook was found to be the most effective in reducing the penetration, number of root knot galls and final soil population (Mojumder and Basu, 1999) of nematode.

A study conducted by Sheela *et al*. (1995) in ginger revealed that application of neemcake @ 2.5 t ha^{-1} at the time of planting and carbofuran @ 1 kg ai ha^{-1}, 45 days after planting was effective in reducing the population of *Meloidogyne incognita* in soil and root samples. It reduced the root knot index and increased the yield of ginger.

Several indigenous plants have been identified for their nematicidal action on root knot nematode. Studies conducted on the use of green leaves like *Calotropis* sp., *Eupatorium* sp. mango and cashew on okra showed reduced root knot nematode infestation and increased growth of plants (Kumar and Nair, 1976). Jasy and Koshy (1992) reported that chopped leaves of *Glyricidia maculata* 10 g kg^{-1} soil applied on soil as green manure found to reduce the population of *Radopholus similis* and promote the growth of black pepper under pot conditions. Application of calotropis leaves @ 80 t ha^{-1} was found significantly better than neem and castor leaves which was proved as effective as carbofuran granules in reducing the nematode population in betel vine gardens (Subbarao *et al*., 1996). Application of chopped green leaves of neem and *Chromolaena odorata* on soil before sowing significantly reduced the nematode population and improved the yield in the case of okra and cowpea (Sheela *et al*., 1999).

2.7 RESIDUAL EFFECT OF ORGANIC MANURES

Organic manure and phosphatic fertilizers have carry over effect on succeeding crops. About less than 30 per cent of nitrogen and small fraction of phosphorus and potash in organic manure may become available to immediate crop and rest to subsequent crops (Gaur, 1982).

The utilization efficiency of applied phosphatic fertilizer seldom exceeds 15 per cent by the first crop but substantial amounts are left as residue for next crop (Roy *et al*., 1978). In a maize mustard rotation, average direct effect on maize was a yield increase of 763 kg ha^{-1} and a further increase of 145 kg ha^{-1} in mustard yield through the residual effect (Pasricha, 1987).

The residual effect of farmyard manure, fertilizer and biofertilizer on wheat during two season was studied by Patidar and Mali (2002). Application of 10 t ha^{-1} FYM and 75 per cent or 100 per cent recommended dose of fertilizer (N and P) to sorghum during rainy season had significant residual effect on succeeding wheat crop and increased grain yield of wheat. However, the effect of biofertilizers was limited to the immediate crop only. The influence of nitrogen level and residual effect of organic manures on growth, yield and essential oil in ratoon crop of Davana under two irrigation regimes was investigated (Chalapathi *et al*., 2003). The residual effect of farmyard manure resulted in higher fresh herbage yield of 12.21 t ha^{-1} and it was at par with residual effect of vermicompost.

The residual availability of N, P, K and organic carbon as a result of vermicompost application was reported by Kadam (2000). Sharu (2000) observed high residual soil K in plots, which received higher level of neemcake along with chemical fertilizer (3:1).

When green manures are applied there is one fraction that decomposes rapidly, usually during the early growth phase of the crop following incorporation and the other decomposes slowly over a longer period. The first fraction (fast N) determines the potential supply of N to the standing crop and the second fraction termed as 'slow N' (Bouldin, 1988) determines the residual effects. With most green manure crops, the first fraction is 50-80 per cent of total N. Residual effects (N supply to a second crop) are relatively small when green manure is applied only once, but the cumulative effects of several annual applications are appreciable.

2.8 TERMINAL RESIDUES OF PESTICIDES

Insect pests and diseases have been a threat to food and seed since man has started growing crops. Hazardous synthetic pesticides apparently seem to be the only solution to control them, but their use had to be restricted for their environmental toxicity, erosion of beneficial natural enemies, pest resurgence etc. Plant bioproductive had been effectively tried to protect the nature from pesticidal pollution by many researchers (Prakash *et al*. 1989; Tiwari *et al*. 1990). Use of pesticides in India is increasing at the rate of 2-5 per cent per annum and is about 3 per cent of total pesticides used in the world (Sharma, 1997). .

Spices being export oriented crops, chemical control of pests though very effective but not preferred in view of the demand for zero pesticide residue products by the importing countries. Reports on analysis have shown that the spices sold in the market contain varying amount of pesticide residues (Kaphalia *et al*., 1990).

Since spices are always in demand in the industrialized world, the exporting of these basic agricultural commodities can be relied upon to bring in much needed cash to the developing world especially India. Though India was holding the monopoly of spices export till recently, it is facing a tough competition today with the newly emerging spices exporting countries like Vietnam, Guatemala, Indonesia, Brazil etc. India's future exports hence stand the risk of rejection, if they are not free from pesticide residue. Therefore bio-control has been receiving increasing attention as a major component in the integrated pest management programmes of spice crops.

In the study of management of important pests and diseases of cowpea, seed oil emulsions of neem / samadera at 10 per cent concentration gave good control of American Serpentine leaf minor, epilachna beetle and pea aphid. In plots treated with seed oil emulsions of neem/samadera buildup of natural enemy population was noted. Plant extract of *Hyptis suaveolens* (emulsified) at 10 per cent was also on par with malathion 0.05 per cent (KAU, 1998).

In almost all major spice crops, occurrence of natural enemies have been reported by IISR, ICRI, TNAU, KAU etc (Selvan, 2001). The shoot borer, *Conogethes punctiferalis* the leaf roller, *Udaspes folus* and the rhizome scale, *Aspidiella hartii* are the important pests of ginger and turmeric. About 30 species of natural enemies occurring on these pests have been reported so far. *Hymenopteran* parasitoids like *Bracon brevicornis* Wes., *Apanteles* sp. *Myosoma* sp. (Braconidae), *Brachymeria euploeae* (Chaludidae), *Theromia inareolala*, *Angitia trochanterata* Morl. (Ichneumonidae) and unidentified mermithid nematodes and dermapteran were found to be significantly suppressing the population of shoot borers.

A field experiment was conducted to evaluate the efficacy of biorationals in the management of thrips and shoot and capsule borer of cardamom. Among the biorationals evaluated, fish oil insecticidal soap (FOIS) (Na) 2.5 per cent + tobacco extract 2.5 per cent significantly reduced the damage caused by thrips. None of the treatment was effective for the control of shoot and capsule borer infestation on the capsules and all the treatments were on par with the control. Spraying quinalphos (0.05 per cent) reduced the damage caused by thrips (6 per cent) and increased the yield (Rajkumar *et al*. 2002).

There is a need to emphasize the role of eco-friendly bioagents in the farming systems to sustain the productivity without ecological hazards.

2.9 ECONOMICS OF ORGANIC MANURES AND MICROBIAL INOCULANTS

2.9.1 Effect of organic manures on economics

The results of three farming systems organic, integrated and conventional in Australia compared in terms of economic results, fertilizer input and leaching and pest control have revealed that total returns on the organic farming were higher than from the other systems due to high premium on standard product prices (Bhardwaj, 1999).

2.9.1.1 Effect of FYM on the economics

Influence of different organic manures and Azospirillum on growth, yield and quality of ginger was studied (KAU, 1999). The benefit cost analysis indicated that application of FYM @ 48 t ha^{-1} recorded highest return (Rs.120245/-) and benefit cost ratio (2.32 : 1). This treatment gave an additional profit of 32.04 per cent over control (package of practices recommendation of KAU). The effect of different organic manures on turmeric was studied by Rakhee (2002). The results revealed that BC ratio was maximum when coirpith compost was used and it was on par with FYM, vermicompost and poultry manure treatment.

2.9.1.2 Effect of vermicompost on the economics

According to Arunkumar (2000) vermicompost application at highest dose (37.5 t ha^{-1}) gave the maximum BC ratio in amaranthus compared to other treatments.

2.9.1.3 Effect of neemcake on the economics

Economic analysis of different treatment revealed that 80 kg N ha^{-1} through nimin coated urea yielded higher B:C than 100 kg N ha^{-1} through prilled urea (Porwal *et al.* 1993). Raj (1999) found that in okra, FYM + Neem cake application recorded the maximum profit and highest BC ratio. Maximum yield and monitory returns per rupee investment was obtained from 600 g N, 300 g P_2O_5, 300 g K_2O + 15 kg Neemcake/plant/year in acid lime (Ingle *et al.*, 2001).

2.9.1.4 Effect of green manures on the economics

Scarcity and highest cost of FYM necessitated studies on low cost soil fertility management practices for cassava. Field experiments conducted at CTCRI revealed that FYM application to cassava can be substituted by green manuring *in situ* with cowpea (Prabhakar and Nair, 1987, Nayar and Mohankumar, 1989, Nayar *et al.*, 1993; Nayar and Potty, 1996).

2.9.2 Effect of microbial inoculants on economics

According to Pradhan (1994) biofertilizers are not only low cost input but also gives high returns under favourable conditions. The experiment conducted at College of Agriculture, Vellayani to standardize the organic nutrient schedule for bhindi using five organic nitrogen sources, three nitrogen levels two microbial inoculants and one control revealed maximum profit at N_3 level of nitrogen (150 kg ha^{-1}) and Azospirillum inoculation (Asha, 1999). In Rose Mary, three levels of N (50, 75, 100 kg ha^{-1}) and phosphorus (20, 30 and 40 kg ha^{-1}) with a constant level of potash at 40 kg ha^{-1} along with three biofertilizer (azotobacter, Azospirillum and

VAM) was significantly superior over the recommended dose of fertilizers. The cost benefit ratio was 1:4.9 compared to recommended dosage of fertilizers of 1:3.15. The economics of essential oil production emphasized the safe use of biofertilizer in place of recommended dose of chemical fertilizers alone (Anuradha *et al*., 2003).

The effect of biofertilizers on growth, yield and economics of the ginger revealed maximum net returns (Rs.91425/- ha^{-1}) and benefit cost ratio (0.95) with azofert treatment while for NPK, the net returns was Rs.41917/- ha^{-1} and 0.43, the B: C ratio (Nath and Korla, 2000).

2.10. QUALITY ASSURANCE

The consumers of spices the world over are becoming more and more quality conscious . The importing countries are stipulating more stringent quality requirement year after year.

One of the earliest standards for spices was the Agmark grade specification of India. Later American Spice Trade Association (ASTA) gave specifications based mainly on purity and cleanliness including microbiological and insect debris contamination. But with the awareness of dangers of mycotoxin, pesticides and heavy metals, the present emphasis is based on food safety, *ie*., low bacteria Hazard Analysis and Critical Control Points (HACCP) control, less chemical additives or environment management system such as ISO 14000, organic products zero defects etc (Sivaraman, 2002).

2.10.1 International Standards bodies

2.10.1.1 International organization for standardization (ISO)

International organization for standardization (ISO) is a world wide federation of national standards bodies from some 140 countries, one from each country. ISO is a non-governmental organization established in 1947. The mission of ISO is to promote the development of standardization and related activity in the world with a view to facilitating the international exchange of goods and services and to developing cooperation in the spears of intellectual, scientific, technological and economic activity. ISO works closely with the Codex Alimentarius Commission in the area of agriculture and food standardization to avoid duplication of effort, to ensure technical co-ordination, and to prevent any contradictory standards from appearing at the international level (Sivaraman, 2002).

2.10.1.2 Codex Alimentarius Commission (CAC)

The Codex Alimentarius Commission (CAC) shall be responsible for making proposals to, and shall be consulted by, the Directors General of the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO) on all matters pertaining to the implementation of the Joint FAO / WHO Food Standards Programme. Both ISO and CAC are concerned with standards of spices. ISO is dealing mainly with cleanliness of spices and CAC on fixing the maximum residue levels of pesticides and fungicides in spices and spices products (Sivaraman, 2002).

2.10.2 National Standards Bodies and Regulations

National standards bodies are established to formulate national standards and codes of practice, lay down procedures for quality control and testing and establish certification and marking schemes. National standards are adopted and made available to the public by the national standards organization which may be governmental, non governmental or a government supported body. Examples of standards bodies are the Bureau of Indian Standards (BIS), American National Standards Institute (ANSI) and the Association Francaise de Normalization (AFNOR) (Sivaraman, 2002).

2.10.3 Integrated quality assurance

HACCP and ISO 9000 Series

There is an ever increasing emphasis on quality assurance systems in food industry. Mainly ISO 9000 standards and HACCP achieve this. An

ISO 9000 standard provides a frame work for the establishment of internal and external audit to ensure maintenance and demonstration of the quality management systems. HACCP system which identifies evaluates and controls hazards that are significant for food safety, can be applied throughout the food chain from the primary production to final consumption. It enhances food safety besides better use of resources and timely response to problem. Both in the ISO 9000 and HACCP system the principles are very similar as well as so flexible and suited to serve as complementary. The emphasis on both the systems is on prevention of non-conformance of the product. ISO 9000 quality assurance system has a wider scope whereas in HACCP, the scope is mainly focused on food safety and wholesomeness (Sivaraman, 2002).

2.10.4 Quality assurance facilities provided by Spices Board

The spices board has launched various programmes for educating farmers, traders and exporters for improving quality of Indian spices to meet the requirements of the consumers. The spices board had set up the Quality Evaluation and Upgradation Laboratory in 1990. The Spices Board has evolved two major concepts for quality improvement. One is the introduction of the Indian Spices Logo and the other The Spice House Certificate (Sivaraman, 2002).

2.10.5 Exports specifications

For export of spices and spice products the exporting countries have to comply with the specifications laid down by the regulatory agencies in importing countries. Before the liberalization, exporters had to comply with the pre-shipment inspection and quality control as per the AGMARK Grade Specification prescribed by the Directorate of Marketing and Inspection (DMI). Export Inspection Agency under the Export Inspection Council of India, also have the mandate for pre-shipment, inspection and quality control certification. With the liberalisation pre-shipment inspection and quality control was withdrawn and the exporters are free to export the spices and spice products as per the specification prescribed by the importing countries. As per the Memorandum of Understanding (MOU) signed between Ministry of Commerce and Industry, Government of India and the United States Food and Drug Administration (USFDA), export of black pepper to USA can be made with the pre-shipment inspection and quality control certification by Export Inspection Agency.

The most popular specification for spices and herbs the world over is the “ASTA Cleanliness Specification for Spices, Seeds and Herbs”. The unified ASTA, USFDA, Cleanliness Specifications for Spices, Seeds and Herbs was made effective from 1-1-1990. Major producing countries have build up facilities to meet the requirements as per ASTA Cleanliness Specification. The importing countries where they do not have specification for spices, use to request the exporting countries to supply spices as per the ASTA specification. Countries like UK, Germany and Netherlands have laid down Cleanliness Specification for Spices. European Spice Association (ESA) comprising of the members of the European Union has come out with the ‘quality minima for herbs and spices’. This serves as a guideline specifications for member countries in European Union. In addition to the cleanliness specification, the importing countries insist on the specification for parameters like pesticides residues, aflatoxin, trace metal contamination and microbial contamination. The clealinesss specification, the limits for pesticide residues, aflatoxin and microbial contamination prescribed by the major importing countries are given as below.

European Spice Association Specifications of Quality Minima for Herbs and Spices (Amended Version, July, 1997) (Sivaraman, 2002).

1. Extraneous matter	- Herbs 2 %, Spices 1 %
2. Sampling	- (for routine sampling) square root of units or lots to a maximum of ten samples (for arbitration purposes) square root of all containers eg: 1 lot of pepper may = 400 bags, therefore square root = 20 samples
3.Foreign matter	- Maximum 2 %
4. Ash	- Specific for each spice
5. Acid insoluble ash	-Specific for each spice
6. H_2O	-Specific for each spice
7. Packaging	-Should be agreed between buyer and seller, if made of jute and sisal, they should conform to the standards set by CAOBISCO Ref. (502-51-5) of 20-02-95. However, these materials are not favoured by the industry, as they are a source of product contamination, with loose fibres from the sacking entering the product.
8. Heavy metals	-Shall comply with national / eu legislation
9. Pesticides	-Shall be utilized in accordance with manufactures recommendations and good agricultural practice and comply with existing national and / or eu legislation
10.Treatments	-Use of any EC approved fumigants in accordance with manufactures instructions, to be indicated on accompanying documents (irradiation should not be used unless agreed between buyer and seller)
11. Microbiology	-Salmonella absent in (at least) 25 grams, yeast and moulds 10^5 / g target, 10^6 / g absolute maximum *E. coli*, 10^2 / g target, 10^3 / g absolute maximum. Other requirements to be agreed between buyer and seller
12. Off odours	-Shall be free from off odour or taste
13. Infestation	-Should be free in practical terms from live and / or

	dead insects, insect fragments and rodent contamination visible to the naked eye (corrected in necessary for abnormal vision)
14. Aflatoxins	-should be grown, harvested, handle and stored in such a manner as to prevent the occurrence of Aflatoxins or minimize the risk of occurrence. If found, levels should comply with existing national and / or eu legislation.
15. Volatile oil	-Specific for each spice
16. Adulteration	-Shall be free from
17. Bulk density	-To be agreed between buyer and seller
18. Species	-To be agreed between buyer and seller
19. Documents	-Should provide-details of any treatments the product has undergone; name of product, weight, country of origin, lot identification / batch number, year of harvest

Notes of methodology used in setting standards (refer to the following methods when analyzing products)

Moisture	– ISO 939
Total Ash	– ISO 928
Acid insoluble Ash	– 1SO 930
Volatile oil	– ISO 6571

The European Spice Association specification of quality minima for ginger is given below :

Ash % W/W Max	– 8 (ISO)
AIA % W/W Max	– 2 (ESA)
H_2O % W/W Max	– 12 (ISO)
V/O % V/W Min	– 1.5 (ISO)

Oleoresins standards as defined by the US Essential Oil Association are as follows :

Volatile oil content	18-35 ml per 100 g
Refractive index	1.488-1.498
Optical rotation	-30^0 to -60^0C

Ginger oil and oleoresin may be standardized to meet specific product requirement. However, when this procedure is done, the product must be labelled WONF (With other Natural Flavours) with the added natural flavour identify (Plotto, 2002).

2.11 REQUIREMENTS FOR ORGANIC SPICES AND PRODUCTS

To be sold as 'organic' a product must be certified by an accredited certification body. There are slight difference in standards between countries. IFOAM, the International Federation of Organic Agriculture Movement has established organic production, processing and trading standards, and tried to harmonize certification systems world wide. The European Union (EU) has established basic regulation for organic products in 1991 (Council Regulation 2092/91) which apply to all products, marketed as 'organic', 'biologic', 'ecologic', 'biodynamic' or 'similar terms'. Imports may be excepted through procedures conforming to the exporting country's regulations or by review of the certification documents, which accompany each shipment. In the United States the Organic Food Production Act (OFPA) was passed into law in 1990, and since October 2002 has made organic production and processing uniformly regulated across all of United States. The Agricultural Marketing Service (AMS) branch of the US Department of Agriculture is administering the National Organic Programme (Plotto, 2002).

To be labelled 'organic' a product must be grown following organic agricultural practices. Post harvest handling and processing must be done in certified facilities, whether on the farm or in food packing or processing facilities. Only mechanical, thermal or biological methods can be used in organic processing. The use of genetically modified organisms (GMO) (Plants, animals or bacteria) and products of GMO are prohibited in organic production likewise ionizing radiation and sewage sludge are prohibited from organic agricultural practices. Labels of organic products must identify the certification body.

In general the Japanese Organic Standards (Japan Agricultural Standards, JAS) follow the US NOP standards. However, JAS does not allow organic labelling on products that contain less than 95 per cent organic ingredients (the EU and NOP allow labelling “made with organic ingredients” for products that contain between 70 per cent and 95 per cent organic ingredients).

IFOAM, EU and US organic standards include lists that allow the use of specific, synthetic, non-agricultural or non-organic agricultural substances. If a substance does not appear on those lists, it must not be used on an organic product in the process or as an ingredient. Those list differ slightly and operators produced for export markets to Europe, United States and Japan should consult and compare those lists carefully to assure compliance in each country.

To comply with organic standards and practices the operators must document all farming and post harvest activities. The following records must be maintained-farm field map, field history, activity register, input records including purchase, output records including sales, harvest records, storage records, pest control records, movement records, equipment cleaning and labelling. All such documentation must meet specific standards that are enumerated in directives issued by the certification agencies.

In the processing plant, the operator must present an “organic handling plan’ that will show how contamination from prohibited materials and commingling with non-organic products will be prevented. This includes a detailed description of the process, receiving and storage of ingredients and finished products, cleaning and sanitation of the processing equipment, facilities pest management and a documentary ‘paper trial’ that must permanently record all the above.

For the spice and oleoresin production, ionizing radiation and the use of volatile synthetic solvents are prohibited for use in the processing of organic products (Plotto, 2002).

Materials and Methods

3. MATERIALS AND METHODS

The investigation was to study the effect of organic manures and microbial inoculants on growth, yield and quality of ginger. The study carried out in the Department of Plantation Crops and Spices, College of Agriculture, Vellayani was meant to develop suitable organic farming practices for producing export quality ginger.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The field experiments were conducted at the Instructional Farm, College of Agriculture, Vellayani. The area is situated at 8° 30' North latitude and 76° 54' East longitude, at an altitude of 29 m above MSL.

3.1.2 Soil

The soil of the experimental site was red loam and belonged to the Vellayani series under the order oxisol. Texturally the soil is classified as clay loam. The fertility status of the soil was classified as low in available N and K and medium available P.

3.2 SEASON

Two field experiments were conducted from April 2000 to January 2001 and from April 2001 to January 2002. The same plots were used for the second year's study and the treatments were superimposed.

3.1.3 Nature and Cropping History of the Coconut Garden

Coconut garden at the age groups of above 25 years and spaced at about 8 m was used for intercropping ginger for the experiment. Clove was also grown in the interspace of coconut.

3.3 WEATHER

The climate of the experimental site was humid tropical. The mean annual rainfall during the cropping period for the first year was 115.56 mm and for the second year was 214.81 mm. The mean annual maximum and minimum temperatures were 30.08 and 22.26°C for the first year and 30.6 and 21.8^{0}C for the second year. The mean annual relative humidity during the cropping period was 81.84 per cent for the first year and 81.80 per cent for the second year. Data on weather conditions such as temperature, rainfall and relative humidity were obtained from the meteorological observatory, College of Agriculture, Vellayani and is given in Appendix I and graphically depicted in Fig. 2a and 2b.

3.4 MATERIALS

3.4.1 Seed Material and Variety

The planting material of ginger cv. Maran was collected from disease and pest free plants.

3.4.2 Manures and Fertilizers

Four organic manures and two microbial inoculants were used in the experiment. The nutrient content of manures used for the experiment were analysed and the values are given in Table 1.

Doses of farmyard manure, vermicompost, neemcake and green leaves were fixed on equivalent nitrogen basis and applied in beds prior to planting. Quantity of major nutrients added through manures and fertilizers are given in Appendix II.

For the control treatment, urea (46 % N) musooriphos (20 % P_2O_5) and muriate of potash (60 % K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively.

Table 1. Nutrient content of organic manures

Sl. No.	Organic manures	Nutrient content (%)					
		N		P		K	
		Expt I	Expt II	Expt I	Expt II	Expt I	Expt II
1	FYM	0.52	0.58	0.40	0.44	0.48	0.55
2	Vermicompost	0.95	0.90	0.64	0.60	0.48	0.50
3	Neemcake	4.30	4.70	0.80	0.91	1.20	1.36
4	Green leaves	0.40	0.40	0.28	0.30	0.12	0.20
5	Ash	-	-	-	-	1.12	1.10
6	Rock phosphate	-	-	22.00	22.00	-	-
	Microbial inoculants						
1	AMF	Commercial mixed inoculum containing native *Glomus fascicutum*, *Glomus etunicatum* and *Glomus* sp. obtained from the Department of _Plant Pathology, College of Agriculture, Vellayani was used					
2	*Trichoderma*	Commercial inoculum of *T. viride* specific for ginger obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was used.					

Table 2. Treatment combination details (4 x 4 + 2 = 18)

Sl. No.	Treatment combination	Details	Notation
1	FYM + No microbial inoculants	FYM 30 t ha^{-1} + FYM to substitute POP recommendations on N equivalent basis	o_1b_0
2	FYM + AMF	FYM 30 t ha^{-1} + AMF	o_1b_1
3	FYM + *Trichoderma*	FYM 30 t ha^{-1}+ *Trichoderma*	o_1b_2
4	FYM + AMF + *Trichoderma*	FYM 30 t ha^{-1} + AMF + *Trichoderma*	o_1b_3
5	Vermicompost + No microbial inoculants	FYM 30 t ha^{-1} + Vermicompost + ash	o_2b_0
6	Vermicompost + AMF	FYM 30 t ha^{-1} + Vermicompost + ash + AMF	o_2b_1
7	Vermicompost+ *Trichoderma*	FYM 30 t ha^{-1} + Vermicompost + ash + *Trichoderma*	o_2b_2
8	Vermicompost + AMF + *Trichoderma*	FYM 30 t ha^{-1} + Vermicompost + ash + AMF + *Trichoderma*	o_2b_3
9	Neemcake + No microbial inoculants	FYM 30 t ha^{-1} + neemcake + rock phosphate + ash	o_3b_0
10	Neemcake + AMF	FYM 30 t ha^{-1} + neemcake + rock phosphate + ash + AMF	o_3b_1
11	Neemcake + *Trichoderma*	FYM 30 t ha^{-1} + neemcake + rock phosphate + ash + *Trichoderma*	o_3b_2
12	Neemcake + AMF + *Trichoderma*	FYM 30 t ha^{-1} + neemcake + rock phosphate + ash + AMF + *Trichoderma*	o_3b_3
13	Green leaves + No microbial inoculants	FYM 30 t ha^{-1} + Green leaves + ash	o_4b_0
14	Green leaves + AMF	FYM 30 t ha^{-1} + Green leaves + ash + AMF	o_4b_1
15	Green leaves + *Trichoderma*	FYM 30 t ha^{-1} + Green leaves + ash + *Trichoderma*	o_4b_2
16	Green leaves + AMF + *Trichoderma*	FYM 30 t ha^{-1} + Green leaves + ash + AMF + *Trichoderma*	o_4b_3
17	Control (POP recommendation)	FYM 30 t ha^{-1} + urea + mussoriphos + MOP	C_1
18	Absolute control	No manures or fertilizers	C_2

Farmyard manure @ 30 t ha^{-1} was applied uniformly to all plots except absolute control as per POP recommendation. Additional quantity of P and K requirement as per organic manure treatments was applied through rock phosphate and ash. In the control treatment (C_1), manures and fertilizers were applied as per the package of packages recommendations of Kerala Agricultural University (KAU, 1996). The

3.5 METHODS

The field experiment conducted during 2000-2001 was repeated during 2001-2002.

3.5.1 Design and layout of the experiment

Design	:	Factorial RBD (4 x 4 + 2)
Treatments	:	18
Replications	:	3
Material	:	Ginger cv. Maran
Plot size	:	3m x 1m (2 bed consist one plot)
Total number of plots	:	108

The layout plan of the experiment is given in Fig.1. Each replication of the treatment was recorded from two plot and the value represents the average of the two.

3.5.1.1 Treatments

A- Organic manures (N on equivalent basis)

1. O_1 – Farmyard manure
2. O_2- Vermicompost
3. O_3- Neemcake
4. O_4 – Green leaves

B-Microbial inoculants

1. B_0 - No microbial inoculants
2. B_1 – AMF
3. B_2 – *Trichoderma*
4. B_3 – AMF + *Trichoderma*

C- Control

C_1 - 75 : 50 : 50 + FYM 30 t/ha (POP recommendation)

C_2 – No manures or fertilizers

Treatment combination details is given in Table 2.

Block III			Block I			Block II		
o_1b_3	o_1b_3	o_2b_0	o_4b_2	o_2b_1	o_3b_3	o_1b_2	o_2b_3	o_2b_3
o_3b_2	o_3b_2	o_2b_0	o_4b_2	o_3b_1	o_3b_3	o_1b_2	o_4b_2	o_4b_2
o_1b_1	o_1b_1	o_1b_2	o_1b_0	o_1b_0	o_1b_1	o_2b_0	o_3b_0	o_3b_0
o_4b_3	o_4b_3	o_1b_2	o_2b_3	o_2b_3	o_1b_1	o_2b_0	o_3b_2	o_3b_2
o_2b_2	o_2b_2	o_3b_1	o_3b_1	o_3b_1	o_4b_0	o_4b_0	o_4b_0	o_4b_2
o_4b_o	o_4b_0	o_3b_1	o_1b_0	o_1b_3	o_4b_0	o_2b_2	o_2b_2	o_4b_2
o_2b_3	o_4b_2	o_4b_2	o_3b_0	o_3b_0	o_4b_3	o_1b_3	o_4b_2	o_4b_2
o_2b_3	o_1b_1	o_1b_1	o_2b_0	o_2b_0	o_4b_3	o_1b_3	o_3b_1	o_3b_1
o_2b_1	o_2b_1	o_3b_3	o_1b_2	o_1b_2	o_3b_2	o_3b_3	o_3b_3	o_1b_1
o_4b_1	o_4b_1	o_3b_3	o_4b_1	o_4b_1	o_3b_2	o_2b_1	o_2b_1	o_1b_1
o_1b_0	o_1b_0	C_2	o_2b_2	o_2b_2	C_1	o_4b_3	o_4b_3	C_2
C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2	C_1

O_1 = FYM treated plots
O_2 = FYM + Vermicompost treated plots
O_3 = FYM + Neemcake treated plots
O_4 = FYM +Green leaves treated plots

Fig. 2. Layout plan of experiment

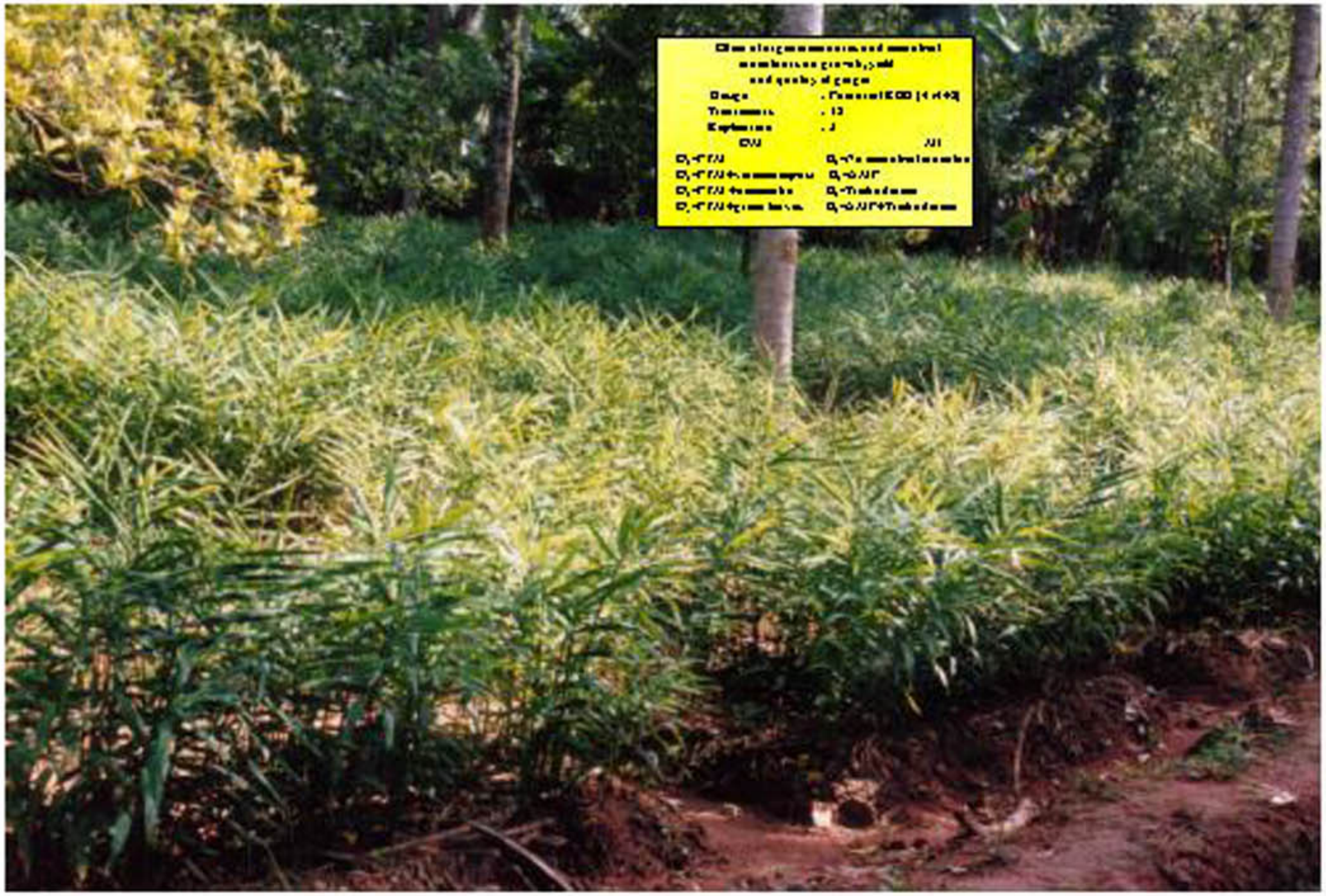


Plate 1. General view of the experimental field

A.FYM + AMF

B.FYM + neem cake + AMF + *Trichoderma*

C. Package of practices recommendation of KAU

D.Absolute control

Plate 2. Various treatments

plants in the absolute control treatment did not receive any manure or fertilizer.

3.5.2 Statistical analysis

Statistical analysis for first and second year was carried out for the 16 treatments and two controls (Factorial RBD) with two factors, organic manures and microbial inoculants. Pooled analysis was carried out for those characters which have to be pooled for both the years. Correlation coefficients were also worked out for yield and growth characters, root characters, physiological characters, other yield parameters, quality aspects and NPK uptake.

3.5.3 Seed treatment

Clean and healthy rhizome bits each weighing 15 g were selected for control treatment C_1, rhizome bits were treated with a combination of mancozeb 0.3 per cent and Malathion 0.1 per cent for 30 minutes. After the treatment, rhizome bits were dried under shade, by spreading them on a clean floor.

3.5.4 Land preparation and planting

The field was worked to a fine tilth and beds of size 3.0 m x 2.0 m and at 25 cm height in the interspaces of coconut garden were taken, leaving an area of two metre radius from the base of the palms. Between two beds a spacing of 40 cm was maintained. Organic manures were applied two weeks before planting to respective plots as per the treatment. Microbial inoculants, AMF and *Trichoderma* were applied at the time of planting as per treatment. Small pits were taken at a spacing of 25 cm x 25 cm in the prepared raised beds and seed rhizomes each weighing 15 g were planted in the pits at a depth of 4-5 cm. For control treatment (C_1) treated rhizomes were used for planting.

3.5.5 Mulching

Mulching was carried out immediately after planting with green leaves at the rate of 15 t ha^{-1} and repeated twice at the rate of 7.5 t ha^{-1} first at two months and the second four months after planting in all the treatments.

3.6 APPLICATION OF MANURES AND FERTILIZERS

Full dose of organic manures as per the treatments were applied as basal dose before planting. Commercial inoculum of AMF containing a mixture of *Glomus fasciculatum*, *Glomus etunicatum* and *Glomus* sp. maintained in pots using sorghum as host was used. The inoculum consisted of root bits, mycelial fragments, rhizosphere soil / vermiculite perlite substrate carrying chlamydospores of AMF. The vermiculite perlite inoculum containing 400 propagules per gram was used for the study. The seed rhizome was treated with starch solution to make it wet. The rhizomes were rolled over the vermiculite perlite based inoculum so as to adhere the inoculum on the surface of rhizome. It was then partially dried and planted (Sivaprasad, 1998).

Commercial inoculum of *Trichoderma viride* specific for ginger obtained from the Department of Plant Pathology, College of Agriculture was applied. Pits were taken in the bed for planting of rhizome and 3 g of *Trichoderma* inoculum was applied in each pit. Organic manures were applied in the bed two weeks before as per the treatment and were thoroughly mixed while preparing the bed. Rhizome bits were then planted in the bed.

In the control plot treatment (C_1) fertilizers were applied as per POP recommendation (KAU, 1996). Nitrogen in the form of urea and potassium in the form of muriate of potash was applied in two split doses, first two months after planting and second at four months after planting.

Full dose of phosphorus was applied at the time of planting. For absolute control no manures and fertilizers were applied.

3.5.7 After cultivation

The crop was grown as rainfed crop. Life irrigation was given as an when it was necessary. Hand weeding was done depending upon the intensity of weed growth.

3.5.8 Plant protection

During the first year of experiment (2000-2001) shoot borer attack was noticed, which was controlled by repeated spraying of neem kernel emulsion (neem kernel based EC containing azadiractin 0.15 % @ 4 ml $litre^{-1}$). Spraying was carried out six times at an interval of 14 days. During the second year the pest population was very less and only one spray was given which brought about the control of the pest. The crop was free of diseases for both the years.

3.5.9 Harvesting

The crop was harvested at 255 days after planting when the leaves turned yellow indicating rhizome maturity.

3.6 OBSERVATIONS

Two beds were maintained per each treatment. Plant height, number of tillers, number of leaves, leaf area index, leaf area duration and rhizome yield at final harvest were recorded from one bed. Five plants on these beds were tagged for the purpose of recording biometric observations. The second bed of the treatment was used for destructive sampling. Observation on green ginger yield at bimonthly intervals, rhizomes spread, rhizome thickness, root spread, root volume, root dry weight, root length, dry matter production, crop growth rate, net assimilation rate, harvest index, root shoot ratio, bulking rate, volatile oil, NVEE, starch and fibre were recorded from five plants uprooted at bimonthly intervals of two, four, six and eight months after planting.

3.6.1 Plant characters

3.6.1.1 Growth characters

The observation on growth characters were taken from five sample plants selected at random at bimonthly intervals for each plot and the average was worked out.

3.6.1.1.1 Height of plant

The height of the plant was measured from the base of the plant to the base of the young fully opened leaf and expressed in centimetre (cm).

3.6.1.1.2 Number of tillers

The number of aerial shoots arising around a single plant was counted.

3.6.1.1.3 Number of leaves

The number of fully opened leaves of the tillers from each sample plant were counted.

3.6.1.2 Root characters

The root length, root spread, root dry weight and root volume were measured at bimonthly intervals from 60 days after planting.

3.6.1.2.1 Root length

The plants were uprooted and maximum length of roots were measured and mean length expressed in centimetre.

3.6.1.2.2 Root spread

Root spread was measured by placing the root system on a marked paper and measuring the spread of the root system at its broadest part. The root spread is expressed in centimetre.

3.6.1.2.3 Root dry weight

Roots separated from individual plants were washed and dried in hot air oven at 70-80^{0}C till constant weight is obtained. It is expressed in gram plant^{-1}.

3.6.1.2.4 Root volume

Root volume per plant was found out by displacement method and expressed in cm^3 plant^{-1}.

3.6.1.3 Physiological characters

Dry matter production, crop growth rate, relative growth rate, net assimilation rate, leaf area index, leaf area duration, harvest index, root shoot ratio were observed from 60 DAP at bimonthly intervals till final harvest.

3.6.1.3.1 Dry matter production

The leaves, petioles, pseudostem, rhizomes and roots of the uprooted plants were separated and dried to a constant weight at 70-80°C in a hot air oven. The sum of dry weights of component parts give the total dry matter production of the plant and expressed as g plant^{-1}.

3.6.1.3.2 Crop growth rate

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

$$CGR = NAR \times LAI$$

3.6.1.3.3 Net assimilation rate

Net assimilation rate (NAR) was calculated as per the procedure given by Watson (1958) as modified by Buttery (1970). The following formula was used to derive NAR and expressed in g m^{-2} day^{-1}.

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

Where, W_2 – total dry weight of the plant in g at time t_2

W_1 – total dry weight of the plant in g at time t_1

$(t_2 - t_1)$ = time interval in days

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

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

3.6.1.3.4 Relative growth rate

Relative growth rate (RGR) was calculated as per the formula suggested by Blackman (1919). It is expressed in g day^{-1}.

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

W_1 – Total dry weights of the plant at time t_1

W_2 – Total dry weights of the plant at time t_2

3.6.1.3.5 Leaf area index

Five sample plants were randomly selected from each bed and the number of leaves of each plant was counted. Maximum length and breadth of leaves from all the sample plants were recorded separately and leaf area was computed based on length, breadth method. Using the equation Y = 0.6695 x – 0.7607 (Ancy, 1992).

Where,

Y = leaf area and

x = Product of length and breadth.

Leaf area index (LAI) was computed based on the following equation.

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

3.6.1.3.6 Leaf area duration

Leaf area duration (LAD) was calculated using the formula given by Power *et al*. (1967).

$$LAD = \frac{L_1 + (L_1 + 1) \times (t_2 - t_1)}{2}$$

where

L_1 – LAI at first stage

$L_1 + 1$ = LAI at second stage

$t_2 - t_1$ = Time interval between these stages

3.6.1.3.7 Harvest index

Harvest index was calculated at final 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

3.6.1.3.8 Root shoot ratio

Root and shoot dry weight of each plant was worked out and the mean expressed as the ratio between the average of root weight and shoot weight.

3.6.1.4 Yield and yield components

3.6.1.4.1 Green ginger yield

The fresh rhizome yield from each treatment was recorded by destructive sampling at bimonthly intervals. At final harvest at 255 DAP, the green ginger yield was recorded from the beds kept for biometric observation and was expressed in g plant^{-1}.

3.6.1.4.2 Dry ginger yield

Dry ginger yield was recorded from 90 days after planting. The rhizomes after harvest were washed and allowed to dry under sun for one week. It was then kept in hot air oven at 70-80°C till constant weight obtained and the dry ginger yield from the net plot was expressed in g plant^{-1}.

3.6.1.4.3 Shoot weight

The yield of above ground portion in each treatment was recorded from the net plot and was expressed as g plant^{-1} on dry weight basis.

3.6.1.4.4 Bulking rate

The bulking rate in rhizome was worked out at bimonthly intervals from 90 days after planting on the basis of increase in dry weight of rhizome per plant per day and expressed as g day^{-1}.

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

where, W_1, and W_2 are dry weight of rhizome at two time units t_1 and t_2.

3.6.1.4.5 Rhizome spread

The maximum width of the rhizomes was measured and expressed in centimetre.

3.6.1.4.6 Rhizome thickness

Rhizome thickness was measured using micrometer and expressed in centimetre.

3.6.1.5 Quality Parameters

3.6.1.5.1 Volatile oil

The content of volatile oil was estimated at bimonthly intervals from 120 days after planting by Clevenger distillation method (AOAC, 1975) and expressed as percentage (v/w) on dry weight basis.

3.6.1.5.2 Non-volatile ether extract

Non-volatile ether extract (NVEE) was estimated at bimonthly intervals from 120 days after planting (AOAC, 1975) and expressed as percentage on dry weight basis.

3.6.1.5.3 Starch

Starch content was analysed at bimonthly intervals from 120 days after planting by potassium ferricyanide method (Aminoff *et al.*, 1970) and expressed as percentage on dry weight basis.

3.6.1.5.4 Crude fibre content

The crude fibre content was estimated at bimonthly intervals from 120 days after planting by AOAC (1975) method and expressed as percentage on dry weight basis.

3.6.2 Soil analysis

Soil samples were collected from the experimental site plot wise for various physico-chemical properties.

3.6.2.1 Soil physical properties

Plot wise analysis of the soil samples were undertaken for various physical properties before and after the experiment. Physical characters of soil such as bulk density, particle density and water holding capacity were determined by the core method (Gupta and Dakshinamoorthy, 1980). Aggregate stability was calculated based on wet sieving technique developed by Yoder (1936).

3.6.2.2 Soil chemical properties

The soil samples were collected from each plot before starting the first crop and thereafter for every succeeding crop. The samples were analysed for pH, organic carbon status, available N, available P and available K as detailed in Table 3.

Table 3. Details of the method used for chemical analysis of the soil

Sl. No.	Characteristics of the soil	Soil solution	Extractant	Method of estimation	Instrument used	References
1	pH	1 : 2.5	-	Direct reading	pH meter	Jackson (1973)
2	Organic carbon	-	-	Walkley and Black's rapid titration method	Titrimetric	Jackson (1973)
3	Available nitrogen	-	-	Alkaline permanganate method	Titrimetric	Subbiah and Asija (1956)
4	Available phosphorus	1 : 10	Bray No. 1 Ascorbic acid blue	Bray No. 1 method	Spectro photometer	Jackson (1973)
5	Available potassium	1 : 10	Neutral normal ammonium acetate	Direct reading after dilution	Flame photometer	Jackson (1973)

3.6.3 Plant analysis

Sample plants collected from each plot were separated into above ground portion and below ground portion. Samples were initially sundried and then oven dried to a constant weight. The samples were finally ground in a willey mill and sieved. The samples were analysed for macro nutrients as detailed below.

Nitrogen was estimated by microkheldahl method (Jackson, 1973). For the analysis of P and K, diacid extracts were prepared by digesting 1 g of the sample in 15 ml of 2 : 1 concentrated nitric perchloric acid mixture. Aliquots of the digests were taken for the analysis of total P and K. P was determined colorimetrically by vanadomolybdo phosphoric yellow colour method (Jackson, 1973). The yellow colour was read in a spectrophotometer (Spectronic 20) at a wave length of 470 nm. K was estimated using flame photometer.

3.6.3.1 Uptake of major nutrients

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

3.6.4 Nutrient balance sheet

Nutrient balance sheets were worked out for available N, P_2O_5 and K_2O in each year as per the procedure outlined by Sadanandan and Mahapatra (1973a). The following parameters were taken into account.

1. Initial status of nutrient in soil (Y) kg ha^{-1}
2. Total amount of nutrient added through manures and fertilizers (A) (kg ha^{-1})
3. Amount of nutrient removed by the crop or uptake (B) (kg ha^{-1})
4. Expected nutrient balance C = (Y +A) – B (kg ha^{-1})

5. Actual nutrient balance or available nutrient status of soil after the experiment (D) (kg ha^{-1})
6. Net loss (-) or gain (+) = D – C (kg ha^{-1})

The total amount of nutrients added through manures and fertilizers were calculated by considering the nutrient values of manures in each year and quantities of manures and fertilizers used were as given in Appendix IV.

3.6.5 Pest and disease scoring

Shoot borer attack was observed during both the years. The number of plants showing row of holes across the leaf blade after unfurling or dead hearts were counted as infested plants and percentage of plants infested per plot was worked out (Kotikal and Kulkarni, 2000) during both the years.

3.6.6 Estimation of nematode population in soil

Soil samples from each plot were collected before planting of rhizomes and after the harvest of first year and second year crop. Soil samples were collected and nematodes were extracted from the representative soil samples following the method of Cobb's sieving and decanting technique (Cobb, 1918) and modified Baermann's method. The nematode thus extracted were counted under a stereoscopic microscope.

3.6.7 Estimation of terminal residues of pesticides

In treatments following POP, seed treatment was carried out using mancozeb and malathion (KAU, 1996). For the control of shoot borer, dimethoate were sprayed for C_1, while for the treatments involving organic manures and microbial inoculants neem kernel emulsion was used.

Terminal residues in dried rhizome following mancozeb and malathion as seed treatment and dimethoate (0.05 %) application at 2 – 5 months age were estimated. The modified CS_2 evaluation method using mancozeb apparatus described by Keppel (1971) was used for the analysis of mancozeb residues in rhizomes. Residues of malathion and dimethoate were estimated following the procedure laid down by Khan *et al*. (1999).

3.6.8 Economics of cultivation

The economics of cultivation was worked out after taking into account the cost of cultivation of ginger and the existing price of ginger rhizomes. For calculating the cost, different variable cost items like planting materials, manures, fertilizers, plant protection chemicals irrigation, labour charges etc. were considered at existing market rate during 2000-01 and 2001 -02.

The net income was calculated as follows,

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

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

Results

4. RESULTS

The results of the investigation conducted during 2000-2001 and 2001-2002 to assess the effect of organic manures, microbial inoculants and their interaction on growth, yield and quality of ginger are presented.

4.1 PLANT CHARACTERS

4.1.1 Effect of organic manures microbial inoculants and their interaction on growth characters

4.1.1.1 Height of the plant

The mean and interaction effects of treatments on height of the plants at different stages of crop growth during ‘00-01’ and ‘01-02’ are furnished in Table 4.

Significant differences in plant height was observed throughout the crop growth stages except at 180 DAP for both years with different organic manure application. Plants that received O_1 (FYM) resulted in maximum height at all growth stages on both the years. At 240 DAP, a plant height of 61.63 cm and 72.82 cm were observed from FYM treated plants (O_1) during first and second year respectively. Green leaves treated plants also produced longer plants followed by FYM at 60 DAP during first year. For the remaining significant stages (120 and 240 DAP) the effect of neemcake + FYM on plant height was superiorly higher than green leaves + FYM but lower than FYM. The plant height observed from neemcake + FYM treated plants were 61.22 cm and 72.50 cm at 240 DAP during first and second year respectively.

The effect of microbial inoculants on plant height was significant at all stages of crop growth during both the years. However the application of AMF and *Trichoderma* together or singly at all stages of growth produced higher plant heights than without application of any microbial inoculants. During the first year the plant height observed in plants that did not receive any microbial inoculant was 58.23 cm while for the second

Table 4. Effect of organic manures, microbial inoculants and their interaction on plant height of ginger, cm

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	27.83	31.51	48.50	51.56	57.47	68.54	61.63	72.82
O_2	27.03	31.28	46.18	49.98	56.94	67.93	60.52	72.06
O_3	27.18	30.96	47.44	49.89	57.46	68.13	61.22	72.50
O_4	27.38	30.74	47.15	49.80	57.18	68.14	61.21	71.65
SE	0.15	0.15	0.24	0.25	-	-	0.11	0.21
CD	0.44	0.44	0.69	0.71	NS	NS	0.32	0.60
B_0	24.54	27.64	38.84	41.54	52.99	63.52	58.23	66.21
B_1	27.87	31.72	47.04	52.14	58.39	69.17	61.88	73.61
B_2	27.37	31.15	48.36	50.30	57.76	68.51	61.36	73.09
B_3	29.63	33.99	53.03	57.25	59.91	71.54	63.11	76.13
SE	0.15	0.15	0.24	0.25	0.18	0.18	0.11	0.21
CD	0.88	0.44	0.69	0.71	0.51	0.53	0.32	0.60
Interaction								
o_1b_0	24.44	27.52	38.33	41.35	52.45	62.62	57.77	65.55
o_1b_1	31.58	35.07	57.24	60.99	61.67	73.12	64.91	77.82
o_1b_2	25.26	28.84	43.49	44.42	55.40	66.17	60.06	70.92
o_1b_3	30.03	34.63	54.92	59.47	60.37	72.24	63.99	77.00
o_2b_0	24.28	27.48	37.25	40.77	52.02	62.49	57.50	65.26
o_2b_1	28.42	33.01	49.63	55.56	59.15	70.85	62.26	75.42
o_2b_2	27.68	31.87	49.03	50.98	58.26	68.96	61.15	73.58
o_2b_3	27.75	32.77	48.83	62.62	58.33	69.43	61.18	74.01
o_3b_0	24.90	27.87	40.53	42.50	34.13	65.00	59.05	67.75
o_3b_1	26.16	30.86	46.38	48.57	57.50	67.19	60.59	72.51
o_3b_2	26.28	29.72	45.65	47.42	56.74	66.87	60.41	71.87
o_3b_3	31.38	35.39	57.20	61.05	61.45	73.47	64.81	77.86
o_4b_0	24.55	27.69	39.26	41.52	53.37	63.98	58.59	66.28
o_4b_1	25.32	27.93	42.93	43.43	55.24	65.53	59.75	68.68
o_4b_2	30.28	34.17	55.26	58.39	60.64	72.02	63.82	75.99
o_4b_3	29.36	33.18	51.15	55.87	59.48	71.00	62.67	75.65
SE	0.31	0.31	0.48	0.50	0.35	0.37	0.22	0.42
CD	0.88	0.88	1.38	1.43	1.01	1.06	0.64	1.20
C_1	25.85	23.58	43.88	36.57	54.57	51.52	59.25	55.24
C_2	23.07	21.28	34.47	31.17	45.64	40.55	49.82	44.17
C_1 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*

*Significant at 5 % level
NS-Non significant

year the plant height increased to 66.21 cm at 240 DAP. The plant which received AMF + *Trichoderma* together produced a plant height of 63.11 cm and 76.13 cm for the corresponding first and second year of study.

The interaction effect, O x B, was significant throughout the period of experimentation on both the years with o_1b_1 producing plants with highest height during the first year (64.91 cm) and o_3b_3 showing plants with higher plant heights during second year (77.86 cm). The general trend of significant increase in plant height with the application of microbial inoculants was conspicuous in O_1, O_2, O_3 and O_4 applied plants at all stages during both the years.

A significant difference in plant height at all stages of growth in both the years was recorded between controls and treatments. The control C_1 as well as C_2 varied significantly from the treatments at all stages. The plant heights recorded between control also varied significantly. The shortest plants were observed from the control, C_2 compared to C_1 and other treatments at all stages of growth on both years.

4.1.1.2 Number of tillers

The effect of treatments on number of tillers at different growth stages during the two years of experimentation is presented in the Table 5.

Organic manures significantly influenced the number of tillers in 240 DAP of first year and 120, 180 and 240 DAP of second year. In general, while O_1 and O_3 produced significantly higher number of tillers, O_2 showed only less number of tillers at these stages. The highest number of tillers at 240 DAP were produced from O_1 (13.47 and 17.91 for first and second year) followed by O_3 (13.27 and 17.17 for first and second year). Treatments O_3 and O_4 were on par at 240 DAP.

The effect of microbial inoculants was significant in almost all stages of growth except at the 60 DAP of second year. Application of AMF and *Trichoderma* in combination resulted in significantly higher production of tillers at all stages except at 60 DAP of second year. The

Table 5. Effect of organic manures, microbial inoculants and their interaction on number of tillers in ginger

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	2.58	3.19	5.37	7.22	10.61	14.10	13.47	17.91
O_2	2.58	3.14	5.32	6.96	10.51	13.72	12.97	16.71
O_3	2.59	3.20	5.37	7.21	10.60	13.85	13.27	17.17
O_4	2.57	3.18	5.35	7.10	10.52	13.83	13.18	17.22
SE	-	-	-	0.07	-	0.08	0.05	0.12
CD	NS	NS	NS	0.19	NS	0.24	0.13	0.35
B_0	2.47	3.11	5.14	6.50	9.98	13.01	12.17	15.18
B_1	2.56	3.22	5.41	7.28	10.71	14.06	13.45	17.64
B_2	2.66	3.18	5.37	7.17	10.63	13.84	13.23	17.11
B_3	2.64	3.20	5.49	7.54	10.91	14.61	14.04	19.08
SE	0.02	-	0.03	0.07	0.03	0.08	0.05	0.12
CD	0.07	NS	0.09	0.19	0.10	0.24	0.13	0.35
Interaction								
o_1b_0	2.50	3.15	5.11	6.35	9.93	12.95	12.13	15.14
o_1b_1	2.73	3.26	5.62	7.97	11.19	15.31	14.76	20.77
o_1b_2	2.45	3.16	5.25	6.91	10.40	13.29	12.63	15.87
o_1b_3	2.64	3.18	5.50	7.66	10.91	14.86	14.36	19.85
o_2b_0	2.42	3.15	5.07	6.27	9.83	12.87	12.03	15.06
o_2b_1	2.70	3.13	5.43	7.28	10.77	14.22	13.44	17.99
o_2b_2	2.71	3.13	5.38	7.13	10.70	13.85	13.21	16.76
o_2b_3	2.50	3.14	5.39	7.16	10.72	13.94	13.21	17.03
o_3b_0	2.48	3.07	5.22	6.77	10.14	13.09	12.35	15.78
o_3b_1	2.44	3.25	5.34	7.04	10.62	13.57	13.05	16.41
o_3b_2	2.72	3.23	5.30	7.01	10.47	13.42	12.93	16.27
o_3b_3	2.71	3.25	5.61	8.01	11.16	15.34	14.73	20.74
o_4b_0	2.50	3.06	5.17	6.61	10.04	13.11	12.19	15.23
o_4b_1	2.35	3.22	5.24	6.83	10.26	13.14	12.56	15.41
o_4b_2	2.74	3.20	5.53	7.62	10.95	14.79	14.14	19.52
o_4b_3	2.69	3.23	5.47	7.33	10.83	14.29	13.85	18.70
SE	0.05	-	0.06	0.13	0.07	0.17	0.09	0.24
CD	0.13	NS	0.19	0.38	0.20	0.48	0.27	0.70
C_1	2.47	1.76	5.30	4.33	10.18	9.80	12.45	11.44
C_2	1.30	1.17	2.32	1.91	8.16	6.51	10.66	7.17
C_1 vs Treated	S**	S*	S**	S*	S*	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*

**Significant at 1 % level
* Significant at 5 % level
NS-Non significant

effect of microbial inoculants B_1 and B_2 on the number of tiller production at 120 and 180 DAP of both the years were almost similar. The application of AMF and *Trichoderma* together produced 19.08 tillers during second year and 14.04 tillers during first year at 240 DAP.

A close scrutiny of data in Table 5 indicated that the interaction between organic manures and microbial inoculants was significant at most of the stages except at 60 DAP in the second year. Organic manures in combination with microbial inoculants enhanced the production of tillers with higher values for o_1b_1 and o_3b_3 combinations. Among the combination of microbial inoculants with FYM, AMF recorded maximum tiller production while with neemcake, the combination of AMF and *Trichoderma* resulted in higher tiller production at all stages of growth. Among the interactions, highest tiller production was noticed in o_1b_1 (14.76) which was on par with o_3b_3 (14.73) during the first year of study at 240 DAP. Similarly treatments o_1b_1 (20.77) and o_3b_3 (20.74) were on par at 240 DAP during the second year of study. Among green leaves, the combination with *Trichoderma* showed better tiller production than with any other microbial inoculants.

Significant difference in the number of tiller production was observed when the treatments and controls were compared. The comparison of the controls C_1 and C_2 also showed significant variation in the number of tiller production at all stages of growth. The number of tillers produced between controls also varied significantly. The tiller production for C_1 was higher than C_2 at all stages of growth for both the years.

4.1.1.3 Number of leaves

The effect of organic manures, microbial inoculants and their interaction on the number of leaves for two years are presented in Table 6.

Perusal of the data in Table 6, clearly indicate that main effects of organic manures and microbial inoculants and their interaction had

Table 6. Effect of organic manures, microbial inoculants and their interaction on number of leaves in ginger

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	11.91	14.40	76.19	89.41	160.93	176.66	198.18	214.94
O_2	11.64	14.22	75.24	87.09	159.85	175.52	196.52	213.60
O_3	11.74	14.16	75.75	89.11	160.52	176.52	197.69	214.05
O_4	11.75	14.15	75.71	89.03	160.36	175.70	197.64	213.77
SE	0.03	-	0.15	-	0.24	0.27	0.23	0.30
CD	0.07	NS	0.44	NS	0.69	0.77	0.66	0.85
B_0	11.23	12.78	72.12	83.17	153.99	171.17	190.27	207.33
B_1	11.88	4.56	76.62	90.18	162.06	177.30	199.37	215.66
B_2	11.75	14.17	76.03	89.39	161.41	176.07	198.69	213.80
B_3	12.17	15.42	78.12	91.90	164.20	179.86	201.71	219.57
SE	0.03	0.08	0.15	0.81	0.24	0.27	0.23	0.30
CD	0.07	0.22	0.44	2.33	0.69	0.77	0.66	0.85
Interaction								
o_1b_0	11.18	12.70	71.63	82.33	153.31	170.31	189.26	206.69
o_1b_1	12.62	16.15	80.33	95.39	166.32	182.40	204.31	223.48
o_1b_2	11.44	13.14	74.34	85.58	159.06	173.65	196.14	209.36
o_1b_3	12.39	15.62	78.45	94.33	165.05	180.27	203.00	220.22
o_2b_0	11.16	12.68	71.30	82.25	152.30	169.98	188.92	206.50
o_2b_1	11.99	15.19	77.05	92.18	163.44	178.31	200.35	217.98
o_2b_2	11.70	14.27	76.32	89.86	161.82	176.54	198.36	213.88
o_2b_3	11.70	14.73	76.31	84.06	161.85	177.26	198.43	216.06
o_3b_0	11.33	12.97	73.07	84.46	155.68	173.02	192.39	208.18
o_3b_1	11.55	13.84	75.05	88.19	160.29	175.09	197.45	212.51
o_3b_2	11.52	13.65	74.92	88.06	159.94	174.96	196.77	211.96
o_3b_3	12.56	16.16	79.94	95.73	166.18	183.00	204.16	223.55
o_4b_0	11.25	12.77	72.48	83.62	154.66	171.36	190.50	207.95
o_4b_1	11.36	13.06	74.05	84.94	158.20	173.13	195.35	208.66
o_4b_2	12.35	15.62	78.54	94.08	164.83	179.13	203.49	220.01
o_4b_3	12.04	15.16	77.77	93.49	163.73	178.93	201.23	218.46
SE	0.05	0.16	0.31	1.62	0.48	0.54	0.46	0.59
CD	0.15	0.45	0.89	4.67	1.38	1.55	1.33	1.71
C_1	11.48	11.05	7.36	70.49	157.14	149.57	193.45	186.13
C_2	9.05	6.74	65.24	59.97	123.04	84.02	143.46	96.16
C_1 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*

*Significant at 5 % level
NS-Non significant

significant influence in the number of leaves at most stages during both the years. However during second year of planting at 60 and 120 DAP, the effect of organic manures was not significant.

Among the organic sources O_1 retained significantly higher number of leaves in all stages during both the years. O_3 and O_4 were on par at all stages of plant growth on both years except at the 180 DAP of second year. The number of leaves produced by FYM treated plants at 180 DAP was 160.93 while it increased to 198.18 at 240 DAP during the first year. During the second year of experimentation the leaf production increased from 176.66 at 180 DAP to 214.94 at 240 DAP.

Application of microbial inoculants resulted in significantly different values at all stages of growth in both the years. During both the years at all stages of growth, B_3 produced significantly highest number of leaves. Among treatments which received AMF and *Trichoderma*, AMF treated plants retained more number of leaves. All these microbial inoculants treated plants produced more number of leaves than the plants which did not receive the microbial inoculants. The B_3 treatments produced more number of leaves (219.57) at 240 DAP and it was significantly superior than the other treatments among the microbial inoculants.

Interaction effects presented in the Table 6 indicate the O x B interaction was present at all stages on both the years. In combination with O_1 and O_2, B_1 resulted in higher number of leaf production in all the stages. During first year highest leaf production was reported from o_1b_1 combination and during second year o_3b_3 combination retained more number of leaves. Among O_4 the combination with B_2 produced more number of leaves. The leaves produced by o_1b_1 (204.31) and o_3b_3 (204.16), o_4b_2 (203.49) and o_1b_3 (203.00) were on par at 240 DAP of first year. During the corresponding stage of second year treatment combination o_1b_1 (223.48) and o_3b_3 (223.55) were on par.

The number of leaves produced by the treatments varied significantly form the controls at all stages of growth in both the years. The comparison of C_1 as well as C_2 with the treatments also indicated significant difference in the number of leaves at all stages of growth on both the years.

Between controls also significant difference was noted at all stages on both the years. However C_1 produced maximum number of leaves almost double (186.13 for C_1 and 96.16 for C_2) at the time of harvest during the second year.

4.1.2 CORRELATION OF GROWTH CHARACTERS IN RELATION TO GREEN GINGER AND DRY GINGER YIELD

4.1.2.1 Plant height

The correlation of plant height with green ginger, dry ginger, number of tillers and number of leaves on first and second year of study is presented in Table 7 and Table 8 respectively.

The plant height shows significant correlation with both green and dry ginger yield on both years of study. The results also reveals the plant height is positively correlated with tiller and leaf production on two years.

4.1.2.2 Number of tillers

Table 7 and Table 8 represented the correlation of number of tillers with green and dry ginger yield, plant height and number of leaves on two years of experimentation. The number of tillers showed a significant positive correlation with green and dry ginger yield as well as plant height and number of leaf production on both years of study.

4.1.2.3 Number of leaves

The intercorrelation of number of leaves with green ginger, dry ginger yield, height of the plant and number of tillers for both years of experimentation are presented in Table 7 and 8. It has been observed that the number of leaves is correlated with growth characters like plant height and number of tillers on both years of study. The number of leaves also

Table 7. Correlation of growth characters in relation to green ginger and dry ginger yield during the first year of experiment

Characters	Green ginger yield	Dry ginger yield	Plant height	No.of tillers	No.of leaves
Green ginger yield	1				
Dry ginger yield	0.9880*	1			
Plant height	0.9660*	0.9919*	1		
No.of tillers	0.9359*	0.9759*	0.9913*	1	
No.of leaves	0.9926*	0.9952*	0.9835*	0.9624*	1

* Significant at 5 % level

Table 8. Correlation of growth characters in relation to green ginger and dry ginger yield during the second year of experiment

Characters	Green ginger yield	Dry ginger yield	Plant height	No.of tillers	No.of leaves
Green ginger yield	1				
Dry ginger yield	0.9959*	1			
Plant height	0.9722*	0.9721*	1		
No.of tillers	0.9801*	0.9720*	0.9181*	1	
No.of leaves	0.9949*	0.9914*	0.9647*	0.9787*	1

* Significant at 5 % level

shows significant positive correlation with green and dry ginger yield on both years of experimentation.

4.1.3 Effect of Organic Manures, Microbial Inoculants and their interaction on Root Characters

4.1.3.1 Root length

Table 9 represents the main and interaction effects of organic manures, microbial inoculants and their interaction on root length for two years of experimentation.

The variation in root length due to the application of different organic manures was not significant at various growth stages in both the years. During first year of experimentation significant differences in root length was observed at 60 and 180 DAP. The main effect of organic manures on root length also showed significant difference at 240 DAP of second year. At 60 and 180 of first year and 240 DAP of second year, O_1 produced longer roots. The root length of ginger at 240 DAP of second year was the highest for O_1 treatment (26.71 cm) and was on par with O_4 (26.59 cm) and O_3 (26.55 cm). The root length was the shortest in O_2 treatment (26.07 cm) at 240 DAP of second year among organic manure treatment.

The effect of microbial inoculants on root length was significant at all stages of growth in both the years. Application of AMF and *Trichoderma* together resulted in longer roots than their individual application. At 240 DAP of second year of study, longest roots were noticed from B_3 treatment (28.18 cm). The next best alternative was AMF which also resulted in higher root length. However the longer roots were produced with the application of microbial inoculants. During the second year of study the root length produced by B_1 (27.73 cm) was shorter that B_3 (28.18 cm) but longer than B_2 (25.71 cm) and B_0 (24.29 cm).

Table 9. Effect of organic manures, microbial inoculants and their interaction on root length in ginger, cm

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	11.38	13.25	15.00	19.11	20.20	23.15	24.20	26.71
O_2	11.28	13.09	14.86	18.94	19.66	22.94	23.81	26.07
O_3	11.33	13.14	15.02	19.09	20.01	23.16	24.19	26.55
O_4	11.35	13.09	14.91	19.02	19.95	23.03	24.03	26.59
SE	0.02	-	-	-	0.05	-	-	0.14
CD	0.07	NS	NS	NS	0.15	NS	NS	0.41
B_0	10.35	12.27	13.78	18.13	17.80	21.92	22.33	24.29
B_1	12.20	13.71	15.96	19.69	21.31	24.04	24.90	27.73
B_2	10.54	12.56	14.01	18.39	18.85	22.18	23.97	25.71
B_3	12.24	14.02	16.04	19.95	21.87	24.15	25.03	28.18
SE	0.02	0.05	0.06	0.07	0.05	0.06	0.11	0.14
CD	0.07	0.13	0.17	0.21	0.15	0.17	0.32	0.41
Interaction								
o_1b_0	10.35	12.29	13.76	18.07	17.65	21.88	22.47	24.00
o_1b_1	12.32	14.15	16.21	20.18	22.27	24.41	25.64	28.72
o_1b_2	10.51	12.50	13.91	18.23	18.76	22.14	23.73	25.63
o_1b_3	12.34	14.04	16.13	19.97	22.11	24.16	24.97	28.49
o_2b_0	10.36	12.13	13.72	17.98	17.58	21.84	21.85	24.03
o_2b_1	12.18	13.98	16.06	19.83	21.42	23.97	24.84	27.64
o_2b_2	10.46	12.40	13.91	18.19	18.58	22.10	23.97	25.29
o_2b_3	12.12	13.84	15.73	19.76	21.07	23.86	24.59	27.30
o_3b_0	10.35	12.39	13.84	18.32	18.06	22.00	22.60	24.74
o_3b_1	12.15	13.40	16.04	19.58	20.87	23.94	24.64	27.44
o_3b_2	10.50	12.60	14.01	18.25	18.89	22.17	23.93	25.25
o_3b_3	12.30	14.19	16.21	20.20	22.23	24.51	25.58	28.77
o_4b_0	10.33	12.28	13.82	18.16	17.90	21.95	22.41	24.40
o_4b_1	12.17	13.30	15.53	19.16	20.68	23.83	24.50	27.11
o_4b_2	10.68	12.73	14.20	18.88	19.15	22.29	24.23	26.67
o_4b_3	12.20	14.03	16.09	19.87	22.08	24.06	25.00	28.17
SE	0.05	0.09	0.12	0.15	0.05	0.12	0.22	0.29
CD	0.13	0.27	0.34	0.42	0.15	0.34	0.64	0.83
C_1	11.90	11.16	15.10	13.19	20.03	18.56	23.72	23.05
C_2	10.15	8.71	13.16	12.29	16.35	14.08	20.70	17.05
C_1 vs Treated	S*	S*	NS	S*	NS	S*	NS	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*

* Significant at 5 % level
NS-Non significant

The interaction of O x B on root length was significant at all stages of growth. AMF alone and AMF + *Trichoderma* in combination with FYM produced significantly longer roots at these growth stages. The combinations, o_1b_3 and o_3b_3 were on par at all these stages. AMF in combination with all organic manures showed significantly longer roots. However the combination of levels of O with B_0 produced shorter roots. Among the interactions, shortest roots were produced from o_2b_0 (21.85 cm) at 240 DAP during the first year and from o_1b_0 (24.00 cm) during the second year.

During both the years, the root length of controls varied significantly from the treatments at most of the stages of growth. The comparison of control C_1 with the treatments indicated a significant variation at 60 DAP during both the years and 120, 180 and 240 DAP of second year. The variation of root length of C_1 was non significant at 120, 180 and 240 DAP of first year compared to the treatments. However the root length of C_2 was significantly different from the treatments at all growth stages. The root length produced by C_1 was also significantly higher than the root length of C_2 at all the growth stages of both the years of experimentation.

4.1.3.2 Root spread

The effect of treatments and control on root spread for the two years of experimentation are presented in the Table 10.

The main effect of organic manures on root spread was significant only during 120 DAP and 240 DAP of first year and 120 and 180 DAP of second year of study. The effect was significant at initial stages of both the years. The root spread of ginger during the first year of experimentation for highest for O_1 treatments (13.32 cm). Treatments O_2, O_3 and O_4 were on par at these stages. Insignificant values were also observed at 180 DAP during first year and 240 DAP during second year. However, the spread of root was higher with organic manure treated

Table 10. Effect of organic manures, microbial inoculants and their interaction on root spread in ginger, cm

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	6.44	7.25	8.89	9.52	10.49	12.53	13.32	15.50
O_2	6.41	7.19	8.77	9.42	10.43	12.20	13.22	15.43
O_3	6.42	7.24	8.84	9.46	10.43	12.50	13.26	15.49
O_4	6.42	7.25	8.80	9.46	10.42	12.30	13.26	15.45
SE	-	-	0.03	0.02	-	0.04	0.02	-
CD	NS	NS	0.07	0.07	NS	0.13	0.06	NS
B_0	6.26	7.02	8.74	9.20	10.07	11.41	13.10	14.18
B_1	6.46	7.32	8.88	9.54	10.54	12.85	13.33	16.17
B_2	6.41	7.19	8.72	9.45	10.40	12.20	13.22	15.13
B_3	6.56	7.41	8.97	9.66	10.77	13.06	13.40	16.40
SE	0.02	0.02	0.03	0.02	0.03	0.04	0.02	0.10
CD	0.04	0.07	0.07	0.07	0.07	0.13	0.06	0.30
Interaction								
o_1b_0	6.24	6.99	8.73	9.21	10.03	11.32	13.07	14.09
o_1b_1	6.63	7.51	9.12	9.81	11.02	13.58	13.57	16.55
o_1b_2	6.33	7.07	8.71	9.37	10.16	12.11	13.22	14.92
o_1b_3	6.57	7.42	9.01	9.70	10.77	13.10	13.41	16.45
o_2b_0	6.24	6.98	8.68	9.16	10.02	11.29	13.05	14.05
o_2b_1	6.47	7.33	8.91	9.53	10.52	12.79	13.32	16.32
o_2b_2	6.41	7.18	8.62	9.47	10.53	12.18	13.22	15.16
o_2b_3	6.49	7.28	8.89	9.50	10.66	12.53	13.27	16.19
o_3b_0	6.30	7.04	8.79	9.22	10.13	11.57	13.15	14.36
o_3b_1	6.40	7.28	8.83	9.43	10.40	12.57	13.18	15.98
o_3b_2	6.36	7.11	8.69	9.37	10.26	12.15	13.14	15.03
o_3b_3	6.62	7.52	9.06	9.81	10.93	13.71	13.57	16.57
o_4b_0	6.27	7.05	8.76	9.21	10.09	11.48	13.13	14.20
o_4b_1	6.32	7.15	8.68	9.39	10.23	12.45	13.24	15.82
o_4b_2	6.55	7.38	8.85	9.59	10.65	12.38	13.30	15.41
o_4b_3	6.54	7.42	8.91	9.63	10.73	12.90	13.36	16.38
SE	0.03	0.02	0.05	0.05	0.05	0.09	0.04	-
CD	0.09	0.07	0.15	0.14	0.15	0.25	0.13	NS
C_1	6.31	6.25	8.78	8.68	10.29	10.00	13.27	13.00
C_2	6.11	5.48	7.51	5.89	8.20	6.43	11.28	9.87
C_1 vs Treated	NS	S*	NS	S*	S*	S*	NS	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*

*Significant at 5 % level
NS-Non significant

plants. In general vermicompost application generally resulted in lower spread of roots compared to other organic sources.

The effect of microbial inoculants on root spread showed significant difference at all stage of growth in both the years. The spread was maximum with B_3 followed by B_2. The application of AMF + *Trichoderma* (B_3) resulted in more root spread (13.40 and 16.40 cm at 240 DAP of first and second year respectively). All the microbial inoculants treated plants produced higher root spread than the plants without microbial inoculants.

Table 8 depicts the significant O x B interaction effect on root spread during 2000-2001 and 2001-2002. The effect was insignificant at 240 DAP during the second year. Treatments o_1b_1 and o_3b_3 showed higher root spread and were on par at all stages. With o_2B, B_3 combinations showed higher root spread. During the first year among FYM + microbial inoculants combination more root spread was noticed for o_1b_1 (13.57 cm) followed by o_1b_3 (13.41 cm). Among the interactions, the root spread was the least for o_2b_0 treatment (13.05 cm for first year and 14.09 cm for second year respectively).

The interaction effect of AMF with FYM produced higher root spread among FYM microbial inoculants combinations. During the years among O_4, B combinations, upto 180 DAP of first year, treatments o_4b_2 and o_4b_3 were on par and at 180 DAP of second year, there was significant difference between o_4b_2 and o_4b_3.

As depicted in the Table 8 the variation in root spread was significant at most of the stages of growth when the treatments were compared with the controls at both the year of study. The root spread of the treatments varied significantly from the control C_2 at all the stages of growth while with C_1, the effect was insignificant at 60, 120 and 240 DAP of first year. A significant variation in root spread was noticed between the controls C_1 and C_2. However among the controls, the root spread was more for C_1.

4.1.3.3 Root weight

The influence of organic manures, microbial inoculants and their interaction on root weight for both years of study are presented in Table 11.

Organic manures, different microbial inoculants either independently or in combination significantly influenced the root weight at some stages (Table 11).

The various organic manures showed significant differences in root weight at 120 and 240 DAP of both the years. At 240 DAP of first and second year the root weight observed was 1.1842 g plant^{-1} and 1.4760 g plant^{-1} for O_1 treatments. At the initial phase (60 DAP) and 180 DAP of both the years the effect of organic manures on root weight was non-significant.

The effect of microbial inoculants on root dry weight was significant at all stages except at 180 DAP of first year. During these periods root weight was more when AMF and *Trichoderma* were applied together. Root weight was the least with B_0 treatments. The treatment like B_1 and B_2 were on par in par at 60 DAP of both the years at 180 DAP of second year and at 240 DAP of first year.

The interactions O x B were significant in both the years at all stages except at 60 DAP of second year and 180 DAP of first year. The combination of FYM with AMF produced more root dry weight compared to other combinations of FYM. Thus the root weight of o_1b_1 observed was 1.2633 g per plant^{-1} and 1.62 g plant^{-1} for first and second year respectively at 240 DAP. With neemcake the combination of AMF and *Trichoderma* resulted in higher root weight. At 240 DAP of first and second year, the root dry weight for o_3b_3 was 1.2467 g plant^{-1} and 1.6467 g plant^{-1} respectively. The treatments o_4b_2 and o_2b_3 also produced more root weights generally at all stages. During both the years, at all the stages of growth, all the combinations of B_0 with organic manures, root weight produced was the least.

Table 11.Effect of organic manures, microbial inoculants and their interaction on root weight in ginger, g plant^{-1}

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	0.2400	0.2983	0.5600	0.8133	0.9958	1.2217	1.1842	1.4760
O_2	0.2492	0.2933	0.5467	0.7967	0.9495	1.2117	1.1533	1.4275
O_3	0.2417	0.2967	0.5558	0.8025	0.9008	1.2158	1.1817	1.4567
O_4	0.2442	0.2925	0.5450	0.8092	0.9867	1.2092	1.1467	1.4426
SE	-	-	0.0039	0.0042	-	-	0.0077	0.0067
CD	NS	NS	0.0111	0.0122	NS	NS	0.0204	0.0193
B_0	0.2242	0.2817	0.5042	0.7092	0.8867	1.1575	1.0950	1.3000
B_1	0.2425	0.3025	0.5783	0.8525	1.0092	1.2283	1.1900	1.4826
B_2	0.2425	0.2917	0.5250	0.7875	0.9742	1.2117	1.1775	1.4525
B_3	0.2658	0.3050	0.5900	0.8725	0.9625	1.2608	1.2033	1.5667
SE	0.0022	0.0021	0.0039	0.0042	-	0.0053	0.0077	0.0067
CD	0.0162	0.0059	0.0112	0.0122	NS	0.0153	0.0204	0.0193
Interaction								
o_1b_0	0.2167	0.2833	0.5033	0.7067	0.8733	1.1500	1.0933	1.2833
o_1b_1	0.2567	0.3100	0.6267	0.9000	0.1000	1.2833	1.2633	1.6200
o_1b_2	0.2333	0.2933	0.5133	0.7667	0.9433	1.1800	1.1633	1.3967
o_1b_3	0.2533	0.3067	0.5967	0.8800	1.0667	1.2733	1.2167	1.6000
o_2b_0	0.2167	0.2800	0.5000	0.7000	0.8500	1.1500	1.0733	1.2800
o_2b_1	0.2400	0.3033	0.5667	0.8533	1.0000	1.2433	1.1800	1.5100
o_2b_2	0.2453	0.2867	0.5167	0.7833	0.9667	1.2200	1.1567	1.4400
o_2b_3	0.2667	0.3033	0.5633	0.8500	0.9800	1.2333	1.2033	1.4800
o_3b_0	0.2333	0.2833	0.5100	0.7200	0.9200	1.1700	1.1333	1.3267
o_3b_1	0.2333	0.3000	0.5600	0.8400	0.9667	1.2100	1.1800	1.4300
o_3b_2	0.2433	0.2933	0.5333	0.7600	0.9467	1.2000	1.1667	1.4233
o_3b_3	0.2567	0.3100	0.6200	0.8900	0.7700	1.2833	1.2467	1.6467
o_4b_0	0.2300	0.2800	0.5033	0.7100	0.9033	1.1600	1.0800	1.3100
o_4b_1	0.2400	0.2967	0.5600	0.8167	0.9700	1.1767	1.1367	1.3700
o_4b_2	0.2500	0.2933	0.5367	0.8400	1.0400	1.2467	1.2233	1.5500
o_4b_3	0.2567	0.3000	0.5800	0.8700	1.0333	1.2533	1.1467	1.5400
SE	0.0043	-	0.0077	0.0085	-	0.0106	0.0142	0.0135
CD	0.0124	NS	0.0221	0.0244	NS	0.0305	0.0408	0.0387
C_1	0.2267	0.2033	0.5300	0.6000	0.9633	0.8333	1.1600	1.0700
C_2	0.1833	0.1700	0.4500	0.3800	0.6867	0.4933	0.8567	0.5933
C_1 vs Treated	S*	S*	S**	S*	NS	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S**	S*	S*	S*

**Significant at 1 % level
* Significant at 5 % level
NS-Non significant

The effect of treatments on root dry weight was significant compared to the controls on most of the stages of growth during both the years of experimentation. The root weight of C_2 varied significantly from the treatments at all stages of growth. Root weight of C_1 differed significantly from all treatments at all stages except at 180 DAP of the first year. Among controls, the root weight noticed on plants which received control C_1 produced 1.16 g plant^{-1} and 1.07 g plant^{-1} for first and second year respectively. The plants which received a control treatment C_2 produced root weight of 0.8567 g plant^{-1} and 0.5933 g plant^{-1} at first and second year respectively. A significant variation in root weight between the controls was also noticed during all the periods. The root weight produced was the least for C_2 among all the combinations.

4.1.3.4 Root volume

The effect of organic manures and microbial inoculants and their interaction on root volume is presented in the Table 12.

The main effects of organic manures was significant at all stages of growth in both the years except at 120 DAP of first year. Root volume produced was the highest under O_1 and the least for O_2. At 180 DAP of first year the root volume produced was 55.55 cm^3 and it increased to 109.43 cm^3 at 240 DAP. During these periods the least volume was produced by O_2 (53.45 cm^3 and 107.37 cm^3 at 180 and 240 DAP respectively). Treatments O_3 and O_4 were on par at all the stages except at 120 DAP of first year and 180 DAP of second year.

Root volume was significantly influenced by different microbial inoculants at all stages of growth in both the years. The application of AMF together with *Trichoderma* produced significantly more root volume. The root volume by B_3 treatments (134.75 cm^3) during the second year was the highest among the main effect of microbial inoculants. The use of microbial inoculants alone or together produced more root volume than without their application.

Table 12.Effect of organic manures, microbial inoculants and their interaction on root volume of ginger, cm^3

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	8.90	10.62	23.57	28.18	55.55	67.91	109.43	128.03
O_2	8.82	10.46	23.32	27.18	53.45	65.93	107.37	124.73
O_3	8.87	10.54	23.50	27.89	55.00	67.16	109.20	125.40
O_4	8.86	10.48	23.37	27.33	54.84	65.66	108.92	125.74
SE	0.02	0.03	-	0.14	0.27	0.31	0.30	0.47
CD	0.06	0.08	NS	0.41	0.78	0.89	0.86	1.35
B_0	8.63	9.93	22.22	25.82	51.61	61.09	105.08	115.58
B_1	8.97	10.85	23.98	28.49	55.77	68.07	109.70	127.69
B_2	8.78	10.18	23.19	26.88	53.52	66.10	108.70	125.69
B_3	9.07	11.12	24.39	29.40	57.94	71.39	111.45	134.75
SE	0.02	0.03	0.10	0.14	0.27	0.31	0.30	0.47
CD	0.06	0.08	0.28	0.41	0.78	0.89	0.86	1.35
Interaction								
o_1b_0	8.61	9.91	22.15	25.78	51.31	60.77	104.86	115.36
o_1b_1	9.23	11.21	24.86	30.90	59.88	75.02	114.28	139.64
o_1b_2	8.67	10.15	22.83	26.48	52.23	62.83	107.54	119.71
o_1b_3	9.11	11.18	24.45	29.55	58.78	73.01	111.03	137.40
o_2b_0	8.54	9.87	21.78	25.38	51.08	60.43	103.57	115.11
o_2b_1	8.98	10.95	24.09	28.39	54.01	68.21	108.64	130.56
o_2b_2	8.83	10.06	23.30	26.85	52.56	67.87	107.46	125.96
o_2b_3	8.97	10.95	24.11	28.11	56.13	67.20	109.82	127.29
o_3b_0	8.71	10.00	22.55	26.08	52.16	61.75	106.65	116.18
o_3b_1	8.80	10.77	23.63	27.76	55.47	66.48	108.31	123.03
o_3b_2	8.74	10.16	23.03	26.76	52.73	64.97	107.87	121.95
o_3b_3	9.21	11.23	24.80	30.98	59.65	75.46	113.99	140.43
o_4b_0	8.66	9.94	22.38	26.03	51.87	61.41	105.24	115.67
o_4b_1	8.86	10.47	23.31	26.93	53.73	62.57	107.58	118.28
o_4b_2	8.90	10.37	23.60	27.44	56.56	68.74	111.93	135.12
o_4b_3	9.02	11.13	24.19	28.94	57.20	69.91	110.94	133.88
SE	0.04	0.05	0.19	0.28	0.55	0.62	0.60	0.94
CD	0.12	0.15	0.56	0.81	1.57	1.79	1.72	2.71
C_1	8.83	8.55	22.85	21.28	53.62	51.26	107.29	103.22
C_2	7.75	5.28	19.30	14.50	47.89	37.71	92.34	77.63
C_1 vs Treated	NS	S*	S*	S*	NS	S*	S**	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*

**Significant at 1 % level
* Significant at 5 % level
NS-Non significant

The interaction between organic manures and microbial inoculants on root volume was significant at all stages of growth during both the years. Root volume produced was highest for the treatment combination o_1b_1 for the first year. For the second year o_3b_3 combination produced maximum root volume. Treatments o_2b_1 and o_3b_3 were on par at all stages of growth during both the years. Among the combination of microbial inoculants with green leaves, o_4b_3 (green leaves + FYM with AMF and *Trichoderma*) produced more root volume generally. But at the final stage of harvest on both the years, o_4b_2 produced more volume of roots. The root volume produced by o_4b_2 during 240 DAP was 111.93 cm^3 and 135.12 cm^3 for first and second year respectively.

While the comparison of C_1 with the treatments showed significant difference at most of all the stages except at 60 and 180 DAP of first years of experimentation, the C_2 differed significantly at all the stages. During both the years the root volume produced was the least for C_2 among all the combinations and controls at all the stages of growth. Between controls also the root volume varied significantly.

4.1.4 Correlation of root characters in relation to green ginger and dry ginger yield

4.1.4.1 Root length

The root length of ginger at 240 DAP is correlated with green ginger, dry ginger, root spread, root weight and root volume on first and second year (Table 13 and 14).

Root length showed a significant positive correlation with green ginger, dry ginger, root spread, root weight and root volume on both years of experimentation. The correlation coefficient obtained between root length and dry yield was 0.9159 and 0.8727 for first and second year respectively. When root length was correlated with root spread the correlation coefficient obtained was 0.8706 and 0.9835 for first and second year respectively.

Table 13. Correlation of root characters in relation to green ginger and dry ginger yield during the first year of experiment

Characters	Green ginger yield	Dry ginger yield	Root length	Root spread	Root weight	Root volume
Green ginger yield	1					
Dry ginger yield	0.9880*	1				
Root length	0.9342*	0.9159*	1			
Root spread	0.8761*	0.9200*	0.8706*	1		
Root weight	0.9413*	0.9433*	0.8848*	0.8644*	1	
Root volume	0.9422*	0.9681*	0.8919*	0.9631*	0.9380*	1

*Significant at 5 % level

Table 14. Correlation of root characters in relation to green ginger and dry ginger yield during the second year of experiment

Characters	Green ginger yield	Dry ginger yield	Root length	Root spread	Root weight	Root volume
Green ginger yield	1					
Dry ginger yield	0.9959*	1				
Root length	0.8785*	0.8727*	1			
Root spread	0.8600*	0.8564*	0.9835*	1		
Root weight	0.9937*	0.9898*	0.9000*	0.8849*	1	
Root volume	0.9939*	0.9892*	0.9649*	0.8451*	0.9880*	1

*Significant at 5 % level

4.1.4.2 Root spread

Root spread of first and second year of study was correlated with green ginger, dry ginger, root length, root weight and root volume of first and second year respectively as presented in Table 13 and Table 14.

A significant positive correlation existed between root spread and green ginger, dry ginger, root length, root weight and root volume as revealed from two years of observation. The correlation coefficient observed between root spread and green ginger yield was 0.8761 and 0.8600 for first and second year of study.

4.1.4.3 Root weight

The root weight was correlated with green ginger, dry ginger, root length, root spread and root volume on two years of study (Table 13 and Table 14).

The correlation coefficient presented showed a significant positive correlation coefficients when root weight was compared with green and dry ginger yield on two years of study. Root weight and root length, root weight and root spread, root weight and root volume were also significantly positively correlated on both years of study.

4.1.4.4 Root volume

The inter correlation of root volume with green ginger, dry ginger, root length, root spread and root weight for two years of study are presented in Table 13 and Table 14.

A significant positive correlation exists between root volume and green and dry ginger yield. Root length, root spread and root weight also showed significant positive correlation with root volume on both years of experimentation. The correlation coefficient noticed between root volume and root dry weight was 0.9380 and 0.9880 for first and second year respectively. During second year, the correlation coefficient observed between root volume and green ginger yield was 0.9939.

4.1.5 Effect of Organic Manures, Microbial Inoculants and Their Interaction on Physiological Characters

4.1.5.1 Dry matter production

The influence of organic manures, microbial inoculants and their interaction on dry matter production at all stages of growth on both the years is depicted in the Table 15.

The influence of different sources of organic manures on drymatter production was significant in both the years except at 240 DAP of second year. A significant response was obtained with O_1 at almost all stages. The dry matter production was the least under O_2 at all stages. The dry matter produced by the main effect of FYM (O_1) at 240 DAP during the first year was 59.23 g plant^{-1}. For vermicompost + FYM, the DMP observed 57.61 g plant^{-1} during the first year.

The main effect of microbial inoculants on dry matter production was significant at all stages of growth on both the years. The dry matter production was the highest with B_3 treatment. The application of microbial inoculants had definite influence on the production of dry matter and is evident when the main effects of microbial inoculants were compared. At 60, 120, 180 and 240 DAP of first year, the dry matter produced by the application of AMF and *Trichoderma* together were 3.93, 19.79, 35.99 and 61.95 g plant^{-1} respectively.

The interaction between organic manures and microbial inoculants had significant influence on dry matter content of ginger during both the years. In combination with FYM and vermicompost AMF resulted is significantly higher values. The combination o_1b_1 accumulated highest dry matter at all stages in the first year. The o_1b_1 treatment produced a DMP of 38.11 and 64.48 g plant^{-1} at 180 and 240 DAP during the first year. During the second year the DMP observed was 49.92 and 87.45 g plant^{-1} at 180 and 240 DAP respectively. During second year o_3b_3 accumulated highest dry matter. The DMP of o_3b_3 at 180 and 240 DAP of second year of experimentation was 50.13 and 87.69 g plant^{-1}. Among O_4

combination with microbial inoculants o_4b_2 treatment showed higher drymatter production.

On both the years of experimentation the variation in dry matter production due to different treatments was significant compared to the controls. As evident from the analysis, DMP of C_1 as well as C_2 varied significantly from the treatments at all stages of growth. The control treatment C_1 produced a dry matter of 55.33 g plant^{-1} while that produced by C_2 was 37.26 g plant^{-1} at 240 DAP of first year. During the corresponding second year the DMP observed was 47.64 and 26.11 g plant^{-1} for C_1 and C_2 respectively. The effect was significant between the controls also.

The data on Table 15 represents the pooled mean of DMP at 240 DAP of first and second year of experimentation.

The DMP of first year varied significantly from the second year of experimentation. The main effect of organic manures showed significant differences in dry matter production at 240 DAP. Treatment O_1 and O_3 were on par. Similarly treatments O_2 and O_4 were also on par. No variation in dry matter production was noticed when the organic manures applied at first year was compared with the second year of experimentation. However general increasing trend in the dry matter production was noticed in the second year.

The main effect of different microbial inoculants on the drymatter production was significant. DMP was highest for B_3 (73.14) followed by B_1 (70.44). Treatments B_1 and B_2 were on par and was significantly superior compared to B_0. The application of different microbial inoculants during first and second year of study significantly influenced the drymatter production. Compared to first year, the drymatter production of second year was generally higher. The effect produced by the application of AMF and *Trichoderma* together was exceptionally superior in the second year.

Table 15. Effect of organic manures, microbial inoculants and their interaction on dry matter production in ginger, g plant^{-1}

Treatments	60 DAP		120 DAP		180 DAP		240 DAP		240 DAP
	I year	II year	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	3.60	4.92	18.23	27.46	33.77	44.86	59.23	80.49	69.86
O_2	3.54	4.89	17.19	26.84	32.61	42.99	57.61	78.56	68.08
O_3	3.55	4.93	17.87	27.28	33.53	44.28	58.85	79.51	69.18
O_4	3.55	4.89	17.57	27.01	33.31	43.85	58.69	79.06	68.88
SE	0.01	0.01	0.13	0.09	0.19	0.21	0.25	-	0.33
CD	0.02	0.03	0.39	0.26	0.54	0.61	0.71	NS	0.95
B_0	3.02	4.59	14.72	24.57	29.25	39.47	53.14	72.64	62.89
B_1	3.68	4.98	18.49	27.82	34.26	44.86	59.95	80.93	70.44
B_2	3.61	4.95	17.88	27.36	33.72	44.31	59.35	79.70	69.53
B_3	3.93	5.12	19.79	28.85	35.99	47.34	61.95	84.33	73.14
SE	0.01	0.01	0.13	0.09	0.19	0.21	0.25	0.48	0.33
CD	0.02	0.03	0.39	0.26	0.54	0.61	0.71	1.39	0.95
Interaction									
o_1b_0	2.97	4.56	14.49	24.30	28.70	39.10	52.18	72.18	62.18
o_1b_1	4.10	5.18	21.97	30.08	38.11	49.92	64.48	87.45	75.96
o_1b_2	3.33	4.82	16.31	26.24	31.97	41.88	47.45	76.49	66.97
o_1b_3	4.00	5.14	20.16	29.21	36.31	48.56	62.83	85.82	74.32
o_2b_0	2.96	4.48	14.36	24.20	28.45	38.86	51.57	71.17	61.37
o_2b_1	3.83	5.06	18.53	28.10	34.25	45.11	60.50	82.48	71.49
o_2b_2	3.66	5.00	17.92	28.10	33.84	43.80	59.10	79.99	69.55
o_2b_3	3.71	5.03	17.97	27.42	33.90	44.18	59.27	80.58	69.93
o_3b_0	3.09	4.70	15.33	27.65	30.45	40.20	55.27	74.21	64.74
o_3b_1	3.56	4.95	17.33	25.35	32.98	43.45	58.03	78.58	68.31
o_3b_2	3.45	4.87	17.00	26.95	32.66	43.35	57.79	77.57	67.68
o_3b_3	4.09	5.21	21.84	30.14	38.03	50.13	64.32	87.69	76.01
o_4b_0	3.04	4.63	14.70	24.42	29.40	39.72	53.54	73.02	63.28
o_4b_1	3.25	4.75	16.11	26.15	31.69	40.98	56.80	75.21	66.01
o_4b_2	3.99	5.11	20.29	29.10	36.41	48.22	63.05	84.77	73.91
o_4b_3	3.93	5.08	19.17	28.38	35.73	46.49	61.38	83.24	72.31
SE	0.01	0.02	0.27	0.18	0.37	0.43	0.49	0.97	0.66
CD	0.02	0.05	0.77	0.52	1.08	1.23	1.42	2.78	1.90
Y mean							58.60	79.14	
SE							0.197		
CD							0.558		
C_1	3.36	2.88	16.33	14.18	31.40	26.9	55.33	47.64	52.48
C_2	2.62	2.09	13.47	13.47	21.2	13.82	37.26	26.11	31.69
C_1 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*	
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*	
CD for OY									NS
SE for BY									1.115
CD for BY									0.394
CD for OBY									NS

*-Significant at 5 % level NS-non significant

Under the pooled mean, the interaction O x B indicated significant difference in drymatter production. Among the various treatment combinations o_3b_3, o_1b_1 and o_1b_3 produced significantly superior dry matter production and were on par. Generally the combinations with organic manure produced less dry matter. The combination of O x B at second year of study did not vary significantly compared to the first year.

The dry matter production of controls C_1 and C_2 varied significantly from other organic treatments. The DMP of C_2 was the lowest among all the treatments. Significant variation in controls was noticed when the DMP of first year was compared with the DMP of second year. The dry matter production of C_2 at 240 DAP in the first year of experimentation was 37.26 g plant^{-1}, which decreased to 26.11 g plant^{-1} at the second year of experimentation.

4.1.5.2 Crop growth rate

The effect of CGR by different organic manures, microbial inoculants and their interaction for two years as well as pooled mean of CGR at 240 DAP are presented in the Table 16.

Crop growth rate was significantly influenced by organic manures on 60-120 DAP of first and second year and 120-180 DAP of second year. The effect was insignificant on 120-180 DAP of first year and 180-240 DAP of both the years. At 60-120 DAP of first and second year and 120-180 of second year O_1, O_3 and O_4 were on par.

The microbial inoculants significantly influenced the crop growth rate on all the stages of growth on both the years. CGR was the maximum under B_3 treatment at all stages. AMF and *Trichoderma* treated plants showed similar effects on crop growth rate at all stages of growth except between 60-120 DAP of the second year.

The interaction effect O x B was significant at most of the stages of growth except between 120-180 DAP of first year. Crop growth rate was maximum for o_1b_1 and o_3b_3 combinations at all stages of growth for both

Table 16. Effect of organic manures, microbial inoculants and their interaction on CGR of ginger, g m^{-2} day^{-1}

Treatments	60-120 DAP		120-180 DAP		180-240 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	0.2447	0.3728	0.2578	0.2897	0.4250	0.5950	0.51
O_2	0.2226	0.3627	0.2578	0.2688	0.4217	0.5950	0.508
O_3	0.2357	0.3690	0.2603	0.2800	0.4283	0.5900	0.509
O_4	0.2290	0.3683	0.2591	0.2783	0.4258	0.5908	0.508
SE	0.0018	0.0013	-	0.0024	-	-	
CD	0.0057	0.0038	NS	0.0069	NS	NS	NS
B_0	0.1952	0.3210	0.2422	0.2462	0.4000	0.5533	0.477
B_1	0.2427	0.3807	0.2627	0.2842	0.4342	0.6033	0.519
B_2	0.2316	0.3744	0.2614	0.2793	0.4250	0.5923	0.509
B_3	0.2618	0.3967	0.2657	0.3069	0.4417	0.6217	0.532
SE	0.0018	0.0013	0.0020	0.0024	0.0038	0.0058	0.003
CD	0.0057	0.0038	0.0058	0.0069	0.0109	0.0166	0.010
Interaction							
o_1b_0	0.1920	0.3180	0.2370	0.2443	0.3933	0.5467	0.470
o_1b_1	0.3033	0.4157	0.2690	0.3343	0.4567	0.6367	0.547
o_1b_2	0.2113	0.3563	0.2597	0.2563	0.4133	0.5767	0.495
o_1b_3	0.2697	0.4010	0.2657	0.3227	0.4367	0.6200	0.528
o_2b_0	0.1900	0.3140	0.2347	0.2430	0.3900	0.5400	0.465
o_2b_1	0.2340	0.3833	0.2617	0.2850	0.4400	0.6136	0.527
o_2b_2	0.2323	0.3730	0.2607	0.2710	0.4267	0.6033	0.515
o_2b_3	0.2340	0.3780	0.2623	0.2763	0.4300	0.6233	0.527
o_3b_0	0.2043	0.3287	0.2523	0.2487	0.4167	0.5700	0.493
o_3b_1	0.2240	0.3676	0.2606	0.2687	0.4200	0.5867	0.503
o_3b_2	0.2183	0.3637	0.2597	0.2690	0.4167	0.5767	0.497
o_3b_3	0.2960	0.4167	0.2690	0.3337	0.4600	0.6267	0.543
o_4b_0	0.1947	0.3233	0.2450	0.2487	0.4000	0.5567	0.478
o_4b_1	0.2093	0.3567	0.2600	0.2487	0.4200	0.5767	0.498
o_4b_2	0.2643	0.4047	0.2657	0.3207	0.4433	0.6133	0.528
o_4b_3	0.2477	0.3887	0.2657	0.2980	0.4400	0.6167	0.528
SE	0.0038	0.0026	-	0.0048	0.0076	0.0116	0.007
CD	0.0103	0.0075	NS	0.0139	0.0218	0.0332	0.020
Y mean					0.425	0.593	
SE					0.002		
CD					0.007		
C_1	0.2163	0.1807	0.2520	0.2123	0.4000	0.3633	0.3817
C_2	0.1557	0.1147	0.1283	0.0527	0.2467	0.1433	0.1950
C_1 vs Treated	S*	S*	NS	S*	S*	S*	
C_2 vs Treated	S*	S*	S	S*	S*	S*	
C_1 vs C_2	S*	S*	S	S*	S*	S*	
CD for OY							NS
CD for BY							NS
CD for OBY							NS

*-Significant at 5 % level NS-non significant

the years. However the combination of B_0 with all the organic manures showed low crop growth rate. The crop growth rate recorded was the highest between 180-240 DAP of the second year (0.6367 g m^{-2} day^{-1}) for o_1b_1.

The crop growth rate showed increasing trend as the period of growth advanced. At final stage of growth, CGR was 0.425 g m^{-2} day^{-1} for O_1 0.4283 g m^{-2} day^{-1} for O_3 and 0.4258 g m^{-2} day^{-1} for O_4 and 0.4217 g m^{-2} day^{-1} for O_2 for the first year. During the second year CGR was 0.6 g m^{-2} day^{-1} for O_1 and O_2 and 0.59 g m^{-2} day^{-1} for O_3 and 0.5908 g m^{-2} day^{-1} for O_4.

Among microbial inoculants, during the first year, between 60-120 DAP, CGR ranged from 0.1952 to 0.2618 g m^{-2} day^{-1} while at the final stage CGR ranged from 0.4000 to 0.4417 0.4 g m^{-2} day^{-1}. CGR showed a similar trend of increase during the second year also.

During the first year generally an increasing trend in CGR was noticed from the initial phase to final phase except with o_3b_3 of second year. Between 60-120 DAP of second year the CGR produced was more than under 120-180 DAP. However at the final stage of growth *ie.,* between 180-240 DAP, the rate of crop growth was higher.

There was significant difference between the CGR of treatments and controls at most of the stages of growth on both the years. While the CGR of C_1 differed from the treatments at all stages except at 120-180 DAP of first year, the C_2 differed from treatments at all stages. When the controls C_1 and C_2 were compared, significant difference in CGR was noted. Generally CGR was higher for C_1 than C_2. For C_1 as the period of growth advances the crop growth rate also increased on both the years.

The pooled mean reveal that the CGR produced by the application of organic manures, microbial inoculants and their interaction during the first year did not vary significantly from the second year of study.

4.1.5.3 Net assimilation rate

The main and interaction effects of treatments on NAR at different growth stages in both the years are presented in Table 17.

Table 17. Effect of organic manures, microbial inoculants and their interaction on NAR of ginger, g m^{-2} day^{-1}

Treatments	60-120 DAP		120-180 DAP		180-240 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	0.1713	0.1836	0.0680	0.0592	0.0598	0.0698	0.0644
O_2	0.1641	0.1789	0.0687	0.0561	0.0603	0.0704	0.0649
O_3	0.1708	0.1814	0.0691	0.0576	0.0603	0.0692	0.0654
O_4	0.1648	0.1810	0.0691	0.0574	0.0602	0.0696	0.0646
SE	0.0012	0.0010	-	0.0004	-	-	-
CD	0.0034	0.0029	NS	0.0013	NS	NS	NS
B_0	0.1582	0.1765	0.0697	0.0551	0.0593	0.0688	0.0629
B_1	0.1708	0.1852	0.0688	0.0577	0.0607	0.0701	0.0625
B_2	0.1670	0.1822	0.0698	0.0573	0.0597	0.0693	0.0643
B_3	0.1748	0.1810	0.0666	0.0603	0.0608	0.0708	0.0655
SE	0.0012	0.0010	0.0005	0.0004	-	-	0.0004
CD	0.0034	0.0029	0.0014	0.0013	NS	NS	0.0012
Interaction							
o_1b_0	0.1567	0.1770	0.0687	0.0553	0.0590	0.0687	0.0639
o_1b_1	0.1900	0.1920	0.0650	0.0640	0.0613	0.0710	0.0662
o_1b_2	0.1627	0.1847	0.0723	0.0547	0.0590	0.0697	0.0644
o_1b_3	0.1757	0.1807	0.0660	0.0627	0.0597	0.0700	0.0649
o_2b_0	0.1563	0.1763	0.0683	0.0553	0.0583	0.0680	0.0632
o_2b_1	0.1627	0.1783	0.0677	0.0570	0.0610	0.0703	0.0657
o_2b_2	0.1687	0.1807	0.0693	0.0557	0.0597	0.0707	0.0652
o_2b_3	0.1687	0.1803	0.0693	0.0563	0.0623	0.0727	0.0675
o_3b_0	0.1630	0.1763	0.0713	0.0543	0.0607	0.0697	0.0652
o_3b_1	0.1673	0.1827	0.0703	0.0560	0.0597	0.0693	0.0645
o_3b_2	0.1657	0.1833	0.0710	0.0563	0.0597	0.0673	0.0635
o_3b_3	0.1870	0.1833	0.0637	0.0637	0.0610	0.0703	0.0656
o_4b_0	0.1570	0.1763	0.0703	0.0553	0.0593	0.0690	0.0642
o_4b_1	0.1633	0.1817	0.0723	0.0537	0.0607	0.0697	0.0652
o_4b_2	0.1710	0.1803	0.0663	0.0623	0.0603	0.0693	0.0648
o_4b_3	0.1677	0.1797	0.0673	0.0583	0.0603	0.0703	0.0667
SE	0.0023	0.0020	0.0016	0.0009	-	-	-
CD	0.0067	0.0057	0.0028	0.0025	NS	NS	NS
Y mean					0.060	0.067	
SE					0.0003		
CD					0.0009		
C_1	0.1657	0.1463	0.0623	0.0623	0.583	0.0390	0.0570
C_2	0.1340	0.1010	0.0173	0.0173	0.0443	0.0283	0.0360
C_1 vs Treated	NS	S*	NS	S*	S**	S*	
C_2 vs Treated	S*	S*	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	S*	S*	
CD for OY							NS
CD for BY							NS
CD for OBY							NS

*Significant at 5 % level

**Significant at 1 % level

NS-non significant

The effect of organic manures in NAR was significant at 60-120 DAP of first year and 60-120 DAP and 120-180 DAP of second year. The effect on NAR was insignificant at 120-180 DAP of first year and 180-240 DAP of first and second year. At these significant periods O_1 and O_3 recorded highest NAR.

Various microbial inoculants influenced NAR significantly through out the period except during the final phase (180-240 DAP) of both the years. The highest values of NAR was obtained due to application of B_1 among the microbial inoculants. The treatments B_2 and B_3 were on par at all these stages.

The effect of the interactions, O x B was significant at almost all stages except during the final phase (180-240 DAP) of both the years. The combination, o_1b_1 resulted in significantly higher NAR at all stages except 180-240 DAP of two years of study o_1b_1 and o_1b_3 were on par at all these stages. Vermicompost (O_2) in combination with microbial inoculants did not produce any significant change in NAR. With O_3 the combination of AMF and *Trichoderma* resulted in significantly higher NAR. Treatments o_4b_0, o_4b_1 and o_4b_2 were on par at all the significant stages except at 120-180 DAP of the second year.

During the first year, NAR was found to decrease as the growth advances. Between 60-120 DAP, the NAR was 0.1641 and 1648 g m^{-2} day^{-1} for O_2, O_4 and 0.1713 and 0.1708 g m^{-2} day^{-1} for O_1, O_3 respectively. The value decreased to 0.0598, 0.0603, 0.0603, 0.0602 g m^{-2} day^{-1} for O_1, O_2, O_3 and O_4 respectively and 0.06 g m^{-2} day^{-1} for the following periods of growth. However for the second year, between 60-120 DAP, NAR was higher (0.1836 g m^{-2} day^{-1}) for O_1. But as the growth advanced, a decrease in NAR was recorded for the period 120-180 DAP (0.0592 g m^{-2} day^{-1}) for O_1. For the final phase of growth, slight increase (0.0698 g m^{-2} day^{-1}) in the value of NAR was resulted.

A general decreasing trend in NAR was noticed as the growth advances during the first year for microbial inoculants also. During the second year between 60-120 DAP, NAR values were higher, 0.1852 g m^{-2} day^{-1} was resulted from B_1 and 0.1765, 0.1822 and 0.1810 g m^{-2} day^{-1} for the rest of microbial treatments. The value of NAR decreased 0.0577 g m^{-2} day^{-1} at 120-180 DAP. However at final phase of second year a slight increase in the value of NAR (0.0701 g m^{-2} day^{-1}) was noted. Between 60-120 DAP of first year a higher value of NAR was reported for all the interaction effects. However, the value decreased for all the interactions between 120-180 DAP.

To compare the interaction effects of plants grown under second year for different phases of growth during the initial phase the value was the high. A decrease in NAR was evident, at the next phase of growth (120-180 DAP). However, at final phase of growth (180-240 DAP) NAR showed a slight increase in value for all the interaction effects.

For the control treatments C_1 as the growth advanced for the first year, NAR was found to decrease. For the second year NAR was 0.1463 g m^{-2} day^{-1} for C_1 between 60-120 DAP and it decreased to 0.06 g m^{-2} day^{-1} for the remaining two phases. During the first year the value of NAR at the initial phase was 0.134 g m^{-2} day^{-1} for C_2 and it decreased to 0.0173 and 0.0443 g m^{-2} day^{-1} for the rest two phases. C_2 showed higher NAR of 0.1010 g m^{-2} day^{-1} between 60-120 DAP and it decreased to 0.0173 g m^{-2} day^{-1} for 120-180 DAP during the second year. At the final phase of second year a slight increase in the value of NAR (0.0283 g m^{-2} day^{-1}) was recorded for C_2.

C_1 differed significant from the treatment at all stages during the second year of experimentation and only at the final stage of first year of experimentation. The control C_2 differed significantly from the treatments as evident from the Table 17. The NAR of C_1 also varied significantly from C_2 at all stages of growth. The NAR was the least for C_2 on all the periods of growth.

The results of the pooled analysis of net assimilation rate at 240 DAP of both the years of experimentation is presented in the Table 17.

Consistent results were obtained between two years in crop growth rate due to organic manures, microbial inoculants and due to their interaction.

4.1.5.4 Relative Growth Rate

The effects of organic manures, microbial inoculants and their interactions on relative growth rate for the two years of study are presented in Table 18.

The main effect of various organic sources showed significance only at the initial phase of growth (60-120 DAP) of both the years. The effect on RGR was insignificant for the remaining phases. Between 60-120 DAP of first year, RGR recorded ranged from 0.0264 to 0.0270 g day^{-1}. The value decreased during the following phases for both the years and for second year the value ranged from 0.0283 to 0.0287.

The variation in RGR due to microbial inoculants was not significant during the various growth phases on both the years. The effect was significant only at 60-120 DAP of second year and 180-240 DAP of first year. At 60-120 DAP of second year the RGR ranged between 0.0278 to 0.0287 g day^{-1}. At 180-240 DAP of the first year, the value of RGR recorded was 0.0100 g day^{-1} for B_0, 0.0094 g day^{-1} for B_1, 0.0093 g day^{-1} for B_2 and 0.0092 g day^{-1} for B_3

Significant interaction O x B occurred only during the initial phase of both the years and for 120-180 DAP of second year. The variation noticed between treatment combinations was non-significant for the remaining period. At 60-120 days after planting, RGR ranged from 0.0263 to 0.0280 g day^{-1} during the first year and 0.0217 to 0.0290 g day^{-1} during the second year. The value decreased to a range of 0.0073 to 0.0087 g day^{-1} for the treatment combinations between 120-180 DAP of second year.

Between 60-120 DAP, RGR recorded was 0.0263 and 0.0273 g day^{-1} for C1 and C2 during the first year and 0.0273 and 0.0277 g day^{-1} for the second year. The value decreased to 0.0110 and 0.0076 g day^{-1} for C_1 and C_2 during the first year and the 0.0100 and 0.0040 g day^{-1} during the second year respectively for the phase 120-180 DAP.

Table 18. Effect of organic manures, microbial inoculants and their interaction on RGR of ginger, g day^{-1}

Treatments	60-120 DAP		120-180 DAP		180-240 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	0.0268	0.0285	0.0102	0.0082	0.0094	0.0097	0.0096
O_2	0.0264	0.0287	0.0109	0.0080	0.0095	0.0100	0.0098
O_3	0.0270	0.0283	0.0187	0.0081	0.0095	0.0098	0.0097
O_4	0.0265	0.0284	0.0110	0.0080	0.0095	0.0098	0.0097
SE	0.0001	0.0001	-	-	-	-	-
CD	0.0004	0.0003	NS	NS	NS	NS	NS
B_0	0.0265	0.0278	0.0196	0.0080	0.0100	0.0101	0.0101
B_1	0.0268	0.0285	0.0105	0.0080	0.0094	0.0098	0.0096
B_2	0.0268	0.0283	0.0108	0.0081	0.0093	0.0098	0.0095
B_3	0.0268	0.0287	0.0100	0.0082	0.0092	0.0096	0.0095
SE	-	0.0001	-	-	0.0001	-	0.0006
CD	NS	0.0003	NS	NS	0.0003	NS	0.0018
Interaction							
o_1b_0	0.0263	0.0280	0.0110	0.0080	0.0100	0.0100	0.0100
o_1b_1	0.0280	0.0290	0.0090	0.0087	0.0090	0.0093	0.0092
o_1b_2	0.0263	0.0280	0.0110	0.0080	0.0097	0.0100	0.0099
o_1b_3	0.0267	0.0290	0.0100	0.0080	0.0090	0.0093	0.0092
o_2b_0	0.0263	0.0217	0.0113	0.0080	0.0100	0.0100	0.0100
o_2b_1	0.0267	0.0287	0.0110	0.0080	0.0097	0.0100	0.0099
o_2b_2	0.0263	0.0280	0.0107	0.0080	0.0090	0.0100	0.0095
o_2b_3	0.0263	0.0280	0.01107	0.0080	0.0093	0.0100	0.0097
o_3b_0	0.0270	0.0280	0.0443	0.0080	0.0100	0.0100	0.0100
o_3b_1	0.0263	0.0280	0.0103	0.0080	0.0093	0.0100	0.0097
o_3b_2	0.0267	0.0280	0.0110	0.0080	0.0097	0.0100	0.0099
o_3b_3	0.0280	0.0290	0.0090	0.0080	0.0090	0.0093	0.0092
o_4b_0	0.0263	0.0217	0.0117	0.0083	0.0100	0.0103	0.0702
o_4b_1	0.0263	0.0283	0.0117	0.0080	0.0097	0.0100	0.0098
o_4b_2	0.0270	0.0290	0.0103	0.0073	0.0090	0.0093	0.0092
o_4b_3	0.0263	0.0287	0.0103	0.0083	0.0093	0.0097	0.0092
SE	0.0003	0.0002	-	0.0002	-	-	0.0072
CD	0.0008	0.0006	NS	0.0006	NS	NS	0.0036
Y mean					0.00948	0.00983	
SE					0.0001		
CD					0.0002		
C_1	0.0263	0.0273	0.0110	0.0100	0.0093	0.0100	0.0097
C_2	0.0273	0.0277	0.0076	0.0040	0.0093	0.0106	0.0070
C_1 vs Treated	NS	S *	NS	S*	NS	NS	
C_2 vs Treated	S**	S*	NS	S*	NS	S*	
C_1 vs C_2	S**	NS	NS	S*	S*	NS	
CD for OY							NS
CD for BY							NS
CD for OBY							NS

*Significant at 5 % level
**Significant at 1 % level
NS-non significant

The relative growth rate of treatments varied significantly from the control C_1 at 60-120 DAP and 120-180 DAP of second year. The difference was significant between the control C_2 and the treatment for 60-120 DAP of both the years and the second year of 120-180 DAP and 180-240 DAP. Significant difference in RGR was reported between the controls at the initial phase of first year and 120-180 DAP both the years insignificant values were reported for the remaining periods.

The pooled data revealed that the relative growth rate of first year was significantly different from second year of experimentation. But the organic manures, microbial inoculants and their interactions produced similar effects of RGR over the two years.

4.1.5.5 Leaf area index

The main effect of organic manures, microbial inoculants and their interaction on leaf area index at different growth stages during two years are presented in Table 19.

The influence of organic manures on leaf area index was significant at most of the stages on both the years. Leaf area index did not show any significant differences on 120 DAP of second year and 240 DAP of first and second year. During the significant stages leaf area index showed by FYM was highest on all stages. Treatment O_2 showed the least LAI.

For the first year at 60 DAP, LAI ranged from 0.54 to 0.48. At 120 DAP the highest LAI was for O_1 (2.2917). Treatments O_2, O_3 and O_4 were on par at these stages. Highest LAI at 180 DAP was for O_1 (5.3275). Each treatment showed significantly different value of LAI at these stages.

During the second year at 60 DAP, O_1 recorded LAI of 0.8517. Treatments O_2, O_3 and O_4 were on par at these stages. At 180 DAP; O_1 and O_3 were on par. LAI produced by O_2 was the least (6. 3592).

Significant difference in LAI was recorded by different sources of microbial inoculants on all stages of growth on both the years.

Table 19. Effect of organic manures, microbial inoculants and their interaction on LAI of ginger

Treatments	60 DAP		120 DAP		180 DAP		240 DAP		
	I year	II year	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	0.5383	0.8517	2.2917	3.2542	5.3275	6.4825	8.8392	10.5183	9.68
O_2	0.4806	0.8183	2.2300	3.2258	5.1942	6.3592	8.7775	10.4675	9.62
O_3	0.5033	0.8317	2.2433	3.2350	5.2642	6.4556	8.9000	10.5088	9.70
O_4	0.5150	0.8242	2.2542	3.2358	5.2717	6.4333	8.8217	10.4500	9.64
SE	0.0043	0.0068	0.0062	-	0.0116	0.0079	-	-	
CD	0.0123	0.0196	0.0177	NS	0.0332	0.0226	NS	NS	NS
B_0	0.4325	0.6842	2.0350	2.9542	4.9183	5.9858	8.5650	10.0650	9.31
B_1	0.5258	0.8617	2.3023	3.3058	5.3458	6.5258	8.8925	10.5975	9.75
B_2	0.5050	0.8342	2.2617	3.2592	5.2733	6.4750	8.8567	10.5025	9.68
B_3	0.5733	0.9458	2.4200	3.4317	5.5200	6.7433	9.0242	10.7767	9.90
SE	0.0043	0.0068	0.0062	0.0104	0.0116	0.0079	0.0436	0.0195.	0.025
CD	0.0123	0.0196	0.0177	0.0298	0.0332	0.0226	0.1251	0.0559	0.073
Interaction									
o_1b_0	0.4333	0.6700	2.0200	2.9233	4.8833	5.9133	8.4033	10.0000	9.20
o_1b_1	0.6506	1.0133	2.5433	3.5167	5.7367	6.9300	9.1567	10.9433	10.05
o_1b_2	0.4600	0.7400	2.1433	3.1200	5.1033	6.2500	8.7300	10.2767	9.50
o_1b_3	0.6100	0.9833	2.4600	3.4567	5.5867	6.8367	9.0667	10.8533	9.96
o_2b_0	0.4233	0.6600	2.0100	2.9033	4.8600	5.8833	8.3667	9.9767	9.17
o_2b_1	0.5300	0.9000	2.3467	3.4000	5.3900	6.6033	8.9700	10.7100	9.84
o_2b_2	0.4833	0.8500	2.2700	3.2767	5.2467	6.4600	8.8800	10.5800	9.73
o_2b_3	0.4833	0.8633	2.2933	3.3233	5.2800	6.4900	8.8933	10.6033	9.75
o_3b_0	0.4400	0.7100	2.0667	3.0167	5.0067	6.1300	8.9500	10.1967	9.57
o_3b_1	0.4700	0.8067	2.2067	3.2100	5.1833	6.3867	8.7400	10.4900	9.62
o_3b_2	0.4567	0.7933	2.1833	3.1767	5.1400	6.3633	8.7500	10.3867	9.57
o_3b_3	0.6467	1.0167	2.5167	3.5367	5.7267	6.9400	9.1600	10.9500	10.03
o_4b_0	0.4333	0.6967	2.0433	3.9733	4.9233	6.0167	8.5400	10.0867	9.31
o_4b_1	0.4533	0.7267	2.1133	3.0967	5.0733	6.1833	8.7033	10.2467	9.47
o_4b_2	0.6200	0.9533	2.4500	3.4633	5.6033	6.8367	9.0667	10.7667	9.92
o_4b_3	0.5533	0.9200	2.4100	3.4100	5.4867	6.7067	8.9767	10.7000	9.84
SE	0.0086	0.0136	0.0123	0.0207	0.0231	0.0157	0.0871	0.0390	0.051
CD	0.0245	0.0392	0.0354	0.0593	0.0664	0.0452	0.2501	0.1118	0.147
Y mean							8.83	10.49	
SE							0.017		
CD							0.049		
C_1	04467	0.4333	2.1667	2.0367	5.0733	4.7733	8.6433	8.1667	8.41
C_2	0.3933	0.3733	1.9633	11.9000	4.5033	4.1867	6.5400	5.8400	6.19
C_1 vs Treated	S*	S*	S*	S*	S*	S*	S**	S*	
C_2 vs Treated	S*	S*	S*	S*	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	S*	S*	S*	S*	
CD for OY									NS
SE for BY									0.035
CD for BY									0.098
CD for OBY									NS

*Significant at 5 % level
**Significant at 1 % level
NS-non significant

Application of AMF and *Trichoderma* together resulted in significantly higher LAI on all the stages. The effect was significantly low for the treatments without microbial inoculation. The application of AMF produced significantly higher LAI compared to *Trichoderma* application.

At 60 DAP, the LAI ranged from 0.43 to 0.5 per cent (for B_0, B_1, B_2 and B_3) treatments) during the first year while for second year LAI changed to 0.68 for B_O and O.95 for B_3. LAI recorded was 2.035 for B_0 and 2.42 for B_3 at 120 DAP of first year. The LAI of 2.95 was recorded for B_O and 3.4317 for B_2 during the corresponding second year at this period. At 180 DAP, LAI was 5.52 for B_3 during the first year and 6.7433 for the second year. At these periods LAI was significantly different for each treatment. At the final stage of harvest LAI was significantly high for B_3 (10.7767) during the second year.

Significant difference in LAI was observed throughout the crop growth in both the years with O x B interaction. Treatments, o_1b_1, o_1b_3, o_3b_3 and o_4b_2 produced significantly higher LAI throughout the crop growth. For all the combinations of B_0 with all the organic manures (o_1b_0, o_2b_0, o_3b_0 and o_4b_0) lower LAI was observed. At 60 DAP of first year o_1b_1 and o_3b_3 showed an LAI of 0.6506 and 0.6467, which increased to 2.5433 and 2.5167 at 120 DAP respectively. However, at the final stage of harvest of LAI of 9.1567 and 9.1600 was resulted from o_1b_1 and o_3b_3 during the first year. During the second year the value was 10.9433 and 10.95 respectively. There was significant difference in the leaf area index of treatments and controls as well between controls for both the year at all stages of growth.

The controls, C_1 as C_2 differed significantly from the treatments during these periods. The leaf area index of C_1 was also significantly different from C_2 at all stages of growth on both the years. LAI observed in C_1 was higher than C_2 while the LAI recorded for C_1 was 8.1667, the LAI for C_2 was only 5.84 at 240 DAP.

The pooled data of leaf area index at 240 DAP of first and second year of study are presented in the Table 15. The leaf area index of plants treated with organic manures during the first year did not differ significantly from the second year of study. But the application of different microbial inoculants resulted in a higher leaf area index during the second year of experimentation, which was significantly different from first year. The combined effect of organic manures and microbial inoculants on the leaf area index of first and second year of experimentation was not different.

4.1.5.6 Leaf area duration

The main and interaction effects of organic manures, microbial inoculants and their interaction on leaf area duration for the first and second year of experiment are presented in Table 20.

Significant difference in leaf area duration was observed throughout the crop growth in both the years with organic manure application. LAD was the highest for O_1 throughout the period of growth. O_3 and O_4 were on par at 120 – 180 DAP of both the years and 180-240 DAP of second year. Between, 180 – 240 DAP of second year O_1 and O_3 were on par. LAD for O_1 during the initial phase of growth of first year was 84.90 while for the second year, it was 123.18. LAD increased to 424.88 and 510.03 at the final stage of harvest for O_1 during the first and second year respectively.

The effect of microbial inoculants on LAD was significantly different at all stages of growth on both the years. The LAD of B_3 was significantly superior compared to other treatments at all the phases of growth on both the years. The application of microbial inoculants showed significantly higher LAD and was evident when the values of other treatments were compared to B_0. During the first year, LAD for B_0 was 74.03 while for B_3 it was 89.80 at the initial phase of growth. The value increased to 402 and 436.23 for B_0 and B_3 respectively at the final stage of

Table 20. Effect of organic manures, microbial inoculants and their interaction on LAD of ginger

Treatments	60-120 DAP		120-180 DAP		180-240 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	84.90	123.18	228.45	292.10	424.88	510.03	467.45
O_2	81.30	121.38	222.73	287.85	419.07	504.68	461.88
O_3	82.35	122.02	225.15	290.65	422.35	509.40	465.88
O_4	83.25	115.57	225.63	290.07	422.53	506.35	464.44
SE	0.28	1.69	0.48	0.46	0.69	0.79	0.621
CD	0.81	4.86	1.37	1.32	2.00	2.27	1.794
B_0	74.03	109.32	208.60	268.20	402.00	481.53	441.76
B_1	84.85	125.03	229.33	294.95	426.80	513.43	470.11
B_2	83.13	116.42	225.98	292.03	423.80	510.05	466.93
B_3	89.80	131.38	238.05	305.50	436.23	525.45	480.84
SE	0.28	1.69	0.48	0.46	0.69	0.79	0.621
CD	0.81	4.86	1.37	1.32	2.00	2.27	1.794
Interaction							
o_1b_0	73.60	107.80	207.10	265.50	398.60	477.40	438.00
o_1b_1	95.80	135.90	247.80	313.40	446.20	436.20	491.20
o_1b_2	78.10	115.80	217.50	281.10	415.10	495.80	455.45
o_1b_3	92.10	133.20	241.40	308.80	439.60	530.70	485.15
o_2b_0	73.00	106.90	206.10	263.60	396.80	475.80	436.30
o_2b_1	86.30	129.00	232.10	300.10	430.50	518.90	474.70
o_2b_2	82.60	123.80	225.50	292.10	423.80	511.20	467.50
o_2b_3	83.30	125.80	227.20	295.60	425.20	512.80	469.00
o_3b_0	75.70	111.80	212.20	274.40	408.70	489.80	449.25
o_3b_1	80.30	120.50	221.40	287.90	417.20	506.30	461.75
o_3b_2	79.00	119.16	219.70	286.20	416.90	505.40	461.75
o_3b_3	94.90	136.60	247.30	314.10	446.60	536.10	491.35
o_4b_0	74.30	110.77	209.00	269.70	403.90	483.10	443.50
o_4b_1	77.00	114.70	216.00	278.40	413.30	492.30	452.80
o_4b_2	92.80	106.90	241.20	308.70	439.40	527.80	483.60
o_4b_3	88.90	129.90	236.30	303.50	433.50	522.20	477.85
SE	0.56	3.38	0.95	0.92	1.39	1.58	1.243
CD	1.61	9.72	2.73	2.64	3.99	4.54	3.589
Y mean					422.21	507.61	
SE					0.370		
CD					1.047		
C_1	78.60	72.00	217.	202.90	411.8	304.70	358.25
C_2	70.70	68.20	194	182.6	255.10	232.20	243.65
C_1 vs Treated	S*	S*	S*	S*	S*	S*	
C_2 vs Treated	S*	S*	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	S*	S*	
CD for OY							NS
SE for BY							0.741
CD for BY							2.095
SE for OBY							1.481
CD for OBY							4.189

*Significant at 5 % level
NS-non significant

harvest. However, the corresponding LAD for the second year was 169.32 for B_0 and 131.38 for B_3 at the initial phase of growth. The LAD increased to 481.53 and 525.45 for B_O and B_3 respectively at the final phase of growth.

The interaction O x B recorded significant differences in leaf area duration at all stages of growth in both the years. Treatments o_1b_1 and o_3b_3 recorded significantly higher LAD and was on par at all the phases of growth on both the years. In combination with vermicompost (O_2) microbial inoculant, AMF produced higher leaf area duration at all the stages of growth on both the years. Among O_4B combinations, o_4b_2 resulted in higher leaf area duration. All the B_O combinations with any of the organic manures resulted in lower leaf area duration. During the first year lowest LAD was resulted from o_2b_O (73) and it increased to 396.80 at the final phase of harvest. The corresponding value recorded during the second year was 106.90 and 475.80.

The leaf area duration of treatment means differed significantly from both control means at all stages of growth in both the years. Controls, C_1 as well as C_2 differed significantly from the treatments. The LAD of C_1 was significantly higher than C_2 at all stages when both were compared. Between 180 – 240 DAP, LAD for C_1 was 304.7 while for C_2 it was only 232.2.

Table 16, also presents the pooled mean of leaf area duration of first and second year at 240 DAP. The pooled analysis reveals that the LAD of first year differed significantly from the second year, but the organic manure application produced similar effects on first and second year. The interaction results clearly indicated that the LAD of first year was significantly different from the LAD of the second year.

4.1.5.7 Harvest Index

Table 21, represents the main effects of different sources of organic manures and microbial inoculants and their interaction on harvest index.

Table 21. Effect of organic manures, microbial inoculants and their interaction on HI of ginger

Treatments	120 DAP		180 DAP		240 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	0.4216	0.4603	0.5014	0.5008	0.5197	0.5187	0.519
O_2	0.4141	0.4583	0.5002	0.4983	0.5187	0.5186	0.519
O_3	0.4159	0.4607	0.5025	0.5015	0.5198	0.5182	0.519
O_4	0.4176	0.4595	0.5003	0.5010	0.5196	0.5190	0.519
SE	-	-	-	-	-	-	-
CD	NS	NS	NS	NS	NS	NS	NS
B_0	0.3843	0.4445	0.4883	0.5002	0.5150	0.5166	0.516
B_1	0.4245	0.4643	0.5051	0.5003	0.5206	0.5192	0.520
B_2	0.4163	0.4637	0.5040	0.5004	0.5207	0.5177	0.519
B_3	0.4441	0.4653	0.5170	0.5007	0.5215	0.5209	0.521
SE	0.0030	0.0010	0.0014	-	0.0006	-	0.001
CD	0.0087	0.0028	0.0041	NS-	0.0047	NS	0.003
Interaction							
o_1b_0	0.3843	0.4433	0.4880	0.5000	0.5143	0.5163	0.515
o_1b_1	0.4583	0.4673	0.5097	0.5007	0.5233	0.5213	0.522
o_1b_2	0.3853	0.4630	0.5010	0.5010	0.5203	0.5157	0.518
o_1b_3	0.4583	0.4673	0.5070	0.5013	0.5210	0.5213	0.521
o_2b_0	0.3843	0.4427	0.4863	0.4987	0.5130	0.5157	0.514
o_2b_1	0.4460	0.4647	0.5057	0.4980	0.5190	0.5210	0.520
o_2b_2	0.4130	0.4630	0.5043	0.4983	0.5213	0.5177	0.520
o_2b_3	0.4130	0.4627	0.5043	0.4980	0.5213	0.5200	0.521
o_3b_0	0.3847	0.4500	0.4913	0.5013	0.5167	0.5170	0.517
o_3b_1	0.4120	0.4620	0.5043	0.5013	0.5197	0.5180	0.519
o_3b_2	0.4093	0.4623	0.5033	0.5010	0.5203	0.5163	0.518
o_3b_3	0.4577	0.4683	0.5110	0.5023	0.5223	0.5213	0.522
o_4b_0	0.3837	0.4457	0.4873	0.5007	0.5160	0.5173	0.517
o_4b_1	0.3817	0.4630	0.5007	0.5010	0.5203	0.5167	0.519
o_4b_2	0.4577	0.4663	0.5073	0.5013	0.5207	0.5210	0.521
o_4b_3	0.4473	0.4630	0.5057	0.5010	0.5213	0.5210	0.521
SE	0.0061	-	-	-	-	-	-
CD	0.0175	NS	NS	NS	NS	NS	NS
Y mean					0.519	0.519	
SE					-		
CD					NS		
C_1	0.3800	0.3797	0.5033	0.5033	0.5197	0.5123	0.516
C_2	0.3800	0.3777	0.5023	0.5017	0.5103	0.5083	0.509
C_1 vs Treated	S*	S*	NS	NS	NS	NS	
C_2 vs Treated	S*	S*	NS	NS	S**	S*	
C_1 vs C_2	NS	NS	NS	NS	S**	NS	
CD for OY						NS	
CD for BY						NS	
CD for OBY						NS	

*Significant at 5 % level
**Significant at 1 % level
NS-non significant

From the data presented it is evident that organic manures could not profoundly influence the harvest index at various growth stages in both the years. As growth advanced harvest index was found to increase on both the years.

Application of different sources of microbial inoculants significantly influenced the harvest index on most of the stages of growth on both the years. Insignificant response was noticed on 180 and 240 DAP of second year. At 240 DAP of first year, the harvest index noticed was the highest for B_3 treatments (0.5215) and it was on par with B_2 (0.5207) and B_1 (0.5206). However, as growth advanced harvest index also increased during both years.

The variation in HI due to O x B interaction was significant only at 120 DAP of the first year. During this period, the HI was the highest for o_1b_1 and o_1b_3 (0.4583). However the difference in HI between the combination of organic manures and microbial inoculants was not significant in the 180 and 240 DAP of first year and all stages of second year. Treatment combination, o_1b_1, o_1b_3, o_3b_3 and o_4b_2 produced similar values of HI (0.4583 and 0.4577 respectively) at 120 DAP of first year. For all the combinations of B_0 with organic manures, lower HI was noticed.

The harvest indices of treatments varied significantly from the controls only at some stages of growth. At 240 DAP of first year, significant difference in harvest index was noticed. Harvest index for C_1 was higher than C_2 at this stage. Between controls not much difference in harvest index was noticed on most of the stages of growth except 240 DAP of first year.

The pooled mean of harvest index at 240 DAP of first year and second year indicates that the harvest index due to organic manure microbial inoculants and their interaction was not significantly different.

4.1.5.8 Root shoot ratio

The different sources of organic manures, microbial inoculants and their interaction on root shoot ratio are presented in Table 22.

Application of different organic manures did not influence root shoot ratio at most of the stages on both the years. During first year at 180 DAP alone significant difference in root shoot ratio was noticed.

Microbial inoculants significantly influenced the root shoot ratio at all the stages of growth on both the years. At 120 and 180 DAP of both the years root shoot ratio was higher which decreased at 240 DAP of both the years.

The interaction O x B was significant only at 120 DAP and 240 DAP of first year and 180 DAP of second year. Root shoot ratio was however not significantly influenced at 120 DAP of both the years and 240 DAP of the second year. As growth advanced root shoot ratio decreased. At final stage of harvest (240 DAP) a root shoot ratio of 0.04 was resulted during first and second year of study.

The root shoot ratio of treatments varied significantly from the controls at most of the stages of first year and second year. The root shoot ratio of treatments significantly differed from the control C_1 at all periods except at 120 DAP of first year. The treatments significantly differed from the control C_2 at most of the periods except 120 DAP of both the years.

4.1.6 Correlation of Physiological characters in relation to green ginger and dry ginger yield

4.1.6.1 Dry matter production

The inter correlation results of DMP with green ginger yield, dry ginger yield, CGR, NAR, RGR, LAI, LAD, HI and root shoot ratio for both years of experimentation are presented in Table 23 and Table 24.

The dry matter production was significantly positively correlated with green ginger yield, dry ginger yield, crop growth rate, net

Table 22. Effect of organic manures, microbial inoculants and their interaction on RS ratio of ginger

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	0.0570	0.0583	0.0629	0.0583	0.0431	0.0396
O_2	0.0572	0.0587	0.0618	0.0586	0.0432	0.0389
O_3	0.0571	0.0578	0.0627	0.0583	0.0433	0.0395
O_4	0.0566	0.0585	0.0638	0.0589	0.0424	0.0395
SE	-	-	0.0003	-	-	-
CD	NS	NS	0.0010	NS	NS	NS
B_0	0.0589	0.0543	0.0630	0.0624	0.0438	0.0385
B_1	0.0579	0.0612	0.0633	0.0585	0.0427	0.0394
B_2	0.0535	0.0568	0.0620	0.0568	0.0434	0.0392
B_3	0.0575	0.0601	0.0629	0.0566	0.0422	0.0403
SE	0.0007	0.0004	0.0003	0.0003	0.0003	0.0003
CD	0.0020	0.0012	0.0010	0.0010	0.0008	0.0010
Interaction						
o_1b_0	0.0597	0.0540	0.0633	0.0627	0.0440	0.0383
o_1b_1	0.0557	0.0617	0.0623	0.0543	0.0430	0.0403
o_1b_2	0.0547	0.0573	0.0627	0.0603	0.0437	0.0390
o_1b_3	0.0580	0.0600	0.0633	0.0557	0.0417	0.0407
o_2b_0	0.0600	0.0540	0.0617	0.0627	0.0447	0.0380
o_2b_1	0.0573	0.0600	0.0627	0.0593	0.0400	0.0393
o_2b_2	0.0527	0.0567	0.0610	0.0533	0.0437	0.0383
o_2b_3	0.0587	0.0607	0.0620	0.0590	0.0443	0.0400
o_3b_0	0.0573	0.0547	0.0630	0.0620	0.0430	0.0390
o_3b_1	0.0590	0.0613	0.0630	0.0590	0.0443	0.0390
o_3b_2	0.0567	0.0560	0.0617	0.0587	0.0440	0.0393
o_3b_3	0.0553	0.0590	0.0630	0.0543	0.0420	0.0407
o_4b_0	0.0587	0.0547	0.0640	0.0623	0.0433	0.0383
o_4b_1	0.0597	0.0617	0.0653	0.0613	0.0433	0.0390
o_4b_2	0.0500	0.0570	0.0627	0.0547	0.0423	0.0403
o_4b_3	0.0580	0.0607	0.0633	0.0573	0.0407	0.0400
SE	0.0014	-	-	0.007	0.0006	-
CD	0.0039	NS	NS	0.0020	0.0017	NS
C_1	0.0553	0.0603	0.0657	0.0633	0.0457	0.0463
C_2	0.0567	0.05867	0.07	0.08	0.0487	0.0480
C_1 vs Treated	NS	S**	S*	S*	S*	S*
C_2 vs Treated	NS	NS	S*	S*	S*	S*
C_1 vs C_2	NS	NS	S*	S*	S*	NS

*Significant at 5 % level
**Significant at 1 % level
NS-non significant

assimilation rate, leaf area index, leaf area duration and harvest index on both years. However, a significant negative correlation was noticed between dry matter production and RGR on both years and dry matter production and root shoot ratio of first year.

4.1.6.2 Crop growth rate

The crop growth rate was correlated with green ginger yield, dry ginger yield, net assimilation rate, relative growth rate, leaf area index, leaf area duration, harvest index and root shoot ratio for two years of experimentation and are presented in Table 23 and Table 24.

The crop growth rate of two years of study was significantly positively correlated with green ginger yield and dry ginger yield. CGR also showed significant positive correlation with dry matter production, net assimilation rate, leaf area index, leaf area duration and harvest index on both years. The crop growth rate was significantly negatively correlated with RGR and root shoot ratio during the first year. At the second year of study, a significant negative correlation was noticed between crop growth rate and RGR only. The crop growth rate was significantly positively correlated with root shoot ratio during the second year.

4.1.6.3 Net assimilation rate

The net assimilation rate was correlated with green ginger yield, dry ginger yield, dry matter production, crop growth rate, relative crop growth rate, leaf area index, leaf area duration, harvest index and root shoot ratio for two years and are presented in Table 23 and Table 24.

A significant positive correlation was noticed between net assimilation rate and green ginger yield, dry ginger yield, dry matter production, crop growth rate, leaf area duration and harvest index during the first year. At the second year, a significant and positive correlation was noticed between net assimilation rate, green ginger yield, dry ginger yield, dry matter production, crop growth rate, leaf area index, leaf area duration, harvest index and root shoot ratio.

Table 23. Correlation of physiological characters in relation to green ginger and dry ginger yield during the first year of experiment

Characters	Green ginger yield	Dry ginger yield	DMP	CGR	NAR	RGR	LAI	LAD	HI	RS ratio
Green ginger yield	1									
Dry ginger yield	0.9880*	1								
DMP	0.8333*	0.8703*	1							
CGR	0.9550*	0.9748*	0.8821*	1						
NAR	0.6043**	0.6005**	0.6433*	0.7084*	1					
RGR	-0.8905*	-0.8958*	-0.8036*	0.8220*	-0.4287	1				
LAI	0.6620*	0.6443*	0.6042**	0.6203**	0.4292	-0.4649	1			
LAD	0.9735*	0.9960*	0.8811*	0.9761*	0.5999**	-0.8807*	0.6207**	1		
HI	0.9340*	0.8925*	0.6967*	0.8583*	0.6199**	-0.8345*	0.6657*	0.8575*	1	
RS ratio	-0.5470**	-0.5699**	0.5538**	-0.6239*	-0.3419	-0.2900	-0.3050	-0.6087**	-0.3431	1

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

Table 24. Correlation of physiological characters in relation to green ginger and dry ginger yield during the second year of experiment

Characters	Green ginger yield	Dry ginger yield	DMP	CGR	NAR	RGR	LAI	LAD	HI	RS ratio
Green ginger yield	1									
Dry ginger yield	0.9959*	1								
DMP	0.9977*	0.9954*	1							
CGR	0.9505*	0.9506*	0.9578*	1						
NAR	0.5247**	0.5250**	0.5283**	0.7198*	1					
RGR	-0.8506*	-0.8265*	-0.8375*	-0.7018*	-0.2436	1				
LAI	0.9877*	0.9874*	0.9940*	0.9727*	0.5638**	-0.7888*	1			
LAD	0.9903*	0.9893*	0.9958*	0.9616*	0.5146**	-0.7888*	0.9963*	1		
HI	0.9256*	0.9318*	0.9143*	0.9016*	0.5898**	-0.7479*	0.9093*	0.8996*	1	
RS ratio	0.8999*	0.8882*	0.8927*	0.8539*	0.4607	-0.84500*	0.8702*	0.8892*	0.8451*	1

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

4.1.6.4 Relative growth rate

The relative growth rate was intercorrelated with green ginger yield, dry ginger yield, dry matter production, crop growth rate, relative crop growth rate, leaf area index, leaf area duration, harvest index and root shoot ratio for two years of study (Table 23 and Table 24).

Significant negative correlation was observed when relative growth rate was correlated with green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate, leaf area index, leaf area duration, harvest index during the first year. The RGR showed a significant negative correlation with respect to green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate leaf area index, leaf area duration, harvest index and root shoot ratio during the second year.

4.1.6.5 Leaf area index

The leaf area index of first and second year of study was correlated with green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate, relative growth rate, leaf area duration, harvest index and root shoot ratio (Table 23 and Table 24).

A significant positive correlation was noticed between the leaf area index and green ginger yield, dry ginger yield, dry matter production, crop growth rate, relative crop growth rate, leaf area index, leaf area duration, harvest index on both years. The leaf area index showed a significant positive correlation with leaf duration during the first year of study only. A significant positive correlation existed between leaf area index and net assimilation rate and leaf area index with root shoot ratio during the second year of experimentation only. There was a significant negative correlation noticed between leaf area index and relative growth rate during the second year.

4.1.6.6 Leaf area duration

Leaf area duration of two years of study was inter correlated with green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate, relative crop growth rate, leaf area index, harvest index and root shoot ratio (Table 23 and Table 24).

Leaf area duration showed a significant positive correlation when correlated with green ginger yield, dry ginger yield, dry matter production, crop growth rate, relative crop growth rate, leaf area index, leaf area duration and harvest index as revealed from the results of first year and second year. Significant negative correlation was noticed between leaf area duration and relative growth rate on both year of study.

4.1.6.7 Harvest index

The inter correlation of harvest index with green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate, relative crop growth rate, leaf area index, leaf area duration and root shoot ratio for two years of experimentation are presented in Table 23 and Table 24. The results indicated a significant positive correlation between harvest index and green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate, relative crop growth rate, leaf area index and leaf area duration on both years of study. Harvest index showed a significant negative correlation with relative growth rate on both years of experimentation. The harvest index when correlated with root shoot ratio, a significant positive correlation was noticed as revealed from the second year of study, while during the first year no such significant correlation was observed.

4.1.6.8 Root shoot ratio

The inter correlation results of root shoot ratio with green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate, relative growth rate, leaf area index, leaf area duration, harvest index for two years are presented in Table 23 and Table 24.

During the first year of experiment, root shoot ratio showed a significant negative correlation with green ginger yield, dry ginger yield, DMP, CGR and LAD. The correlation was not significant between root shoot ratio and NAR, RGR, LAI and harvest index at the first year of study. During the second year, a significant positive correlation was noticed between root shoot ratio and green ginger yield, dry ginger yield, dry matter production, crop growth rate, leaf area index, leaf area duration and harvest index. A significant negative correlation existed between root shoot ratio and RGR during second year as revealed from Table 24.

4.1.7 Effect of organic manures, microbial inouclants and their interaction on yield and yield characters

4.1.7.1 Green ginger yield

The influence of different sources of organic manures, microbial inoculants and their varied combination on green ginger yield are presented in Table 25.

Various organic manures influenced the green ginger yield at most of the stages in both the years. At final stage of harvest different organic manures did not influence the green ginger yield. At 180 DAP of first year also the effect was insignificant. At 120 DAP of both years and 180 DAP of second year, highest green ginger yield was reported from O_1. At 120 DAP, the green ginger yield of 40.12 g plant^{-1} and 62.46 g plant^{-1} were observed from O_1 during first and second year of study. During second year 110.20 g plant^{-1} of green ginger yield was noticed from O_1 at 180 DAP. The green ginger yield produced by O_1 treatment at 255 DAP was 145.03 and 204.52 g plant^{-1} during first and second year of experimentation. Treatments O_3 and O_4 were on par at 120 DAP of first and second year and 180 DAP of second year.

The effect of microbial inoculants on green ginger yield is significant. Green ginger yield from plants, which received the combination of AMF and *Trichoderma* produced significantly higher

Table 25.Effect of organic manures, microbial inoculants and their interaction on green ginger yield, g plant^{-1}

Treatments	120 DAP		180 DAP		255 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	40.12	62.46	84.01	110.20	145.03	204.52	174.78
O_2	37.63	60.70	81.50	105.41	142.06	198.72	170.39
O_3	37.75	61.76	83.61	108.13	144.67	202.19	173.43
O_4	37.98	61.03	83.25	107.98	144.46	201.39	172.93
SE	0.14	0.29	-	0.73	-	-	
CD	0.41	0.82	NS	2.11	NS	NS	NS
B_0	30.20	54.79	74.73	97.12	132.30	182.85	157.59
B_1	40.01	63.29	84.64	110.04	147.23	205.87	176.55
B_2	37.82	61.96	84.14	107.77	146.38	201.66	174.02
B_3	45.45	65.94	88.87	116.78	150.32	216.43	183.37
SE	0.14	0.29	1.35	0.73	1.48	1.42	1.40
CD	0.41	0.82	3.88	2.11	4.25	4.07	4.03
Interaction							
o_1b_0	29.90	54.81	73.85	96.33	130.52	181.50	156.06
o_1b_1	51.80	68.87	92.34	122.99	154.51	225.59	190.05
o_1b_2	32.01	59.67	79.75	101.31	143.10	191.87	167.48
o_1b_3	46.77	67.07	90.11	120.18	151.91	219.14	185.53
o_2b_0	29.69	53.60	72.79	95.30	128.17	178.42	153.30
o_2b_1	43.23	63.87	85.38	111.73	147.70	209.85	178.78
o_2b_2	38.40	62.45	83.88	106.95	146.19	201.63	173.91
o_2b_3	39.20	62.87	83.95	107.64	146.19	204.99	175.59
o_3b_0	30.92	56.08	77.01	99.36	136.68	187.15	161.92
o_3b_1	33.58	60.88	82.30	104.64	144.62	198.58	171.60
o_3b_2	34.86	60.46	81.75	103.86	143.42	195.17	169.30
o_3b_3	51.63	69.60	93.39	124.65	153.95	227.86	190.90
o_4b_0	30.27	55.25	75.28	97.48	133.73	184.44	159.09
o_4b_1	31.43	59.39	78.54	100.81	142.08	189.44	165.76
o_4b_2	46.01	65.25	91.16	118.97	152.82	217.96	185.39
o_4b_3	44.21	64.21	88.02	114.63	149.21	213.72	191.46
SE	0.29	0.57	2.70	1.47	2.96	2.83	2.792
CD	0.82	1.65	7.75	4.21	8.50	8.14	8.062
Y mean					144.06	201.71	
SE					0.744		
CD					2.103		
C_1	33.18	28.53	78.41	67.63	138.23	122.10	130.22
C_2	25.29	20.37	63.06	35.22	95.40	66.32	80.86
C_1 vs Treated	S*	S*	NS	S*	NS	S*	
C_2 vs Treated	S*	S*	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	S*	S*	
CD for OY							NS
SE for BY							1.487
CD for BY							4.206
SE for OBY							2.974
CD for OBY							8.412

*Significant at 5 % level

NS-non significant

green ginger yield. At final harvest, the green ginger yield recorded from B_3 was 150.32 g plant^{-1} and 216.43 g plant^{-1} for first and second year of experimentation. Treatments B_1 and B_2 were on par at 180 and 240 DAP during first year. Plants which did not receive microbial inoculants showed significantly lower green ginger yield.

Significant influence of O x B interaction was observed with regard to green ginger yield on both the years. Treatment combinations o_1b_1 and o_3b_3 were on par on second year and were significantly superior compared to other treatment combinations in producing green ginger yield. At 255 DAP, highest green ginger yield was noticed from o_1b_1 (154.51 g plant^{-1}) and was on par with o_3b_3 (153.95 g plant^{-1}), o_4b_2 (152.82 g plant^{-1}), o_1b_3 (151.91 g plant^{-1}), o_4b_3 (149.21 g plant^{-1}), o_2b_1 (147.70 g plant^{-1}), o_2b_2 (146.19 g plant^{-1}) and o_2b_3 (146.19 g plant^{-1}) during first year. At final harvest of second year treatment combination o_3b_3 (227.86 g plant^{-1}) and o_1b_1 (225.59 g plant^{-1}) were on par. Among different combinations of microbial inoculants with vermicompost, the application of AMF (o_2b_1) resulted in higher green ginger yield (147.70 and 209.85 g plant^{-1} for first and second year respectively) on both the years. Among green leaf and microbial combinations, o_4b_2 and o_4b_3 were on par at most of the stages except at 120 DAP of first year and 180 DAP of second year. The green ginger yield was lower in all the treatment combinations of B_0 in both the years.

The treatments differed significantly from the control with respect to the rhizome yield at most of the periods during both the years. While the control C_2 differed from the treatment at all the stages of growth in both the years, C_1 showed significance at all periods except 180 DAP and 240 DAP of first and second year respectively. The rhizome yield produced by C_1 was significantly higher than C_2. Similarly the rhizome yield of ginger produced during the first year was significantly higher than the second year of experimentation as evident from the pooled data.

Significant difference in green ginger yield was observed between the controls C_1 and C_2 also. The green ginger yield produced by C_1 was significantly higher than C_2 on all the stages of growth. The green ginger yield observed from the control C_2 treatment during 255 DAP was 95.40 and 66.32 g plant^{-1} during first and second year respectively. At the final harvest, the plants which received manures as per the Package of Practices Recommendation of Kerala Agricultural University (C_1), the green ginger produced was 138.23 and 122.10 g plant^{-1} for the first and second year. While for control C_2 the green ginger yield was only 95.40 and 66.32 g plant^{-1} for first and subsequent year respectively.

Perusal of the pooled data in Table 25, clearly indicated that the rhizome yield of first year due to the application of organic manures did not differ significantly from the second year of application. But the application of microbial inoculants produced significantly different rhizome yield at first year compared to the second year. The rhizome yield produced by the interaction effect was also different when the green ginger yield of first year was compared with second year.

4.1.7.2 Dry ginger yield

Table 26 represents the effect of organic manures and microbial inoculants either alone or in combination on dry ginger yield.

As depicted in Table 26, the variation in dry ginger yield due to application of different organic manures was significant at all stages of growth on both the years. The dry ginger yield produced by the plants, which received FYM (O_1) was superiorly higher at all stages of growth on both the years. Followed by FYM, neemcake application (O_3) also resulted in higher dry ginger yield. However, the dry ginger yield was the lowest in vermicompost (O_2) treated plots, when all the other organic sources were compared. The dry ginger yield at 120, 180 and 255 DAP observed for O_1 treatment were 7.81, 16.97 and 30.75 g plant^{-1} during the first year and 12.59, 22.52 and 41.75 g plant^{-1} for the second year. During all these periods, the dry ginger observed was the least for O_2 (7.21, 16.30 and 29.94 g plant^{-1} during the first year and 12.23, 21.52 and 40.71 g plant^{-1} for the second year of experimentation).

The effect of various microbial inoculants on the dry ginger yield was significant during both the years of experimentation. It is clearly evident from the Table 26, that application of both AMF and *Trichoderma* together (B_3) resulted in significantly higher dry ginger yield. A dry ginger yield of 8.85, 18.18 and 32.34 g plant^{-1} were noticed from B_3 treatments during first year at 120, 180 and 255 DAP. However the dry ginger yi eld of B_0 treatment during the corresponding periods at the first year of study was 5.65, 14.29 and 27.39 g plant^{-1}. The next best alternative was AMF (B_1), which also resulted in higher dry ginger yield. The influence of microbial inoculants on dry ginger yield is obvious when the values of B_0, which is very low were compared to other microbial inoculants.

Significant difference in dry ginger yield due to O x B interaction was observed throughout the crop growth period on both the years of experimentation. During first year, the treatment combination of FYM with AMF (o_1b_1) produced highest dry ginger yield, while on the second year the microbial inoculants AMF and *Trichoderma* together with neemcake (o_3b_3) resulted in highest dry ginger yield. During the first year of experimentation the dry ginger yield observed was 10.07, 19.42 and 33.81 g plant^{-1} for o_1b_1 and 14.11, 25.19 and 45.69 g plant^{-1} for o_3b_3 during the second year at 120, 180 and 255 DAP. Among vermicompost (o_2B) microbial combination the microbial inoculants AMF (B_1) resulted in higher dry ginger yield. *Trichoderma* with green leaves (o_4b_2) produced higher dry ginger yield among green leaf combinations. However, at final stage of harvest, o_4b_3 and o_4b_2 were on par in both the years. All combinations of B_0 with all the organic manures resulted in lower dry ginger yield in both the years.

The effect of treatments on dry ginger yield was significantly different from the controls at most of the stages of growth on both the

Table 26. Effect of organic manures, microbial inoculants and their interaction on dry ginger yield, g plant^{-1}

Treatments	120 DAP		180 DAP		255 DAP		
	I year	II year	I year	II year	I year	II year	Pooled mean
O_1	7.81	12.59	16.97	22.52	30.75	41.75	36.25
O_2	7.21	12.23	16.30	21.52	29.94	40.71	35.32
O_3	7.52	12.47	16.85	22.21	30.58	41.20	35.89
O_4	7.46	12.39	16.63	22.01	30.45	40.90	35.68
SE	0.03	0.05	0.10	0.15	0.19	0.25	0.191
CD	0.09	0.15	0.28	0.42	0.55	0.72	0.552
B_0	5.65	10.63	14.29	19.74	27.39	37.78	32.58
B_1	7.95	12.91	17.31	22.59	31.18	42.01	36.59
B_2	7.48	12.70	16.97	22.20	30.82	41.27	36.04
B_3	8.85	13.44	18.18	23.71	32.34	43.92	38.13
SE	0.03	0.05	0.10	0.15	0.19	0.25	0.191
CD	0.09	0.15	0.28	0.42	0.55	0.75	0.552
Interaction							
o_1b_0	5.57	10.49	14.01	19.53	26.84	37.28	32.06
o_1b_1	10.07	14.05	19.42	25.09	33.81	45.53	39.67
o_1b_2	6.38	12.16	16.03	21.10	29.66	39.42	34.54
o_1b_3	9.24	13.66	18.41	24.35	32.70	44.78	38.74
o_2b_0	5.52	10.32	13.84	19.37	26.62	36.70	31.66
o_2b_1	8.25	13.05	17.33	22.85	31.40	42.92	37.16
o_2b_2	7.49	12.72	16.95	21.83	30.82	41.39	36.105
o_2b_3	7.56	12.82	17.06	22.01	30.90	41.82	36.36
o_3b_0	5.89	10.98	14.96	20.16	28.45	38.33	33.39
o_3b_1	7.22	12.45	16.66	21.78	30.16	40.73	35.45
o_3b_2	6.98	12.34	16.42	21.71	29.95	40.05	35.00
o_3b_3	10.00	14.11	19.36	25.19	33.75	45.69	39.72
o_4b_0	5.64	10.71	14.34	19.89	27.63	38.80	33.22
o_4b_1	6.25	12.11	15.82	20.65	29.33	38.86	34.09
o_4b_2	9.07	13.58	18.47	24.18	32.85	44.22	38.54
o_4b_3	8.61	13.16	17.88	23.30	31.99	43.38	37.69
SE	0.06	0.11	0.20	0.30	0.38	1.50	1.104
CD	0.18	0.31	0.57	0.85	1.09	1.44	27.08
Y mean					30.43	41.24	
SE					0.113		
CD					0.321		
C_1	6.21	5.29	15.74	13.53	28.72	25.44	27.08
C_2	5.10	4.12	10.65	7.19	19.03	13.10	16.07
C_1 vs Treated	S*	S*	NS	S*	NS	S*	
C_2 vs Treated	S*	S*	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	S*	S*	
CD for OY							NS
SE for BY							0.227
CD for BY							0.6541
CD for OBY							NS

Significant at 5 % level

NS-non significant

years. Among controls the dry ginger produced by C_2 was significantly different from the treatment at all stages of growth on both the years. But the variation in dry ginger yield of C_1 and treatment was significantly different at 120 DAP of both the years and 180 and 240 DAP of second year study.

Significant difference in dry ginger yield was noticed between controls also. Plants which received manuring as per Package of Practices Recommendations of Kerala Agricultural University produced significantly higher rhizome yields compared to plants, which did not receive any treatment (C_2).

The pooled mean of dry ginger yield at harvest during the first and second year of experimentation are presented in the Table 26.

The results reveals that the dry ginger yield trends of first year was similar to the second year of experimentation due to organic manure application. However, the dry ginger yield produced as a result of different microbial inoculants showed significant variation between the years. The yield produced during first year was significantly lower than the second year of experimentation. The dry ginger yield trends between years were consistent due to the absence of treatment x year interaction.

4.1.7.3 Shoot weight

The data on Table 27, represents the main as well as the interaction effects of organic manures and microbial inoculants in shoot weight of ginger.

Different sources of organic manures significantly influenced shoot weight at most of the stages in both the years. However, the effect was insignificant at 120 DAP and 240 DAP of first and second year respectively. Among the organic manures, shoot yield produced by O_1 treatment was the highest at all the stages of growth on both the years. At 240 DAP the shoot weight of O_1 was 27.30 g $plant^{-1}$ for the first year and 37.26 g $plant^{-1}$ for the second year of study.

Table 27.Effect of organic manures, microbial inoculants and their interaction on shoot weight, g plant^{-1}

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	9.86	14.06	15.81	21.14	27.30	37.26
O_2	9.48	13.78	15.34	20.26	26.53	36.44
O_3	9.77	13.89	15.69	20.86	27.11	36.85
O_4	9.63	13.82	15.48	20.64	27.09	36.54
SE	-	0.05	0.10	0.11	0.12	-
CD	NS	0.15	0.30	0.32	0.36	NS
B_0	8.56	13.08	14.08	18.57	24.67	33.83
B_1	10.01	14.05	15.94	21.06	27.61	37.44
B_2	9.84	13.87	15.75	20.90	27.34	36.98
B_3	10.33	14.55	16.56	22.37	28.41	38.84
SE	0.11	0.05	0.10	0.11	0.12	0.29
CD	0.30	0.15	0.30	0.32	0.36	0.82
Interaction						
o_1b_0	8.41	13.10	13.82	18.41	24.28	33.61
o_1b_1	11.28	15.13	17.58	23.62	29.40	40.30
o_1b_2	9.42	13.31	14.99	19.60	26.63	35.68
o_1b_3	10.33	14.71	16.84	22.94	28.89	39.44
o_2b_0	8.34	13.01	13.76	18.34	23.89	33.26
o_2b_1	9.91	14.20	15.92	21.00	27.98	38.05
o_2b_2	9.82	13.91	15.82	20.76	27.10	37.16
o_2b_3	9.84	13.99	15.85	20.94	27.17	37.27
o_3b_0	8.93	13.19	14.57	18.87	25.71	34.54
o_3b_1	9.54	13.66	15.35	20.46	26.72	36.42
o_3b_2	9.45	13.59	15.29	20.45	26.67	36.10
o_3b_3	11.16	15.14	17.57	23.65	29.34	40.32
o_4b_0	8.56	13.03	14.16	18.67	24.82	33.91
o_4b_1	9.30	13.22	14.90	19.15	26.34	34.98
o_4b_2	10.68	14.68	16.88	22.79	28.98	38.98
o_4b_3	9.98	14.35	15.97	21.94	28.24	38.31
SE	0.21	0.10	0.21	0.22	0.25	0.57
CD	0.61	0.29	0.59	0.64	0.71	1.64
C_1	4.59	8.27	14.70	12.53	25.45	23.13
C_2	7.92	6.47	9.82	6.21	17.42	12.36
C_1 vs Treated	NS	S*	S*	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*

*Significant at 5 % level
NS-non significant

The results revealed that application of microbial inoculants significantly influenced the shoot weight in both the years. Enhanced shoot weight was observed from B_3, followed by B_2. On the whole, it appeared that plants, which did not receive microbial inoculants produced less shoot yield. Treatments B_1 and B_2 were on par at all stages except the 120 DAP of second year. The shoot weight of B_3 at 240 DAP was 28.41 and 38.84 g plant^{-1} at first and second year respectively.

O x B interaction showed significant difference in shoot weight at all stages of growth on both the years. Among O_1 combination with microbial inoculants, o_1b_1 produced higher shoot weight, which was on par with o_3b_3 at all stages of growth on both years. The shoot weight of o_1b_1 at 240 DAP was 29.40 g plant^{-1} while for o_3b_3 it was 29.34 g plant^{-1} for the first year. During the second year the shoot weight of o_1b_1 was 40.30 g plant^{-1} while for o_3b_3 the shoot weight 40.32 g plant^{-1}. The combination of AMF with vermicompost (o_2b_1) produced higher shoot weight compared to other combinations of vermicompost on two years. The shoot of o_2b_1 at 240 DAP observed were 27.98 and 38.05 g plant^{-1} for first and second year respectively. Among O_4 combinations, o_4b_2 resulted in significantly higher shoot weight followed by o_4b_3 in all the stages of growth on both the years.

The shoot weight of treatments differed significantly from the controls at most of the stages on both the years. As indicated in the Table 27, C_1 differed from the treatments at all stages except at 120 DAP of first year. The shoot weight of C_1 at 240 DAP was 25.45 g plant^{-1} while for C_2 the shoot weight was 17.42 g plant for the first year of experimentation. The shoot weight produced by treatments differed from C_2 at all stages of growth on both the years. The significant variation between controls C_1 and C_2 was also evident from the analysis.

4.1.7.4 Bulking Rate

The data on Table 28, represents the main and interaction effects of organic manures and microbial inoculants on bulking rate.

The main effect of organic manures on bulking rate was significant only at 120 – 180 DAP of second year. Bulking rate was insignificant at the remaining period of growth. At 120-180 DAP of second year the application of FYM, neemcake and green leaves had similar effects. Bulking rate was less in vermicompost treated plants. The bulking rate noticed for O_1 treatment was 0.1656 and was significantly higher than O_2 (0.1512) at 120-180 DAP of second year of experimentation.

Application of different types of microbial inoculants significantly influenced the bulking rate. Higher bulking rate was observed in plots treated with a combination of AMF and *Trichoderma*. At all the stages except 180 – 240 DAP of second year treatments, B_1, B_2 and B_3 were on par. Among microbial inoculants the highest bulking rate noticed for B_3 treatment at 180-240 DAP was 0.2364 and 0.3385 for first and second year respectively. However, in the plants where microbial inoculants were not applied showed lower bulking rate.

The interaction O x B was significant throughout except at 120-180 DAP of first year. The combinations of FYM, vermicompost, neemcake and green leaves with all microbial and non-microbial treatments showed significant effects. The bulking rate observed for o_1b_1 treatment was 0.2400 during the first year 0.3410 during the second year. Treatments o_1b_1, o_1b_3, o_2b_1, o_2b_2, o_2b_3, o_3b_O, o_3b_1, o_3b_2 and o_4b_2 and o_4b_3 were on par at final harvest stage of second year.

There was significant variation in bulking rate of treatments and controls as well as between controls at most of the stages of growth on both the years. Bulking rate of C_1 was significantly higher than C_2. The control C_2 differed significantly from the treatment at all stages of growth on both the years. But the bulking rate of plants which received manures as per Package of Practices Recommendations of Kerala Agricultural University (C_1) differed significantly from the treatment at all stages except at 120 – 180 DAP of first year.

Table 28. Effect of organic manures, microbial inoculants and their interaction on BR

Treatments	120-180 DAP		180-240 DAP		Pooled mean
	I year	II year	I year	II year	
O_1	0.1532	0.1656	0.2298	0.3208	0.275
O_2	0.1517	0.1512	0.2274	0.3199	0.274
O_3	0.1655	0.1634	0.2287	0.3182	0.273
O_4	0.1541	0.1608	0.2306	0.3178	0.274
SE	-	0.0019	-	-	
CD	NS	0.0056	NS	NS	NS
B_0	0.1438	0.1521	0.2184	0.2967	0.258
B_1	0.1562	0.1583	0.2311	0.3237	0.277
B_2	0.1578	0.1585	0.2306	0.3178	0.274
B_3	0.1566	0.1722	0.2364	0.3385	0.287
SE	0.0015	0.0019	0.0021	0.0032	0.002
CD	0.0042	0.0056	0.0060	0.0091	0.006
Interaction					
o_1b_0	0.1407	0.1513	0.2143	0.2960	0.255
o_1b_1	0.1557	0.1840	0.2400	0.3410	0.291
o_1b_2	0.1600	0.1493	0.2267	0.3053	0.266
o_1b_3	0.1563	0.1777	0.2383	0.3407	0.290
o_2b_0	0.1387	0.1507	0.2130	0.2890	0.251
o_2b_1	0.1520	0.1483	0.2340	0.3343	0.284
o_2b_2	0.1577	0.1520	0.2313	0.3260	0.279
o_2b_3	0.1583	0.1537	0.2313	0.3303	0.281
o_3b_0	0.1510	0.1530	0.2247	0.3030	0.264
o_3b_1	0.1573	0.1587	0.2250	0.3160	0.271
o_3b_2	0.1573	0.1570	0.2253	0.3053	0.265
o_3b_3	0.1563	0.1850	0.2397	0.3483	0.294
o_4b_0	0.1450	0.1533	0.2217	0.3343	0.260
o_4b_1	0.1597	0.1420	0.2253	0.3347	0.264
o_4b_2	0.1563	0.1757	0.2390	0.3300	0.287
o_4b_3	0.1553	0.1723	0.2363	0.3300	0.286
SE	-	0.0039	0.0042	0.0063	0.004
CD	NS	0.0112	0.0120	0.0182	0.012
Y mean			0.229	0.319	
SE			0.001		
CD			0.004		
C_1	0.159	0.135	0.2163	0.1986	0.208
C_2	0.093	0.0497	0.1400	0.1003	0.12
C_1 vs Treated	NS	S*	S*	S*	
C_2 vs Treated	S*	S*	S*	S*	
C_1 vs C_2	S*	S*	S*	S*	
CD for OY					NS
SE for BY					0.003
CD for BY					0.008
CD for OBY					NS

*Significant at 5 % level
NS-non significant

The data of pooled mean of bulking rate at final harvest for both the years of experimentation and its variation over the years is presented in the Table 28.

The BR of first year did not vary from the second year and was unaffected by various organic manures. On the other hand application of different microbial inoculants produced significant difference in the bulking rate of first and second year of experimentation. The organic manure and microbial inoculants interaction resulted in significant variation of bulking rate of first and second year as revealed from the pooled data.

4.1.7.5 Rhizome spread

The effect of organic manures and microbial inoculants and their interactions on rhizome spread during two years of experimentation are presented in Table 29.

The significant effect of organic manures in rhizome spread was noted on initial period (120 DAP) of both the years and 180 and 240 DAP of plants in the second year. However, during first year the application of organic manures did not exert any influence on rhizome spread at 180-240 DAP. Among organic manures O_1 showed more spread of rhizomes. At all the stages, O_3 and O_4 were at par on both years. Lowest values were recorded from O_2. The rhizome spread due to the application of FYM alone (O_1) was 18.46 cm at 240 DAP of second year. Treatments, O_3 (18.17) and O_4 (18.00 cm) were on par with O_1 at 240 DAP during the second year.

The effect of microbial inoculants on rhizome spread was significant on both the years. Significantly highest rhizome spread was noticed on B_3 at all stages. However the spread of rhizome was least with B_0. The effect of B_1 on rhizome spread was more than either B_2 or B_0 but lower than B_3. The rhizome spread under B_3 treatment was 16.54 cm and 18.86 cm for first and second year of experimentation at 240 DAP.

Table 29. Effect of organic manures, microbial inoculants and their interaction on rhizome spread, cm

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	6.44	7.37	12.19	14.69	16.39	18.46
O_2	6.40	7.22	11.99	14.03	16.20	17.68
O_3	6.37	7.30	12.12	14.34	16.41	18.17
O_4	6.38	7.27	12.12	14.28	16.38	18.00
SE	0.01	0.02	-	0.07	-	0.18
CD	0.04	0.06	NS	0.21	NS	0.52
B_0	6.12	6.95	11.43	12.49	15.98	17.23
B_1	6.45	7.36	12.32	14.71	16.45	18.29
B_2	6.39	7.31	12.16	14.27	16.41	17.94
B_3	6.61	7.55	12.52	15.87	16.54	18.86
SE	0.01	0.02	0.07	0.07	0.12	0.18
CD	0.04	0.06	0.19	0.21	0.34	0.52
Interaction						
o_1b_0	6.12	6.92	11.25	12.42	15.99	17.17
o_1b_1	6.76	7.73	13.00	16.77	16.69	20.12
o_1b_2	6.18	7.15	11.91	13.21	16.29	17.44
o_1b_3	6.68	7.69	12.60	16.37	16.59	19.11
o_2b_0	6.11	6.88	11.12	12.14	15.59	17.11
o_2b_1	6.56	7.40	12.47	15.03	16.45	18.05
o_2b_2	6.43	7.30	12.14	14.27	16.38	17.70
o_2b_3	6.48	7.31	12.25	14.68	16.37	17.87
o_3b_0	6.13	7.03	11.76	12.88	16.24	17.35
o_3b_1	6.35	7.25	12.03	14.02	16.36	17.61
o_3b_2	6.25	7.17	11.94	13.67	16.34	17.58
o_3b_3	6.74	7.75	12.77	16.80	16.69	20.15
o_4b_0	6.12	6.97	11.57	12.55	16.10	17.29
o_4b_1	6.13	7.07	11.79	13.03	16.28	17.37
o_4b_2	6.71	7.60	12.65	15.92	16.63	19.03
o_4b_3	6.54	7.45	12.46	15.62	16.51	18.30
SE	0.03	0.02	0.13	0.14	-	0.36
CD	0.07	0.06	0.38	0.41	NS	1.03
C_1	6.17	6.05	11.78	11.12	15.84	14.98
C_2	5.87	5.26	9.00	7.83	11.33	9.10
C_1 vs Treated	S*	S*	S**	S*	S**	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*

*Significant at 5 % level
**Significant at 1 % level
NS-Non significant

O x B interaction was significant at all stages except final (240 DAP) stage of first year. Application of O_1 in combination with B_1 during first year and O_3 in combination with B_3 during second year showed significantly higher rhizome spread. During the first year of planting the rhizome spread was 16.69 cm for o_1b_1 and o_3b_3 at 240 DAP. The rhizome spread was 20.15 cm for o_3b_3 and 20.12 for o_1b_1 during the second year of planting at 240 DAP. With vermicompost (O_2) the application of AMF (B_1) resulted in higher yields, while with green leaves (O_4) combination of *Trichoderma* (B_2) resulted in significantly highest yield. However, the rhizome spread was independent of organic manures and microbial inoculants combination at the final stage (240 DAP) of the first year.

Significant difference in rhizome spread was noticed between treatments and control as well as between controls at all stages of growth on both the years. However, the rhizome spread was the lowest for C_2. For all the observations recorded C_1 varied significantly from the treatments at all the stages of growth. Rhizome spread of C_2 also differed significantly from the treatments. The significant difference of rhizome spread between the controls C_1 and C_2 on all the growth stages of both year of experimentation was noticed.

4.1.7.6 Rhizome thickness

The main and interaction effect of organic manures, microbial inoculants and controls on rhizome thickness at different growth stages during the two years are presented in Table 30.

During the initial stages of both the years, the effect was insignificant for organic manures, microbial inoculants and their interactions.

Organic manures had significant influence on rhizome thickness at 180 DAP of first year and 180 and 240 DAP of second year. During these periods, O_1 recorded highest rhizome thickness and O_3 and O_4 were on par. The rhizome thickness observed was 1.71 cm and 1.99 cm for O_1

Table 30. Effect of organic manures, microbial inoculants and their interaction on rhizome thickness, cm

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	1.12	1.21	1.71	1.99	2.32	2.91
O_2	1.12	1.21	1.68	1.97	2.28	2.83
O_3	1.12	1.21	1.69	1.98	2.31	2.89
O_4	1.11	1.20	1.69	1.99	2.33	2.87
SE	-	-	0.01	0.01	-	0.02
CD	NS	NS	0.02	0.02	NS	0.05
B_0	1.12	1.20	1.61	1.93	2.15	2.76
B_1	1.13	1.21	1.71	1.99	2.36	2.90
B_2	1.11	1.20	1.70	1.98	2.32	2.88
B_3	1.12	1.22	1.75	2.03	2.41	2.95
SE	-	-	0.01	0.01	0.03	0.02
CD	NS	NS	0.02	0.02	0.07	0.05
Interaction						
o_1b_0	1.11	1.21	1.60	1.93	2.11	2.76
o_1b_1	1.13	1.20	1.82	2.07	2.51	3.06
o_1b_2	1.10	1.21	1.66	1.94	2.22	2.88
o_1b_3	1.13	1.21	1.76	2.04	2.43	2.94
o_2b_0	1.12	1.20	1.59	1.92	2.09	2.71
o_2b_1	1.13	1.22	1.71	2.00	2.34	2.86
o_2b_2	1.12	1.21	1.69	1.97	2.34	2.88
o_2b_3	1.12	1.22	1.70	1.99	2.34	2.85
o_3b_0	1.12	1.19	1.63	1.94	2.22	2.80
o_3b_1	1.12	1.19	1.67	1.96	2.29	2.85
o_3b_2	1.12	1.22	1.66	1.96	2.25	2.84
o_3b_3	1.13	1.23	1.81	2.07	2.48	3.08
o_4b_0	1.12	1.20	1.60	1.94	2.16	2.77
o_4b_1	1.12	1.22	1.66	1.96	2.31	2.84
o_4b_2	1.12	1.19	1.78	2.04	2.46	2.94
o_4b_3	1.10	1.20	1.71	2.02	2.39	2.93
SE	-	-	0.01	0.01	0.05	0.04
CD	NS	NS	0.03	0.03	0.15	0.10
C_1	1.11	1.09	1.59	1.53	2.19	1.93
C_2	0.98	0.94	1.36	1.16	1.49	1.20
C_1 vs Treated	NS	S*	S*	S*	S**	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	S*	S*

NS-Non significant
*Significant at 5 % level
**Significant at 1 % level

treatment at 180 DAP of first and second year respectively. However, the effect was insignificant during initial phase (120 DAP) of first and second year and final phase (240 DAP) of first year.

The influence of microbial inoculants on rhizome thickness was found to be significant at later stages of rhizome development (180 and 240 DAP). During the initial stage of rhizome formation (120 DAP) the effect of microbial inoculants on rhizome thickness was insignificant. At 180 and 240 DAP of first and second year, B_3 showed higher values compared to all other microbial treatments. The effect produced by AMF and *Trichoderma* on rhizome thickness was almost similar.

The interaction O x B was significant at 180 and 240 DAP during both the years. O x B interactions on rhizome thickness was insignificant at 120 DAP on both the years. The combination o_1b_1 and o_3b_3 showed significantly higher rhizome thickness. The rhizome thickness noticed for o_1b_1 during the first year was 2.51 cm while during the second year was 3.06 cm. Treatment combination o_3b_3 (2.48 cm) was on par with o_1b_1 during first year (2.51 cm) and second year (3.06 cm and 3.08 cm) at 240 DAP. With O_2, B_1 combination produced higher values and with O_4, B_2 showed higher values. In all the organic manure combinations with B_O, rhizome thickness was found to be lower. Thus in general, organic manures in combination with microbial inoculants showed more thickness of rhizome at later stages.

There was significant variation in rhizome thickness of treatments and controls. The rhizome thickness of C_1 and C_2 varied significantly from other treatments at all stages of growth of both the years. The variation in rhizome thickness was evident between the controls also. At 240 DAP, the rhizome thickness noticed for control C_1 was 2.19 cm and 1.49 cm for control C_2 during the first year. During the corresponding second year the rhizome thickness was 1.93 and 1.20 cm for C_1 and C_2 respectively. The rhizome thickness of C_2 was generally low compared to all other observations of the corresponding period.

4.1.8 Correlation of yield characters in relation to green and dry ginger yield

4.1.8.1 Green ginger yield

The green ginger yield of first and second year of study is inter correlated with dry ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness of first and second year and the results are presented in Table 31 and Table 32.

The results indicated a significant positive correlation of green ginger yield with dry ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness on two years.

4.1.8.2 Dry ginger yield

The correlation of dry ginger yield with green ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness for two years of study are presented in Table 31 and Table 32.

Significant positive correlation exists between dry ginger yield and green ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness on two years of experimentation.

4.1.8.3 Shoot weight

Table 31 and Table 32 represents the correlation of shoot weight of first and second year to green ginger yield, dry ginger yield, bulking rate, rhizome spread and rhizome thickness.

The results revealed that shoot weight is significantly correlated to both green ginger yield as well as dry ginger yield on two years of study and the correlation is positive. Bulking rate, rhizome spread and rhizome thickness observed during two years also showed significant positive correlation with shoot weight.

4.1.8.4 Bulking rate

The bulking rate is intercorrelated with green and dry ginger yield rhizome thickness, rhizome spread on both years of experimentation (Table 31 and Table 32).

Table 31. Correlation of yield characters in relation to green ginger and dry ginger yield during the first year of experiment

Characters	Green ginger yield	Dry ginger yield	Shoot weight	Bulking rate	Rhizome spread	Rhizome thickness
Green ginger yield	1					
Dry ginger yield	0.9880*	1				
Shoot weight	0.9904*	0.9954*	1			
Bulking rate	0.9724*	0.9501*	0.9585*	1		
Rhizome spread	0.9594*	0.9400*	0.9526*	0.9362*	1	
Rhizome thickness	0.9712*	0.9818*	0.9769*	0.9384*	0.9340*	1

*Significant at 5 % level

Table 32. Correlation of yield characters in relation to green ginger and dry ginger yield during the second year of experiment

Characters	Green ginger yield	Dry ginger yield	Shoot weight	Bulking rate	Rhizome spread	Rhizome thickness
Green ginger yield	1					
Dry ginger yield	0.9959*	1				
Shoot weight	0.9956*	0.9924*	1			
Bulking rate	0.9631*	0.9644*	0.9689*	1		
Rhizome spread	0.9347*	0.9213*	0.9165*	0.8585*	1	
Rhizome thickness	0.9324*	0.9176*	0.9316*	0.8836*	0.9382*	1

*Significant at 5 % level

Bulking rate showed a significant positive correlation with green and dry ginger yield on both years. It also showed a positive correlation with rhizome spread and rhizome thickness on two years of study.

4.1.8.5 Rhizome spread

Table 31 and Table 32 evidently correlates the rhizome spread with green ginger yield, dry ginger yield, bulking rate and rhizome thickness on two years of experimentation.

The spread of rhizome on two years of study indicated a significant positive correlation with green and dry ginger yield; shoot weight, and rhizome thickness. The correlation coefficient when rhizome spread was compared to dry ginger yield during first year was 0.9400 and 0.9213 during the second year.

4.1.8.6 Rhizome thickness

The rhizome thickness is intercorrelated with green and dry ginger, shoot weight, bulking rate, and rhizome spread on two year of study on Table 31 and Table 32.

A significant positive correlation was noticed between rhizome thickness and green ginger, dry ginger, shoot weight, bulking rate and rhizome spread on both years of experimentation. The correlation coefficient between rhizome thickness and green ginger yield during the first year of experimentation was 0.9712 and during the second year was 0.9324. The correlation coefficient between rhizome thickness and rhizome spread was 0.9340 and 0.9382 for first and second year respectively.

4.1.9 Effect of organic manures, microbial inoculants and their interaction on the quality aspects

4.1.9.1 Volatile oil

The effect of organic manure, microbial inoculants and their interaction on volatile oil are presented in Table 33.

Various organic manures had profound influence on the volatile oil content of ginger at most of the stages. The effect was insignificant at 120 and 240 DAP of second year. At all the stages of 120 DAP of first year, 180 DAP of first and second year and 240 DAP of first year, higher volatile oil content was resulted from FYM treated plants. The volatile oil content was the least in vermicompost treated plants. The volatile oil content noticed for O_2 treatment was 2.43 and 2.45 per cent during first and second year at 180 DAP. At 240 DAP of first year, the volatile oil content produced by O_2 treatment was 2.12 per cent while for O_1 the volatile oil content was 2.15 per cent.

The main effect of different microbial inoculants are presented in Table 25. The results revealed the significant effect of microbial inoculants on volatile oil content of ginger. The application of AMF together with *Trichoderma* produced highest volatile oil content among all other treatments. Plants, which did not receive any treatment with microbial inoculants, resulted in lower volatile oil content. Among microbial inoculants the highest volatile oil content was noticed from B_3 treatment at 180 DAP of second year (2.51 %) which during the corresponding first year the volatile oil content was 2.46 per cent for B_3 treatment. At final harvest the volatile oil content decreased to 2.14 and 2.16 per cent for first and second year respectively for B_3 treatment.

Among the interaction between organic manures and microbial inoculants significant difference in volatile oil content was noticed only at 120 DAP of both the years. The interaction was not significant for other periods at both the years. At 180 DAP of first year o_1b_1, o_1b_3, o_2b_1, o_3b_2, o_3b_3, o_4b_2 and o_4b_3 produced significantly higher volatile oil content and were on par. During second year among FYM, treatment like o_1b_2 and o_1b_3, among vermicompost, o_2b_1, o_2b_3, among neemcake, o_3b_1 and o_3b_2 and among green leaves o_4b_1, o_4b_2 and o_4b_3 were on par and they resulted significantly higher volatile oil content. Maximum volatile oil was

Table 33. Effect of organic manures, microbial inoculants and their interaction on volatile oil content of ginger, %

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	1.99	2.04	2.46	2.51	2.15	2.16
O_2	1.96	2.02	2.43	2.45	2.12	2.12
O_3	1.98	2.03	2.43	2.46	2.12	2.14
O_4	1.97	2.03	2.43	2.46	2.11	2.14
SE	0.01	-	0.01	0.01	0.01	-
CD	0.02	NS	0.02	0.02	0.03	NS
B_0	1.95	1.99	2.41	2.44	2.09	2.11
B_1	1.98	2.05	2.44	2.47	2.14	2.15
B_2	1.98	2.04	2.45	2.47	2.13	2.13
B_3	1.99	2.05	2.46	2.51	2.14	2.16
SE	0.01	0.01	0.01	0.01	0.01	0.01
CD	0.02	0.02	0.02	0.02	0.03	0.03
Interaction						
o_1b_0	1.97	1.99	2.40	2.45	2.09	2.13
o_1b_1	2.01	2.08	2.49	2.53	2.18	2.18
o_1b_2	1.98	2.03	2.47	2.51	2.17	2.14
o_1b_3	2.00	2.05	2.49	2.53	2.17	2.19
o_2b_0	1.94	1.98	2.42	2.42	2.12	2.09
o_2b_1	1.98	2.05	2.43	2.45	2.13	2.13
o_2b_2	1.95	2.03	2.44	2.45	2.12	2.12
o_2b_3	1.95	2.03	2.44	2.48	2.11	2.14
o_3b_0	1.95	1.99	2.42	2.44	2.08	2.11
o_3b_1	1.95	2.02	2.42	2.45	2.11	2.14
o_3b_2	1.99	2.03	2.44	2.45	2.12	2.12
o_3b_3	2.01	2.08	2.46	2.52	2.16	2.19
o_4b_0	1.94	1.99	2.40	2.43	2.07	2.12
o_4b_1	1.97	2.03	2.44	2.46	2.14	2.14
o_4b_2	1.98	2.05	2.44	2.46	2.12	2.14
o_4b_3	2.00	2.04	2.45	2.50	2.11	2.14
SE	0.01	0.01	-	-	-	-
CD	0.04	0.04	NS	NS	NS	NS
C_1	1.86	1.84	2.35	2.34	2.04	2.04
C_2	1.82	1.79	2.34	2.31	2.03	1.97
C_1 vs Treated	S*	S*	S*	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*
C_1 vs C_2	NS	S**	NS	NS	NS	S**

NS-Non significant
*Significant at 5 % level
**Significant at 1 % level

reported from o_1b_1 and o_3b_3 on both years. At 120 DAP of second year the volatile oil content of o_1b_1 and o_3b_3 were 2.08 per cent.

The variation in volatile oil content between treatments and control was significant at all the period of growth on both the years. The volatile oil content of C_1 as well as C_2 differed significantly from the treatments at all the above stages of growth. The volatile oil content produced among controls was the highest for C_1 at 180 DAP of first year (2.35 %). At 240 DAP of first and second year the volatile oil content was 2.04 for C_1 while for C_2 it was 2.03 and 1.97 per cent for first and second year. Between controls significant difference in volatile oil content was noticed only at 120 DAP and at 240 DAP of second year. However, volatile oil content was not dependent at all other stages of growth on both the year.

4.1.9.2 Non-Volatile Ether Extract (NVEE)

The effect of organic manures, microbial inoculants and their interaction on non-volatile ether extract are presented in Table 34.

The non-volatile ether extract was consistent over various stages on both the years due to the independent effect of organic manures. However, NVEE was highest under FYM for both the years.

Microbial inoculants significantly influenced the NVEE on all stages of growth on both the years (Table 26). The combination of AMF and *Trichoderma* together resulted in highest NVEE on both the years. The effect of microbial inoculants on NVEE is so evident, that the plants which did not receive microbial inoculants (B_0), resulted in significantly low NVEE. Treatment B_1 and B_2 were on par at all the stages of growth on both the years. Among microbial inoculants the highest NVEE was noticed from B_3 (7.31 during the first year and 7.32 per cent during the second year at 180 DAP). At 240 DAP the NVEE of B_3 decreased to 6.53 and 6.55 per cent at first and second year respectively.

The interaction between organic manures and microbial inoculants did not produce any significant variation on the non-volatile ether extract.

Table 34. Effect of organic manures, microbial inoculants and their interaction on NVEE of ginger, %

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	5.45	5.49	7.27	7.31	6.51	6.55
O_2	5.42	5.46	7.26	7.28	6.49	6.51
O_3	5.43	5.47	7.27	7.29	6.51	6.53
O_4	5.52	5.48	7.26	7.29	6.50	6.52
SE	-	-	-	-	-	-
CD	NS	NS	NS	NS	NS	NS
B_0	5.34	5.38	7.18	7.21	6.43	6.46
B_1	5.44	5.50	7.28	7.31	6.52	6.55
B_2	5.46	5.51	7.29	7.32	6.52	6.55
B_3	5.48	5.52	7.31	7.32	6.53	6.55
SE	0.01	0.01	0.01	0.02	0.01	0.02
CD	0.03	0.04	0.03	0.6	0.04	0.05
Interaction						
o_1b_0	5.35	5.37	7.18	7.22	6.45	6.48
o_1b_1	5.47	5.52	7.29	7.33	6.55	6.58
o_1b_2	5.47	5.53	7.29	7.33	6.52	6.57
o_1b_3	5.51	5.55	7.31	7.34	6.53	6.57
o_2b_0	5.34	5.38	7.18	7.20	6.42	6.44
o_2b_1	5.42	5.47	7.27	7.31	6.51	6.54
o_2b_2	5.45	5.49	7.30	7.31	6.52	6.53
o_2b_3	5.46	5.51	7.31	7.32	6.51	6.54
o_3b_0	5.35	5.38	7.19	7.22	6.43	6.46
o_3b_1	5.44	5.49	7.28	7.30	6.53	6.55
o_3b_2	5.46	5.50	7.31	7.32	6.54	6.55
o_3b_3	5.48	5.53	7.31	7.33	6.53	6.55
o_4b_0	5.33	5.38	7.19	7.22	6.42	6.45
o_4b_1	5.43	5.51	7.28	7.31	6.51	6.54
o_4b_2	5.44	5.50	7.28	7.30	6.51	6.54
o_4b_3	5.48	5.52	7.29	7.31	6.53	6.55
SE	-	-	-	-	-	-
CD	NS	NS	NS	NS	NS	NS
C_1	5.31	5.18	7.13	7.13	6.10	6.09
C_2	5.14	4.95	6.95	6.53	6.03	5.83
C_1 vs Treated	S*	S*	S*	S*	S*	S*
C_2 vs Treated	S*	S*	S*	S*	S*	S*
C_1 vs C_2	S*	S*	S*	S*	NS	S*

NS-Non significant
*Significant at 5 % level
**Significant at 1 % level

Hence it is evident that different combinations of organic manures and microbial inoculants did not favour non-volatile ether extract.

The non-volatile ether extract of treatments varied significantly from the controls at all stages of observation on both the years. The influence of treatments on non-volatile ether extract was significant compared to controls C_1 and C_2 separately. Significant difference in non-volatile ether extract was noticed between the controls C_1 and C_2 at most of the stages. However, at 240 DAP of first year no significant difference in NVEE was noticed. Manuring as per package of practices recommendation of Kerala Agricultural University (C_1) resulted in higher non-volatile ether extract compared to plants, which did not receive any manures and fertilizers (C_2). During the first year of experimentation the NVEE noticed from C_1 was 7.13 while that from C_2 was 6.95 per cent at 180 DAP. At the corresponding second year the NVEE observed was 7.13 and 6.53 per cent for control C_1 and C_2.

4.1.9.3 Starch

The data on starch content of ginger as influenced by organic manures, microbial inoculants and their interaction are presented in Table 35.

The starch content of ginger was significantly influenced by different organic manures on most of the stages on both the years of experimentation. The starch content was not dependent on the organic manures at 180 and 240 DAP of first year. During the significant stages highest starch content was resulted from green leaves treated plot (O_4) on most of the stages except at 180 DAP of second year. The starch content of ginger was the lowest for the FYM treated plants at 120 DAP of both years, 180 and 240 DAP of second year. The starch content of ginger due to FYM + green leaves was the highest (43.45 %) at 240 DAP of second year.

Significant differences in starch content were noticed by the use of different microbial inoculants all stages of growth on both the years. The combined effect of AMF and *Trichoderma* lowered the starch content.

Table 35. Effect of organic manures, microbial inoculants and their interaction on starch content of ginger, %

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	22.41	22.27	28.11	27.90	42.46	42.38
O_2	22.89	22.73	28.25	28.22	42.57	42.52
O_3	22.50	22.27	28.07	28.02	42.47	42.43
O_4	22.87	22.72	28.19	28.10	42.53	43.45
SE	0.11	0.07	-	0.04	-	0.03
CD	0.32	0.21	NS	0.11	NS	0.08
B_0	23.02	22.77	28.37	28.25	42.71	42.67
B_1	22.65	22.50	28.13	28.07	42.54	42.47
B_2	22.53	22.39	28.10	27.98	42.44	42.33
B_3	22.46	22.32	28.01	27.95	42.35	42.31
SE	0.11	0.07	0.05	0.04	0.04	0.03
CD	0.32	0.21	0.14	0.11	0.10	0.08
Interaction						
o_1b_0	22.89	22.54	28.52	28.24	42.72	42.69
o_1b_1	22.31	22.21	28.11	27.92	42.43	42.32
o_1b_2	22.20	22.12	27.99	27.69	42.37	42.25
o_1b_3	22.23	22.19	27.82	27.76	42.33	42.26
o_2b_0	23.12	22.85	28.41	28.35	42.71	42.65
o_2b_1	22.98	22.74	28.24	28.19	42.62	42.54
o_2b_2	22.84	22.68	28.21	28.21	42.54	42.46
o_2b_3	22.63	22.63	28.15	28.14	42.43	42.42
o_3b_0	22.91	22.73	28.30	28.28	42.70	42.67
o_3b_1	22.52	22.32	28.03	28.01	42.56	42.47
o_3b_2	22.36	22.13	28.04	27.93	42.37	42.30
o_3b_3	22.19	21.91	27.90	27.86	42.26	42.26
o_4b_0	23.17	22.96	28.24	28.13	42.71	42.66
o_4b_1	22.77	22.75	28.17	28.14	42.55	42.54
o_4b_2	22.72	22.62	28.16	28.09	42.48	42.31
o_4b_3	22.81	22.54	28.19	28.05	42.39	42.29
SE	-	-	-	-	-	-
CD	NS	NS	NS	NS	NS	NS
C_1	23.33	23.25	28.52	28.43	42.89	42.86
C_2	22.68	28.07	28.07	27.94	42.35	42.33
C_1 vs Treated	S*	S*	S*	S*	S*	S*
C_2 vs Treated	NS	NS	NS	NS	S**	NS
C_1 vs C_2	S**	S*	S*	S*	S*	S*

NS-Non significant
*Significant at 5 % level
**Significant at 1 % level

Among all the treatments, B_0 produced significantly higher starch content. Starch content resulted by the application of AMF as well as *Trichoderma* separately was almost similar on each stages except at the final harvest of second year. The starch content of ginger produced by B_0 treatment (42.71 % and 42.67 % at first and second year respectively) was the highest while that produced by B_3 treatment was the lowest (42.35 and 42.31 % for first and second year respectively) at 240 DAP.

The interaction of organic manures and microbial inoculants did not influence the starch content of ginger on both the year at all stages of growth.

The starch content produced was significantly different when the controls were compared. The starch content was comparatively lower in plots, which did not receive any fertilizers and manures.

The variation in starch content between treatments and control C_1 was significant for all the periods of second year and at the harvest stages of first year of experimentation. The starch content of ginger plants which received manures as per package of practices recommendation of Kerala Agricultural University (C_1) significantly differed from the plants, which received organic treatments at all stages of growth on both the years. However, the effect of organic treatments did not differ significantly from the starch content of ginger which did not receive any type of manures or fertilizers (C_2) at all stages of growth except at 240 DAP of first year. The starch content of control C_1 at 240 DAP was 42.89 per cent while that for C_2 was 42.35 per cent during the first year.

4.1.9.4 Crude fibre

The influence of organic manures and microbial inoculants either independently or in combination on the crude fibre content of ginger are presented in the Table 36.

The influence of different organic manures on crude fibre content was significant on most of the stages on both the years. However, the

Table 36. Effect of organic manures, microbial inoculants and their interaction on crude fibre content of ginger, %

Treatments	120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year
O_1	1.99	1.98	3.76	3.74	5.79	5.76
O_2	2.04	2.04	3.78	3.78	5.82	5.81
O_3	2.02	2.02	3.77	3.75	5.78	5.77
O_4	2.05	2.04	3.79	3.78	5.81	5.79
SE	0.01	0.01	-	0.01	-	0.01
CD	0.02	0.02	NS	0.03	NS	0.04
B_0	2.03	2.02	3.79	3.78	5.84	5.80
B_1	2.03	2.02	3.78	3.76	5.79	5.79
B_2	2.02	2.02	3.77	3.75	5.79	5.77
B_3	2.02	2.02	3.76	3.75	5.78	5.77
SE	-	-	-	-	-	-
CD	NS	NS	NS	NS	NS	NS
Interaction						
o_1b_0	2.01	2.00	3.80	3.74	5.83	5.78
o_1b_1	1.99	1.98	3.76	3.73	5.75	5.74
o_1b_2	1.97	1.97	3.78	3.72	5.80	5.75
o_1b_3	1.97	1.98	3.72	3.75	5.79	5.76
o_2b_0	2.04	2.03	3.78	3.78	5.87	5.84
o_2b_1	2.05	2.03	3.79	3.79	5.82	5.81
o_2b_2	2.04	2.04	3.79	3.76	5.79	5.79
o_2b_3	2.05	2.06	3.77	3.77	5.78	5.78
o_3b_0	2.03	2.03	3.79	3.78	5.82	5.79
o_3b_1	2.03	2.02	3.76	3.74	5.79	5.78
o_3b_2	2.01	2.02	3.77	3.75	5.77	5.74
o_3b_3	2.02	2.01	3.74	3.73	5.76	5.76
o_4b_0	2.03	2.01	3.80	3.81	5.83	5.81
o_4b_1	2.05	2.04	3.81	3.79	5.82	5.81
o_4b_2	2.06	2.05	3.75	3.76	5.79	5.79
o_4b_3	2.05	2.05	3.80	3.84	5.79	5.77
SE	-	-	-	-	-	-
CD	NS	NS	NS	NS	NS	NS
C_1	2.12	2.10	3.90	3.91	5.98	5.97
C_2	2.02	2.02	3.83	3.83	5.86	5.88
C_1 vs Treated	S*	S*	S*	S*	S*	S*
C_2 vs Treated	NS	NS	S*	S*	NS	S*
C_1 vs C_2	S*	S*	S**	S**	S**	S**

NS-Non significant
*Significant at 5 % level
**Significant at 1 % level

effect was not at all significant at 180 and 240 DAP of first year. Application of FYM resulted in lower crude fibre content at 120 DAP of both years, 180 and 240 DAP of second year. The use of vermicompost + FYM and green leaves + FYM produced similar effects on crude fibre content at all the stages of growth on both the years. At 240 DAP of second year the crude fibre content produced by O_2 treatment was the highest (5.81 %) while that for O_1 treatment (5.76 %) was the least.

The application of different microbial inoculants did not influence the crude fibre content.

The interaction effects of organic manure and microbial inoculants on crude fibre content are furnished in Table 36. It is clearly evident that the interactions were also not at all significant on both the years of experimentation.

The crude fibre content of treatments varied significantly from the controls at all stages of growth on both the years. Significant difference in crude fibre content at all stages of growth on both the years was observed when the control C_1 was compared with the treatments; as well as when the controls, C_1 and C_2 were compared. But the control C_2 differed from treatments only at 180 DAP of both the years and 240 DAP of second year of experimentation. At final harvest of first and second year the crude fibre content was 5.98 and 5.97 per cent for C_1 and 5.86 and 5.88 per cent for C_2 respectively.

4.1.10 Correlation of quality aspects in relation to green ginger and dry ginger yield

4.1.10.1 Volatile oil

The correlation of various quality characters with green and dry ginger, the inter correlation among volatile oil, NVEE, starch and fibre on two years of experimentation at 255 DAP are presented in the Table 37 and Table 38.

Table 37. Correlation of quality aspects in relation to green ginger and dry ginger yield during the first year of experiment

Characters	Green ginger yield	Dry ginger yield	Volatile oil	NVEE	Starch	Crude fibre
Green ginger yield	1					
Dry ginger yield	0.9880*	1				
Volatile oil	0.6350*	0.6396*	1			
NVEE	0.8617*	0.8095*	0.6830*	1		
Starch	-0.7950*	-0.7793*	-0.7056*	-0.8272*	1	
Fibre	-0.8436*	-0.8275*	-0.4975**	-0.8384*	0.8094*	1

*Significant at 5 % level

Table 38. Correlation of quality aspects in relation to green ginger and dry ginger yield during the second year of experiment

Characters	Green ginger yield	Dry ginger yield	Volatile oil	NVEE	Starch	Crude fibre
Green ginger yield	1					
Dry ginger yield	0.9959*	1				
Volatile oil	0.8108*	0.8081*	1			
NVEE	0.7296*	0.7262*	0.7179*	1		
Starch	-0.7528*	-0.7480*	-0.6734*	-0.8620*	1	
Crude fibre	-0.5144**	-0.5039**	-0.6253*	-0.7116*	0.7480*	1

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

The volatile oil showed significantly positive correlation with green ginger (0.6350, 0.8108) and dry ginger yield (0.6396, 0.8081) for two years respectively. The volatile oil is also significantly correlated to NVEE as revealed from the experiment of two years (0.6830, 0.7179). However, the volatile oil was found to be negatively correlated with starch (-0.7056, -0.6734) and fibre (-0.4975, -0.6253) for first and second year of experimentation respectively.

4.1.10.2 Non-volatile ether extract

The correlation of NVEE with green ginger yield, dry ginger yield, volatile oil, starch and fibre for two years of study are presented in the Table 37 and Table 38.

The results revealed a significant positive correlation of NVEE with green and dry ginger as well as with volatile oil on both year of experimentation. A significant negative correlation was observed between NVEE and starch (-0.8272, for first year and -0.8620 for second year) and NVEE and crude fibre (-0.8384 for first year and -0.7116 for second year).

4.1.10.3 Starch

The inter correlation of starch to green and dry ginger, volatile oil, NVEE and crude fibre for two years of experimentation are presented in Table 37 and Table 38.

The results revealed a significant negative correlation with green and dry ginger, volatile oil and NVEE on both years of study. A significant positive correlation was observed between starch and fibre on two years. During the first year and second year correlation coefficient of 0.8094 and 0.7480 was noticed between starch and fibre.

4.1.10.4 Crude fibre

The correlation between crude fibre and green ginger yield, dry ginger yield, volatile oil, NVEE and starch are presented in Table 37 and Table 38 during both year of study.

The crude fibre content of ginger during first and second year of study showed a significant positive correlation with starch. But the crude fibre content showed a significant negative correlation with green and dry ginger, volatile oil and NVEE. The correlation coefficient was -0.8436 during the first year and -0.5144 during the second year between starch and crude fibre.

4.2 SOIL CHARACTERS

4.2.1 Effect of organic manures, microbial inoculants and their interaction on soil physical properties

The variation in the soil physical properties namely bulk density, particle density, water holding capacity and soil aggregate stability due to the effect of organic manures, microbial inoculants and their interaction are presented.

4.2.1.1 Bulk density

The data on bulk density of the soil before and after the first and second year of experimentation are presented in the Table 39.

A significant difference was observed in the bulk density of the soil after second year of experimentation where different organic manures were applied. Among organic manure treatments, the significant effect of green leaves on the bulk density of soil was evident after the first year of experiment itself while FYM, vermicompost and neemcake application significantly reduced the bulk density of the soil after the second year of experimentation only. The bulk density of soil before the first year of study was 1.54 g cc^{-1} for O_4 treatment which decreased to 1.49 g cc^{-1} after the first year of study. At the end of second year, the bulk density reduced to 1.36 g cc^{-1} which was the lowest among different organic manures. However for the FYM treatment (O_1) a significant change in bulk density was observed after the second year of study (1.39 g cc^{-1}). Significant reduction in the bulk density of the soil after the second year of experimentation was noticed when compared to the initial status for all the organic manure treatments.

Table 39. Effect of organic manures, microbial inoculants and their interaction on bulk density of soil, g cc^{-1}

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	1.51	1.50	1.39	1.47
O_2	1.54	1.51	1.49	1.51
O_3	1.54	1.51	1.49	1.51
O_4	1.54	1.49	1.36	1.46
SE				0.01
CD				0.02
B_0	1.54	1.51	1.45	1.50
B_1	1.54	1.52	1.44	1.50
B_2	1.52	1.48	1.43	1.48
B_3	1.53	1.50	1.41	1.48
SE				-
CD				NS
Interaction				
o_1b_0	1.52	1.51	1.42	1.48
o_1b_1	1.51	1.49	1.39	1.46
o_1b_2	1.49	1.47	1.38	1.45
o_1b_3	1.53	1.52	1.37	1.47
o_2b_0	1.55	1.53	1.51	1.53
o_2b_1	1.55	1.55	1.50	1.53
o_2b_2	1.51	1.45	1.47	1.48
o_2b_3	1.54	1.52	1.48	1.52
o_3b_0	1.54	1.51	1.51	1.52
o_3b_1	1.57	1.56	1.50	1.54
o_3b_2	1.54	1.52	1.49	1.52
o_3b_3	1.51	1.46	1.44	1.47
o_4b_0	1.54	1.49	1.37	1.47
o_4b_1	1.55	1.48	1.37	1.46
o_4b_2	1.53	1.49	1.36	1.46
o_4b_3	1.54	1.51	1.35	1.47
CD				NS
Treatment mean				1.489
Y mean	1.53	1.50	1.43	
SE		0.01		
CD		0.02		
C_1	1.55	1.56	1.59	1.5667
C_2	1.50	1.50	1.52	1.5067
C_1 vs Treated				S
C_2 vs Treated				NS
C_1 vs C_2				NS
SE for OY				0.01
CD for OY				0.04
CD for BY				NS
CD for OBY				NS

NS-Non significant

The application of different microbial inoculants did not significantly change the bulk density of the soil even after the second year of experimentation.

The organic manure microbial inoculants interaction did not significantly influence the bulk density of soil over the two years of experimentation.

As revealed from the analysis, the bulk density of the treatments varied significantly from the control C_1. The pooled mean of C_1 (1.5667 g cc^{-1}) differed significantly from the treatment mean (1.4891 g cc^{-1}). However, there was not much variation in the bulk density of the soil between the controls C_2 and treatment as well as between C_1 and C_2. The pooled mean of C_2 (1.5067 g cc^{-1}) did not significantly vary from treatment means (1.4891 g cc^{-1}).

4.2.1.2 Particle density

The variation in the particle density due to the effects of organic manures, microbial inoculants and their interaction after each experiments are presented in the Table 40.

Significant variation in the particle density was observed when the particle density of soil before and after the experiment were studied. Among organic manure treatments, FYM and green leaves + FYM treatment showed significant variation after first year of experiment. The particle density of soil before the first year of study was 2.55 g cc^{-1} while it decreased to 2.34 g cc^{-1} at the end of second year of experiment for O_4 treatment. However for O_1 the particle density was 2.47 before the first year of experiment which decreased to 2.42 g cc^{-1} at the end of first year and 2.33 g cc^{-1} after the second year of experiment. However, a significant variation in the particle density of soil was evident for all the organic manure treatments after the second year of experimentation.

The application of different microbial inoculants as well as their combinations with organic manure did not influence the particle density after each year of experimentation.

Table 40. Effect of organic manures, microbial inoculants and their interaction on particle density, g cc^{-1}

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	2.47	2.42	2.33	2.41
O_2	2.54	2.51	2.48	2.51
O_3	2.57	2.51	2.49	2.52
O_4	2.55	2.47	2.34	2.46
SE				0.01
CD				0.02
B_0	2.54	2.48	2.42	2.48
B_1	2.55	2.49	2.41	2.49
B_2	2.52	2.47	2.40	2.46
B_3	2.52	2.47	2.41	2.47
SE				-
CD				NS
Interaction				
o_1b_0	2.46	2.42	2.34	2.41
o_1b_1	1.48	2.43	2.32	2.41
o_1b_2	1.44	2.39	2.29	2.37
o_1b_3	1.50	2.46	2.35	2.44
o_2b_0	1.54	2.49	2.48	2.50
o_2b_1	1.59	2.56	2.52	2.55
o_2b_2	2.52	2.49	2.46	2.49
o_2b_3	2.52	2.49	2.47	2.49
o_3b_0	2.58	2.53	2.50	2.54
o_3b_1	2.58	2.53	2.49	2.53
o_3b_2	2.56	2.52	2.49	2.52
o_3b_3	2.54	2.47	2.47	2.49
o_4b_0	2.55	2.49	2.36	2.47
o_4b_1	2.55	2.46	2.32	2.44
o_4b_2	2.57	2.48	2.37	2.47
o_4b_3	2.54	2.47	2.33	2.45
SE				0.02
CD				0.04
Treatment mean				2.4736
Y mean	2.53	2.48	2.41	
SE		0.01		
CD		0.02		
C_1	2.6	2.61	2.63	2.6133
C_2	2.5	2.52	2.54	2.5200
C_1 vs Treated				S
C_2 vs Treated				S
C_1 vs C_2				NS
SE for OY				0.01
CD for OY				0.04
CD for BY				NS
CD for OBY				NS

NS-Non significant

The particle density of the soil, which received organic treatments varied significantly from the controls C_1 as well as C_2 as revealed from the results. Thus the treatment mean was 2.4736 g cc^{-1} which differs significantly from the mean of control C_1 (2.6133 g cc^{-1}) and control C_2 (2.5200 g cc^{-1}). However, the effect produced by the controls C_1 and C_2 on particle density was not different.

4.2.1.3 Water holding capacity

The influence of organic manures, microbial inoculants and their interaction on water holding capacity of the soil over the two years of experimentation are presented in the Table 41.

A significant difference in the water holding capacity of the soil was noticed when the initial soil was compared with the soil after the first and second year of experiment following organic manure treatment. While the water holding capacity of FYM and green leaves treated soil increased significantly after the first year of treatment itself, the neemcake treated soils produced the significant effect only after the second year. The vermicompost treated soil did not show any significant effect on water holding capacity of the soil even after the second year of experimentation. The water holding capacity of the soil for O_4 treatment before the experiment was 28.47 per cent which increased to 28.94 per cent after the first year and 29.90 per cent after the second year of experiment. For FYM treated soils the water holding capacity was 28.66 per cent before the experiment which increased to 28.98 per cent after the first year and 29.48 per cent after the end of second year.

The application of different microbial inoculants did not significantly change the water holding capacity of the soil after the first and second year of experimentation.

The water holding capacity of the soil after each experiment did not vary significantly from the initial water holding capacity and was not influenced by the application of organic manure microbial combinations.

Table 41. Effect of organic manures, microbial inoculants and their interaction on WHC, %

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	28.66	28.98	29.48	29.04
O_2	28.39	28.48	28.68	28.51
O_3	28.48	28.67	28.90	28.68
O_4	28.47	28.94	29.90	29.10
SE				0.06
CD				0.18
B_0	28.50	28.74	29.16	28.80
B_1	28.43	28.70	29.21	28.78
B_2	28.53	28.83	29.31	28.89
B_3	28.53	28.78	29.28	28.87
SE				-
CD				NS
Interaction				
o_1b_0	28.90	29.37	29.57	29.28
o_1b_1	28.50	28.83	29.43	28.92
o_1b_2	28.57	28.83	29.47	28.96
o_1b_3	28.67	28.87	29.47	29.0
o_2b_0	28.23	28.27	28.37	28.29
o_2b_1	28.37	28.33	28.53	28.41
o_2b_2	28.63	28.80	29.17	28.87
o_2b_3	28.33	28.50	28.63	28.49
o_3b_0	28.53	28.67	28.87	28.69
o_3b_1	28.40	28.57	28.87	28.61
o_3b_2	28.37	28.67	28.77	28.60
o_3b_3	28.60	28.77	29.10	28.82
o_4b_0	28.33	28.67	29.83	28.94
o_4b_1	28.47	29.07	30.00	29.18
o_4b_2	28.53	29.03	29.83	29.13
o_4b_3	28.53	29.00	29.93	19.16
SE				0.13
CD				0.36
Treatment mean				28.8340
Y mean	28.5	28.76	29.24	
SE		0.06		
CD		0.16		
C_1	28.43	28.33	28.17	28.31
C_2	28.23	28.10	29.93	28.7533
C_1 vs Treated				S*
C_2 vs Treated				NS
C_1 vs C_2				NS
SE for OY				0.11
CD for OY				0.31
CD for BY				NS
CD for OBY				NS

NS-Non significant
*Significant at 5 % level

Table 42.Effect of organic manures, microbial inoculants and their interaction on soil aggregate index

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	0.5909	0.6142	0.6433	0.6161
O_2	0.5975	0.6208	0.6484	0.6222
O_3	0.5975	0.6233	0.6575	0.6222
O_4	0.5983	0.6325	0.6599	0.6302
SE				0.0030
CD				0.0087
B_0	0.5959	0.6258	0.6483	0.6233
B_1	0.5959	0.6225	0.6575	0.6253
B_2	0.5958	0.6184	0.6425	0.6189
B_3	0.5967	0.6242	0.6608	0.6272
SE				-
CD				NS
Interaction				
o_1b_0	0.5967	0.6233	0.6500	0.6233
o_1b_1	0.5767	0.6067	0.6400	0.6078
o_1b_2	0.5867	0.6067	0.6233	0.6056
o_1b_3	0.6033	0.6200	0.6600	0.6278
o_2b_0	0.6000	0.6233	0.6400	0.6211
o_2b_1	0.5900	0.6100	0.6467	0.6156
o_2b_2	0.6100	0.6333	0.6567	0.6333
o_2b_3	0.5900	0.6167	0.6500	0.6189
o_3b_0	0.5900	0.6233	0.6500	0.6211
o_3b_1	0.5967	0.6200	0.6623	0.6263
o_3b_2	0.5933	0.6167	0.6433	0.6178
o_3b_3	0.6100	0.6333	0.6733	0.6389
o_4b_0	0.5967	0.6333	0.6533	0.6278
o_4b_1	0.6200	0.6533	0.6800	0.6511
o_4b_2	0.5933	0.6167	0.6466	0.6189
o_4b_3	0.5833	0.6267	0.6600	0.6233
SE				0.0060
CD				0.0173
Treatment mean				0.6240
Y mean	0.59	0.62	0.65	
SE		0.00		
CD		0.01		
C_1	0.5967	0.5900	0.6033	0.5944
C_2	0.5967	0.5933	0.5767	0.5889
C_1 vs Treated				S*
C_2 vs Treated				NS
C_1 vs C_2				S*
CD for OY				NS
CD for BY				NS
CD for OBY				NS

NS-Non significant
*Significant at 5 % level

The application of treatments influenced the water holding capacity of the soil and differed significantly from the control, C_1. However between the controls, as well as between C_2 and treatment also, the water holding capacity did not differ.

4.2.1.4 Soil aggregate index

The effect of organic manures, microbial inoculants and their interaction on soil aggregate index over two years of experimentation are presented in the Table 42.

The application of different organic manures, microbial inoculants and their interaction did not make a significant change in the soil aggregate index over two year of experimentation.

The pooled analysis of the data clearly indicates the significant effect of treatments on soil aggregate index compared to the control, C_1. The control C_2 produced similar effect as that of treatments. The aggregate index of C_1 also did not differ from C_2.

4.2.2 Effect of organic manures, microbial inoculants and their interaction on the available nutrients of the soil

4.2.2.1 Available nitrogen

The available nitrogen content of the soil before the first year of experiment and after the first and second year of experimentation as well as their pooled mean are presented in the Table 43.

The available nitrogen content of the soil was significantly influenced by different organic manures, microbial inoculants and their interactions. The available nitrogen content before the first year of experiment was generally low, which increased after each experiment in plots where organic treatments were carried out. The available nitrogen content of the soil before the first year of experiment for O_1 was 141.12 kg ha^{-1} which increased to 175.88 kg ha^{-1} at the end of second year. The addition of available N content was the highest for O_4 treatment (180.97 kg

Table 43. Effect of organic manures, microbial inoculants and their interaction on available nitrogen content of the soil, kg ha^{-1}

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	141.12	154.19	175.88	157.06
O_2	141.38	153.92	174.57	156.63
O_3	141.77	153.53	175.36	156.89
O_4	140.73	155.49	180.97	159.06
SE				0.24
CD				0.67
B_0	141.38	153.79	174.83	156.67
B_1	141.64	154.06	176.01	157.24
B_2	140.60	153.40	176.80	156.93
B_3	141.38	155.89	179.15	158.80
SE				0.24
CD				0.67
Interaction				
o_1b_0	140.60	153.66	173.53	155.93
o_1b_1	141.12	153.14	175.62	156.63
o_1b_2	140.07	153.14	175.62	156.28
o_1b_3	142.69	156.80	178.75	159.41
o_2b_0	142.17	153.14	173.00	156.10
o_2b_1	140.60	152.18	172.48	155.23
o_2b_2	141.12	154.18	175.62	156.97
o_2b_3	141.64	155.75	177.18	158.19
o_3b_0	141.12	153.14	174.05	156.10
o_3b_1	143.21	155.75	176.66	158.54
o_3b_2	141.12	152.62	174.57	156.10
o_3b_3	141.64	152.62	176.14	156.80
o_4b_0	141.64	155.23	178.75	158.54
o_4b_1	141.64	154.71	179.27	158.54
o_4b_2	140.07	153.66	181.37	158.37
o_4b_3	139.55	158.37	184.50	160.81
SE				0.47
CD				1.33
Treatment mean				157.41
Y mean	141.25	154.28	174.70	
SE		0.21		
CD		0.58		
C_1	141.64	137.98	134.33	137.98
C_2	141.12	90.94	76.83	102.96
C_1 vs Treated				S*
C_2 vs Treated				S*
C_1 vs C_2				S*
SE for OY				0.41
CD for OY				1.15
SE for BY				0.41
CD for BY				0.15
CD for OBY				NS

NS-Non significant
*Significant at 5 % level

ha^{-1}) after the second year of experiment. However the available nitrogen content was found to decrease after each experiment for controls C_1 and C_2.

The pooled data revealed that the application of different organic manures significantly increased the available nitrogen content of the soil after each year of experimentation. Among different organic manures the plants, which received green leaves + FYM treatments accumulated higher nitrogen content after second year of experimentation. The application of different microbial inoculants also resulted in significantly higher available nitrogen content at the end of second year of experimentation. The soils which received AMF + *Trichoderma* resulted in 179.15 kg N ha^{-1} after the end of second year, adding 37.77 kg N ha^{-1} compared to the available nitrogen content of the soil before the first year of experimentation (141.38 kg ha^{-1}). An addition of 33.45 kg N ha^{-1} was noticed after two years of experimentation even without microbial inoculants (B_0). However, the interaction effects did not result in a significant variation in available nitrogen content after each experiment.

As depicted in the Table 43, the available nitrogen as a result of different treatments varied significantly from the control C_1 and C_2. The pooled treatment means 157.41 kg N ha^{-1} was significantly higher than C_1 (137.98 kg N ha^{-1}) and C_2 (102.96 kg N ha^{-1}). The available nitrogen content of the soil showed significant difference between controls.

4.2.2.2 Available phosphorus

The effect of different organic manures, microbial inoculants and their interaction on the available phosphorus content of the soil and the pooled mean of soil before the first year of experiment and the available phosphorus after the first and second year of experimentation are also indicated in the Table 44.

The available P content of the soil was not affected by different organic manures. But the microbial inoculants as well as organic manure microbial inoculant interaction significantly influenced the available P

Table 44. Effect of organic manures, microbial inoculants and their interaction on available phosphorus content of the soil, kg ha^{-1}

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	18.48	23.35	35.00	25.61
O_2	19.04	23.58	34.07	25.56
O_3	18.67	24.03	35.00	25.90
O_4	17.92	24.27	36.40	26.20
SE				-
CD				NS
B_0	18.67	23.33	34.07	25.36
B_1	18.67	23.82	35.70	26.06
B_2	17.92	23.33	35.23	25.50
B_3	18.85	24.75	35.47	25.36
SE				0.23
CD				0.65
Interaction				
o_1b_0	17.92	22.40	33.60	24.64
o_1b_1	18.67	23.40	35.47	25.84
o_1b_2	17.92	22.40	35.47	25.26
o_1b_3	19.41	25.20	35.47	26.69
o_2b_0	19.41	22.40	32.62	24.83
o_2b_1	18.67	22.40	33.60	24.89
o_2b_2	18.67	24.27	34.53	25.82
o_2b_3	19.41	25.27	35.47	26.72
o_3b_0	18.67	24.27	34.53	25.82
o_3b_1	18.67	25.20	36.40	26.76
o_3b_2	17.92	22.40	34.53	24.95
o_3b_3	19.41	24.27	34.53	26.07
o_4b_0	18.67	24.27	35.67	26.13
o_4b_1	18.67	24.27	37.33	26.76
o_4b_2	17.17	24.27	36.40	25.95
o_4b_3	17.17	24.27	36.40	25.95
SE				0.46
CD				1.31
Treatment mean				25.89172
Y mean	18.53	26.81	35.12	
SE		0.20		
CD		0.57		
C_1	19.41	17.17	15.68	17.42
C_2	19.41	9.95	8.21	12.52
C_1 vs Treated				S*
C_1 vs Treated				S*
C_1 vs C_2				S*
SE for OY				0.4
CD for OY				1.13
CD for BY				NS
CD for OBY				NS

NS-Non significant

*Significant at 5 % level

content. The available phosphorus content of the soil after the second year of experimentation was generally higher than the initial status. The plots, which received organic treatment showed higher available phosphorus content after the experiment. But the available phosphorus content of the soil decreased after the experiment for control treatments.

The pooled analysis reveals that the application of organic manures significantly increased the available phosphorus content of the soil after its application. The available P content of O_1 before the experiment was 18.48 kg ha^{-1} which increased to 23.35 and 35.00 kg ha^{-1} after first and second year of experiments. Hence the addition was 16.52 kg P ha^{-1}. While for O_4, the phosphorus content of soil increased from 17.92 to 36.40 kg ha^{-1} adding 18.48 kg P ha^{-1}. Treatments O_2 and O_3 added 15.03 and 16.33 kg ha^{-1} after two years of experimentation. The application of different microbial inoculants did not influence the available phosphorus content over the two years of experimentation. The organic manure microbial inoculant interaction also did not produce any significant effect on the available phosphorus content of the soil after each year of experiment.

The available phosphorus content of the soil varied for the plots, which received organic treatments compared to the controls, C_1 and C_2. The available phosphorus content of the plots, which received manures as per package of practices recommendation of Kerala Agricultural University (C_1) showed significant variation in the available phosphorus content compared to the plots which did not receive any manurial or fertilizer treatment (C_2). The available P content for the treatments was 25.8172 kg ha^{-1} which was significantly higher than C_1 (17.42 kg ha^{-1}) and C_2 (12.52 kg ha^{-1}) as revealed from the pooled data.

4.2.2.3 Available potassium

The effect of treatment on the available potassium content of the soil before the first experiment and after each crop year are provided in the Table 45.

Table 45. Effect of organic manures, microbial inoculants fertilizers and their interaction on available potassium content of the soil, kg ha^{-1}

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	103.60	121.32	140.93	121.95
O_2	106.40	122.27	142.80	123.82
O_3	104.53	118.52	140.93	121.33
O_4	100.80	120.40	145.60	122.27
SE				-
CD				NS
B_0	104.53	120.40	141.87	122.27
B_1	105.47	120.37	142.80	122.88
B_2	100.80	117.60	140.93	119.78
B_3	104.53	124.13	144.67	124.44
SE				0.93
CD				2.62
Interaction				
o_1b_0	100.80	115.73	138.13	118.22
o_1b_1	104.53	119.40	141.87	121.93
o_1b_2	100.80	115.73	138.13	118.22
o_1b_3	108.27	134.40	145.60	129.42
o_2b_0	108.27	123.20	141.87	124.44
o_2b_1	104.53	115.73	141.87	120.71
o_2b_2	104.53	123.20	141.87	123.20
o_2b_3	108.27	126.93	145.60	126.93
o_3b_0	104.53	119.47	141.87	121.96
o_3b_1	108.27	123.13	141.87	124.42
o_3b_2	100.80	115.73	138.13	118.22
o_3b_3	104.53	115.73	141.87	120.71
o_4b_0	104.53	123.20	145.60	124.44
o_4b_1	104.53	123.20	145.60	124.44
o_4b_2	97.07	115.73	145.60	119.97
o_4b_3	97.07	119.47	145.60	120.71
SE				1.86
CD				5.24
Treatment mean				122.3417
Y mean	103.83	120.63	142.57	
SE		0.81		
CD		2.27		
C_1	104.53	100.80	97.07	100.80
C_2	108.27	59.73	44.80	70.933
C_1 vs Treated				S*
C_2 vs Treated				S*
C_1 vs C_2				S*
CD for OY				NS
CD for BY				NS
CD for OBY				NS

NS-Non significant
*Significant at 5 % level

The available K content of the soil did not vary significantly due to the application of different organic manures. However, the application of microbial inoculants as well as organic manure microbial inoculant interaction significantly influenced the available K content. The available potassium status was found to increase over the years after each crop year in the plots, which received organic treatments. However the available potassium content of the soil was found decreased in the plot, which received control treatments.

The pooled results reveal that the available potassium content of the soil before the first year of experiment did not differ significantly after each crop year by the application of organic manures, microbial inoculants and their combination.

However, the available potassium contents of the plots, which received organic treatment varied significantly from the control plots, C_1 and C_2. A significant difference in the available potassium content of the soil was observed between the controls also. The available K content of the treatments was 122.3417 kg ha^{-1} compared to C_1 (100.80 kg ha^{-1}) and C_2 (70.9333 kg ha^{-1}).

4.2.2.4 Organic carbon

The organic carbon content of the soil before and after the first and second year of application of organic manures, microbial inoculants and their interaction are presented in the Table 46.

The application of different organic manures, microbial inoculants or their combination for over the two years did not influence the organic carbon content of the soil compared to the initial level.

The results also revealed that the organic carbon content of the plots, which received treatments, varied significantly from the control plots, C_1 and C_2. As revealed from the pooled results the organic carbon content of the treatments (0.6475 %) was significantly higher than the

Table 46. Effect of organic manures, microbial inoculants and their interaction on organic carbon content of soil, %

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	
O_1	0.5675	0.6325	0.7575	0.6525
O_2	0.5750	0.6350	0.7400	0.6500
O_3	0.5825	0.6275	0.7400	0.6500
O_4	0.5625	0.6200	0.7300	0.6375
SE				0.0132
CD				0.0186
B_0	0.5725	0.6200	0.7325	0.6417
B_1	0.5800	0.6300	0.7375	0.6492
B_2	0.5600	0.6175	0.7425	0.6400
B_3	0.5750	0.6475	0.7550	0.6592
SE				0.0132
CD				0.0186
Interaction				
o_1b_0	0.5500	0.6100	0.7500	0.6367
o_1b_1	0.5700	0.6200	0.7500	0.6467
o_1b_2	0.5500	0.6100	0.7500	0.6367
o_1b_3	0.6000	0.6900	0.7800	0.6900
o_2b_0	0.5900	0.6300	0.7200	0.6467
o_2b_1	0.5600	0.6100	0.7200	0.6300
o_2b_2	0.5700	0.6400	0.7500	0.6533
o_2b_3	0.5800	0.6600	0.7700	0.6700
o_3b_0	0.5700	0.6200	0.7300	0.6400
o_3b_1	0.6100	0.6700	0.7500	0.6600
o_3b_2	0.5700	0.6100	0.7400	0.6400
o_3b_3	0.5800	0.6100	0.7400	0.6433
o_4b_0	0.5800	0.6200	0.7300	0.6433
o_4b_1	0.5800	0.6200	0.7300	0.6433
o_4b_2	0.5500	0.6100	0.7300	0.6300
o_4b_3	0.5400	0.6300	0.7300	0.6333
SE				0.01
CD				0.02
Treatment mean				0.6475
Y mean	0.57	0.63	0.74	
SE		0.0033		
CD		0.0091		
C_1	0.5800	0.5500	0.5100	0.5467
C_2	0.5700	0.5200	0.4600	0.5167
C_1 vs Treated				S*
C_1 vs Treated				S*
C_1 vs C_2				S*
CD for OY				NS
CD for BY				NS
CD for OBY				NS

NS-Non significant
*Significant at 5 % level

control C_1 (0.5467 %) and C_2 (0.5167 %). Variation in organic carbon content between the controls was also evident from the Table 46.

4.2.2.5 Soil pH

The data on soil pH before the experiment and after the first and second year of experimentation are presented in the Table 47.

The application of different organic manures or microbial inoculants did not influence the soil pH. But the organic manure, microbial interaction resulted in significant change in soil pH. The pH value of the treatment combination ranged from 5.17 to 5.33 as revealed from the pooled mean.

Neither the organic manures nor the microbial inoculants alone or in combination influenced the soil pH even after two years of experimentation compared to the initial pH. Though the effect was insignificant, a reduction in soil pH was noticed after each experiment for the main effect of organic manures, microbial inoculants as well as for organic manure microbial inoculant interaction.

The soil pH of the treatments did not differ from the control C_1 and C_2. The soil pH between the control was also not significantly different. No variation in soil pH was noticed for control C_2 after each experiment (5.30)

4.3 PLANT ANALYSIS

4.3.1 Effect of organic manures, microbial inoculants and their interaction on the uptake of nutrients

4.3.1.1 Uptake of nitrogen

The effects of treatments on the uptake of nitrogen for both the years are presented in Table 48.

The main effect of organic manures on the uptake of nitrogen was significant during both the years. Application of FYM resulted in significantly higher uptake of nitrogen in the first year (60.14 kg ha^{-1}) followed by neemcake + FYM (60.08 kg ha^{-1}) in the second year. However the plant uptake of nitrogen was the lowest under vermicompost + FYM

Table 47. Effect of organic manures, microbial inoculants and their interaction on soil pH

Treatments	2000-2001 Before the expt	2001-2002 After the I expt	2002-2003 After the II expt	Pooled mean
O_1	5.33	5.27	5.16	5.25
O_2	5.28	5.22	5.14	5.21
O_3	5.30	5.23	5.17	5.24
O_4	5.30	5.26	5.22	5.26
SE				-
CD				NS
B_0	5.29	5.23	5.17	5.23
B_1	5.28	5.23	5.15	5.22
B_2	5.34	5.28	5.21	5.27
B_3	5.30	5.24	5.17	5.24
SE				-
CD				NS
Interaction				
o_1b_0	5.37	5.30	5.17	5.28
o_1b_1	5.30	5.23	5.13	5.22
o_1b_2	5.37	5.30	5.23	5.30
o_1b_3	5.30	5.23	5.10	5.21
o_2b_0	5.23	5.17	5.10	5.17
o_2b_1	5.33	5.30	5.23	5.29
o_2b_2	5.30	5.20	5.10	5.20
o_2b_3	5.23	5.20	5.13	5.19
o_3b_0	5.30	5.23	5.20	5.24
o_3b_1	5.20	5.13	5.07	5.13
o_3b_2	5.43	5.37	5.27	5.36
o_3b_3	5.27	5.20	5.17	5.21
o_4b_0	5.27	5.23	5.20	5.23
o_4b_1	5.27	5.23	5.17	5.22
o_4b_2	5.24	5.23	5.23	5.24
o_4b_3	5.40	5.33	5.27	5.33
SE				0.03
CD				0.09
Treatment mean				5.2396
Y mean	5.3	5.24	5.17	
SE		0.01		
CD		0.04		
C_1	5.33	5.30	5.27	5.300
C_2	5.30	5.30	5.30	5.300
C_1 vs Treated				NS
C_1 vs Treated				NS
C_1 vs C_2				NS
CD for OY				NS
CD for BY				NS
CD for OBY				NS

NS-Non significant

treatment (59.57 kg ha^{-1}). During the second year also higher N uptake was noticed for O_1 (85.42 kg ha^{-1}) followed by O_3 (84.57 kg ha^{-1}).

The main effect of microbial inoculants on the uptake of nitrogen was significant on both the years. Application of AMF and *Trichoderma* together (B_3) resulted in a better nitrogen uptake by the plants in both the years. The uptake of nitrogen by B_3 treatment was 62.99 kg ha^{-1} and 90.37 kg ha^{-1} for the first and second year of experiment. The next best alternative was AMF, which showed a higher uptake than the application of *Trichoderma*. Thus the uptake of nitrogen by B_1 was 61.20 kg ha^{-1} and 86.24 kg ha^{-1} for the first and second year of experiment. The plant uptake of nitrogen was the least for the treatments, which did not receive any microbial inoculants (54.34 and 75.20 kg ha^{-1} for the first and second year respectively).

The interaction between organic manures and microbial inoculants was significant on both the years. Significantly higher plant uptake was registered in o_1b_1 for the first year (64.32 kg ha^{-1}) and o_3b_3 for the second year (94.81 kg ha^{-1}). Among vermicompost, the combination with AMF resulted in higher uptake than other combinations with vermicompost for both years (61.97 and 87.66 kg ha^{-1} for first and second year respectively). *Trichoderma* together with green leaves + FYM (o_4b_2) resulted in significantly higher uptake than any other combination of green leaves in both years (63.60 and 91.11 kg ha^{-1} for first and second year respectively).

The uptake of nitrogen by the first year (59.85 kg ha^{-1}) was significantly different from that of second year (84.13 kg ha^{-1}).

Significant difference in the uptake of nitrogen was observed when the treatments and controls, C_1 and C_2 were compared. The uptake of nitrogen was fairly higher for treatments compared to the controls. The uptake of nitrogen by treatments (71.9921 kg ha^{-1}) was significantly higher than C_1 (54.2350 kg ha^{-1}) and C_2 (43.53 kg ha^{-1}). The uptake of nitrogen significantly varied between the controls also.

The pooled data on the uptake of nitrogen at the end of crop growth of both the years are also presented in the Table 48. The effect of organic manures as well as microbial inoculants on the uptake of nitrogen at the first year of experimentation varied significantly from the uptake during second year of experimentation. The interaction between organic manure and microbial inoculants also resulted in significantly different uptake of nitrogen at the first year compared to second year. The uptake of nitrogen for o_1b_1 was 64.32 kg ha^{-1} for the first year which increased to 94.08 kg ha^{-1} during the second year. Similarly the uptake of N by o_3b_3 during the first year was 64.26 kg ha^{-1} which increased to 64.81 kg ha^{-1} during the second year.

4.3.1.2 Uptake of phosphorus

The data on uptake of phosphorus at the end of crop growth on both the years are presented in the Table 48.

Organic manures significantly influenced the plant uptake of phosphorus. The treatment O_1 resulted in higher uptake and was significantly superior compared to other treatments. The uptake of P during the first year was 9.85 kg ha^{-1} which was the highest for FYM compared to other organic manures. The effects of neemcake and green leaves in plant uptake were at par on both years. The uptake of P was 9.49 kg ha^{-1} for O_3, 9.53 kg ha^{-1} for O_4 during the first year of experiment. During the second year the uptake was 15.70 and 15.42 kg ha^{-1} for O_3 and O_4 respectively.

Application of microbial inoculants significantly influenced the phosphorus uptake. Significantly higher uptake was observed when microbial inoculants like AMF and *Trichoderma* were applied in combination on both years. Among the microbial inoculant the highest uptake was noticed for B_3 treatment (10.52 and 18.22 kg ha^{-1} for first and second year respectively). The uptake was least for B_0.

Table 48.Effect of organic manures, microbial inoculants and their interaction on uptake of N, P and K

Treatments	N			P			K		
	I year	II year	Pooled mean	I year	II year	Pooled mean	I year	II year	Pooled mean
O_1	60.14	85.42	72.78	9.85	16.50	13.17	80.57	113.10	95.16
O_2	59.57	82.84	71.21	9.28	14.99	12.13	79.92	109.87	94.89
O_3	60.08	84.57	72.33	9.49	15.70	12.60	80.25	111.77	96.01
O_4	59.61	83.70	71.66	9.52	15.42	12.47	80.27	111.17	102.19
SE	0.17	0.27	0.16	0.10	0.21	0.12	0.65	0.57	0.44
CD	0.48	0.77	0.44	0.29	0.60	0.33	1.86	1.65	1.24
B_0	54.34	75.20	64.77	8.19	12.59	10.39	78.13	102.79	93.74
B_1	61.20	86.24	73.72	9.84	16.45	13.14	80.79	113.52	98.66
B_2	60.87	84.73	72.80	9.58	15.36	12.47	80.32	112.04	96.18
B_3	62.99	90.37	76.68	10.52	18.22	14.37	81.79	117.56	99.67
SE	0.17	0.27	0.16	0.10	0.21	0.12	0.65	0.57	0.44
CD	0.48	0.77	0.44	0.29	0.60	0.33	1.86	1.65	1.24
Interaction									
o_1b_0	54.70	74.09	64.39	8.11	12.35	10.23	77.92	102.60	90.26
o_1b_1	64.32	94.08	79.20	11.58	20.56	16.07	83.11	121.45	95.58
o_1b_2	58.36	81.01	69.68	8.80	13.86	11.33	81.19	108.44	93.82
o_1b_3	63.18	92.51	77.84	10.91	19.22	15.07	84.06	119.90	100.98
o_2b_0	52.98	73.36	63.17	8.11	12.17	10.14	77.74	99.76	88.77
o_2b_1	61.97	87.66	74.81	9.95	12.57	13.35	81.08	115.61	98.38
o_2b_2	61.61	84.74	73.17	9.50	15.30	12.40	80.35	111.78	96.06
o_2b_3	61.74	85.62	73.68	9.55	15.73	12.64	80.50	112.31	96.40
o_3b_0	55.38	77.61	66.49	8.41	13.07	10.74	78.56	105.12	91.84
o_3b_1	60.80	83.77	72.28	9.07	14.78	11.93	81.90	110.78	95.34
o_3b_2	59.90	82.08	70.99	8.98	14.22	11.60	79.56	109.52	94.54
o_3b_3	64.26	94.81	79.53	11.50	20.73	16.12	83.98	121.64	102.31
o_4b_0	54.32	75.73	65.03	8.13	12.75	10.44	79.26	103.66	104.10
o_4b_1	57.71	79.44	68.58	8.75	13.69	11.22	81.15	106.22	105.38
o_4b_2	63.60	91.11	77.36	11.03	18.07	14.55	79.50	118.42	100.29
o_4b_3	62.80	88.53	75.66	10.14	17.18	13.66	81.61	116.38	99.00
SE	0.33	0.53	0.31	0.20	0.42	0.23	1.30	1.15	0.87
CD	0.96	1.53	0.88	0.57	1.21	0.65	3.73	3.30	2.47
Trt mean			71.9921			12.592			97.0619
Y mean	59.85	84.13		9.53	15.65		83.49	110.64	
SE	0.11			0.08			0.31		
CD	0.31			0.23			0.87		
C_1	56.43	52.04	54.2350	8.66	8.03	8.345	78.76	75.55	77.155
C_2	46.89	40.17	43.5353	6.45	4.75	5.600	63.50	48.28	55.890
C_1 vs Treated	S*			S*			S*		
C_2 vs Treated	S*			S*			S*		
C_1 vs C_2	S*			S*			S*		
SE for OY	0.22			0.16			0.62		
CD for OY	0.62			0.46			1.75		
SE for BY	0.22			0.16			0.62		
CD for BY	0.62			0.46			1.75		
SE for OBY	0.44			0.33			1.24		
CD for OBY	1.25			0.92			3.50		

NS-Non significant
*Significant at 5 % level

Interaction effects furnished in the table clearly indicate that plant uptake of phosphorus was significantly influenced by O x B interaction. Significantly higher uptake was reported from o_3b_3 and o_1b_1 which were on par on both years. The uptake of P by o_1b_1 was 11.58 kg ha^{-1} and 20.56 kg ha^{-1} while that for o_3b_3 treatment was 11.50 kg ha^{-1} and 20.73 kg ha^{-1} for first and second year respectively. All the B_0 combination with organic manures resulted in lower uptake of phosphorus. Application of *Trichoderma* and green leaves + FYM together in the soil resulted in higher uptake than any other combination of green leaves on both years.

Significant difference in the plant uptake of phosphorus was observed when both the years were compared. The uptake of phosphorus was significantly higher during the second year (15.65 kg ha^{-1}) compared to first year (9.53 kg ha^{-1}).

The uptake of phosphorus by the treatments differed significantly from the controls, C_1 and C_2. The uptake by C_1 also differed from that of C_2.

The pooled data of uptake of phosphorus after the termination of each experimentation is also presented in the Table 48.

The phosphorus uptake during the first year as a result of organic manures, microbial inoculants and their interaction was significantly different from the effect produced during second year.

4.3.1.3 Uptake of potassium

The data on the uptake of potassium at the end of each experimentation in each year are presented in Table 48.

Application of different organic manures significantly favoured the uptake of potassium. Application of FYM resulted in significantly higher plant uptake of potassium and was on par with the uptake of potassium by neemcake + FYM and green leaves + FYM treatment during the first year. The plant uptake of potassium was almost similar for neemcake and FYM. The uptake of potassium by O_1 was 80.57 kg ha^{-1} during the first year and 113.10 kg ha^{-1} for the second year. Significantly lower values were noted for O_2 during the first (79.92 kg ha^{-1}) and second year of experimentation (109.87 kg ha^{-1}).

Significant difference in the plant uptake of potassium was observed by the application of different microbial inoculants. The use of AMF and *Trichoderma* together resulted in higher plant uptake than their individual application on both years. The uptake of K was the highest for B_3 treatments (81.79 kg ha^{-1} and 117.56 kg ha^{-1} for the first and second year respectively) and the lowest for B_0 treatment (78.13 and 102.79 kg ha^{-1} for the first and second year respectively).

The interaction effect O x B was also found to be significant. However, the o_1b_3 resulted in highest uptake of potassium than any other combination on the first year of study. o_3b_3 combination resulted in an uptake of 83.98 kg K ha^{-1} and 121.64 kg K ha^{-1} during the first and second year of experiment. The potassium uptake by o_1b_3 was on par with o_1b_1 (83.11 kg ha^{-1}), o_1b_2 (81.19 kg ha^{-1}) , o_{2b1} (81.08 kg ha^{-1}), o_2b_2 (80.35 kg ha^{-1}), o_2b_3 (80.50 kg ha^{-1}), o_3b_1 (81.90 kg ha^{-1}), o_3b_3 (83.98 kg ha^{-1}), o_4b_1 (81.15 kg ha^{-1}) and o_4b_3 (81.63 kg ha^{-1}) during the first year of experimentation. During second year among organic manure, microbial combination, o_3b_3 resulted in higher plant uptake of potassium (121.64 kg ha^{-1}).

Significant difference in the uptake of potassium was observed when both the years were compared. The uptake was more in the second year (110.64 kg ha^{-1}) than the first year (83.49 kg ha^{-1}).

The potassium uptake on plots, which received treatments varied significantly from the controls, C_1 and C_2. The variation was significant between the controls also.

The pooled analysis presented in the Table 48, indicated a significant difference in the uptake of potassium among organic manures, microbial inoculants and their interactions during first year compared to the second year of experimentation which shows a dependence on the organic manures, microbial inoculants and their interaction.

4.3.2 Correlation of uptake of N, P and K in relation to green ginger and dry ginger yield

4.3.2.1 Uptake of N

The correlation studies of green and dry ginger with the uptake of N for the first year of experiment is presented in the Table 49 and for the second year of experiment is presented in the Table 50.

The correlation studies revealed a significant positive influence of green and dry ginger yield with the uptake of N on both year of experimentation. The uptake of nitrogen is also significantly dependent on the uptake of P as well as K as revealed from the first and second years of study. The correlation coefficient was significantly higher (0.980) for first year (0.9800) and for second year (0.9941), when compared to green ginger yield of both years.

4.3.2.2 Uptake of P

The uptake of P is inter correlated with green and dry ginger, uptake of N and uptake of K for the first year of experimentation and is presented in Table 49 and for second year in Table 50.

Significant positive association was noticed between uptake of P and green ginger and dry ginger yield on both years of study. The uptake of P also showed significant positive correlation with uptake of N and K as revealed from the Table 49 and Table 50.

4.3.2.3 Uptake of K

The correlation between uptake of K with green ginger, dry ginger uptake of N and uptake of P on first and second year of experimentation are presented in Table 49 and Table 50.

Significant positive correlations of K uptake with green and dry ginger yield, was noticed on both years of experimentation. Similarly the uptake of K showed a significant positive correlation with the uptake of N and K as revealed from two years of study. During the second year the

Table 49. Correlation of uptake of N, P and K in relation to green ginger and dry ginger yield during the first year of experimentation

Characters	Green ginger yield	Dry ginger yield	Uptake of N	Uptake of P	Uptake of K
Green ginger yield	1				
Dry ginger yield	0.9880*	1			
Uptake of N	0.9800*	0.9732*	1		
Uptake of P	0.9276*	0.9706*	0.9174*	1	
Uptake of K	0.8147*	0.8121*	0.7759*	0.7664*	1

*Significant at 5 % level

Table 50. Correlation of uptake of N, P and K in relation to green ginger and dry ginger yield during the second year of experimentation

Characters	Green ginger yield	Dry ginger yield	Uptake of N	Uptake of P	Uptake of K
Green ginger yield	1				
Dry ginger yield	0.9959*	1			
Uptake of N	0.9941*	0.9919*	1		
Uptake of P	0.9115*	0.8994*	0.9023*	1	
Uptake of K	0.9940*	0.9938*	0.9969*	0.8918*	1

*Significant at 5 % level

association of K uptake with yield was higher (0.9940) compared to P uptake with yield (0.9115).

4.4 EFFECT OF ORGANIC MANURES, MICROBIAL INOCULANTS AND THEIR INTERACTION ON NUTRIENT BALANCE SHEET OF FIRST AND SECOND YEAR OF EXPERIMENTATION

4.4.1 Balance sheet for available nitrogen

The balance sheet for available nitrogen during both the years is presented in Table 51 and 52.

A considerable loss of nitrogen was observed during the first year in all the treatments (Table 51) whereas during the second year the loss was comparatively lower (Table 52).

During first year of study among different organic manures the loss was comparatively lower in green leaf (O_4) incorporated treatments (120.63 kg ha^{-1}). The loss was highest in neemcake (O_3) treated plots (123.15 kg ha^{-1}).

Among microbial inoculants, the loss was much reduced in plots which received both *Trichoderma* and AMF, B_3 (117.49 kg ha^{-1}). The loss was highest in plots which did not receive any microbial inoculants, B_0 (128.24 kg ha^{-1}).

The results of interaction effect of O x B revealed that the loss of N was minimum in all the organic manure combination with B_3. However, the loss was least in o_4b_3 combination (112.38 kg ha^{-1}). The B_0 combination with organic manures O_1, O_2, O_3 and O_4 showed heavier nitrogen loss.

Among all the treatments the loss was mere in control, C_1 (142.23 kg ha^{-1}). However the loss was the least in C_2 (3.29 kg ha^{-1}) compared to all the treatments.

The balance sheet of nitrogen for the second year of experimentation is represented in Table 52.

Table 51. Nutrient balance sheet N for first year (main and interaction effect)

Treatments	Initial Y (kg ha^{-1})	N addition A (kg ha^{-1})	N uptake B (kg ha^{-1})	Expected balance C (kg ha^{-1})	Available N status D (kg ha^{-1})	Net loss/gain (kg ha^{-1})
O_1	142.12	195	60.14	275.98	151.19	-121.79
O_2	141.38	195	59.58	276.80	153.92	-122.88
O_3	141.77	195	60.09	276.68	153.53	-123.15
O_4	140.73	195	59.61	276.12	155.49	-120.63
B_0	141.38	195	54.38	282.03	153.79	-128.24
B_1	141.64	195	61.20	275.44	154.06	-121.38
B_2	140.60	195	60.87	274.73	153.40	-121.33
B_3	141.38	195	63.00	273.38	155.89	-117.49
o_1b_0	140.60	195	54.70	280.90	153.66	-127.24
o_1b_1	141.12	195	64.32	271.80	153.14	-118.66
o_1b_2	140.07	195	58.36	276.71	153.14	-123.57
o_1b_3	142.69	195	63.18	274.51	156.80	-117.71
o_2b_0	142.17	195	52.98	284.19	153.14	-131.05
o_2b_1	140.60	195	61.97	273.63	152.62	-121.01
o_2b_2	141.12	195	61.61	274.51	154.18	-120.33
o_2b_3	141.64	195	61.74	274.90	155.75	-119.15
o_3b_0	141.12	195	55.38	280.74	153.14	-127.60
o_3b_1	143.21	195	60.80	277.41	155.75	-121.66
o_3b_2	141.12	195	59.90	276.22	152.62	-123.60
o_3b_3	141.64	195	64.26	272.38	152.62	-119.76
o_4b_0	141.64	195	54.32	282.32	155.23	-127.09
o_4b_1	141.64	195	57.71	279.54	154.71	-124.83
o_4b_2	140.07	195	63.60	271.47	153.66	-117.81
o_4b_3	139.55	195	63.80	270.75	158.37	-112.38
C_1	141.64	195	56.43	280.21	137.98	-142.23
C_2	141.12	-	46.89	94.23	90.94	-3.29

Table 52. Nutrient balance sheet N for second year (main and interaction effect)

Treatments	Initial Y (kg ha^{-1})	N addition A (kg ha^{-1})	N uptake B (kg ha^{-1})	Expected balance C (kg ha^{-1})	Available N status D (kg ha^{-1})	Net loss/gain (kg ha^{-1})
O_1	154.19	195	85.42	263.77	175.87	-87.90
O_2	153.92	195	82.85	266.07	174.57	-95.50
O_3	153.53	195	84.57	263.96	175.36	-88.60
O_4	155.49	195	83.70	266.79	181.22	-85.57
B_0	153.79	195	75.20	273.59	174.83	-98.76
B_1	154.06	195	86.24	262.82	176.01	-86.81
B_2	153.40	195	84.74	263.66	177.05	-86.61
B_3	155.89	195	90.37	260.52	179.14	-81.38
o_1b_0	153.66	195	74.09	274.57	173.50	1-01.07
o_1b_1	153.14	195	94.08	254.06	175.62	-78.44
o_1b_2	153.14	195	81.01	267.13	175.62	-91.51
o_1b_3	156.80	195	92.51	259.29	178.78	-80.54
o_2b_0	153.14	195	73.36	274.78	173.00	1-01.78
o_2b_1	152.62	195	87.66	259.96	172.48	-87.48
o_2b_2	154.18	195	84.74	264.44	175.62	-88.82
o_2b_3	155.75	195	85.62	265.13	177.18	-87.95
o_3b_0	153.14	195	77.61	270.53	174.05	-96.48
o_3b_1	155.75	195	83.77	266.98	176.66	-90.32
o_3b_2	152.62	195	82.08	265.54	174.57	-90.97
o_3b_3	152.62	195	94.81	252.81	176.14	-76.67
o_4b_0	155.23	195	75.73	274.50	178.75	-95.75
o_4b_1	154.71	195	79.44	270.27	179.27	-91.00
o_4b_2	153.66	195	91.11	257.55	182.37	-78.18
o_4b_3	158.37	195	88.53	264.84	184.50	-80.34
C_1	137.98	195	52.04	280.94	134.33	-146.61
C_2	90.94	-	40.17	50.77	56.83	+6.06

Considering the organic manure treatments alone, similar to the first year of experimentation the loss of nitrogen was the least in green leaves + FYM treated plots, O_4 (85.57 kg ha^{-1}) followed by FYM treated plots, O_1 87.90 kg ha^{-1}). The loss was highest in vermicompost + FYM treated plots, O_2 (95.50 kg ha^{-1}).

Among microbial inoculants, the application of AMF and *Trichoderma* (B_3) together in the field reduced the nitrogen loss considerably (81.38 kg ha^{-1}). The effect of microbial inoculants on nitrogen loss is evident when the loss was compared to plots which did not receive microbial inoculants (98.76 kg ha^{-1}).

Among O x B combination the loss was least in o_4b_2 (78.18 kg ha^{-1}). However the loss was less in all microbial combination with organic manures. Highest loss of nitrogen was observed in o_2b_0 combination (101.78 kg ha^{-1}).

The loss of nitrogen was the highest in all the plots which received manures as per package of practices recommendation of Kerala Agricultural University (146.61 kg ha^{-1}) compared to other treatments. However gain in nitrogen was observed in C_2 plots (16.06 kg ha^{-1}) during the second year.

4.4.2 Balance sheet for available phosphorus

Table 53 and 54, represents the balance sheet for available phosphorus for the first and second year of experimentation. A considerable decrease in the magnitude of net loss of phosphorus was observed in the second year in all the treatments.

During the first year of experimentation (Table 54) among organic manure treatments net loss was comparatively less in green leaves + FYM, O_4 treated plots, (124.14 kg ha^{-1}) followed by FYM treated plots,O_1 (125.05 kg ha^{-1}). The loss of phosphorus was highest in plots, which received vermicompost + FYM treatments, O_2 (126.43 kg ha^{-1}).

Among microbial inoculants the loss was least in plots which received the combination of AMF and *Trichoderma*, B_3 (123.17 kg ha^{-1}). The effect of AMF, B_1 (125.51 kg ha^{-1}) and *Trichoderma*, B_2 (125.24 kg ha^{-1}) was almost similar.

The interaction of O x B reveals that o_4b_2 combination showed the least loss (121.87 kg ha^{-1}). For all the organic combination with B_3, the loss was comparatively less among FYM microbial inoculant combination. The combination of AMF with FYM, o_1b_1 (123.69 kg ha^{-1}) produced less loss. However among green leaves, the application of *Trichoderma* together with green leaves + FYM resulted in less loss of phosphorus (121.87 kg ha^{-1}), which was the least loss observed among organic manure microbial inoculant combinations.

Among controls, net loss of phosphorus was more in C_1 (142.24 kg ha^{-1}). However the loss of phosphorus was the least in C_2 (2.81 kg ha^{-1}).

Table 54, represents the nutrient balance sheet for the second year of experimentation.

Among organic manures, the net loss of phosphorus was the highest for vermicompost + FYM treatments, O_1 (115.32 kg ha^{-1}). However green leaves + FYM, O_4 treatment produced significantly less net loss (111.75 kg ha^{-1}).

The net loss of phosphorus by the application of microbial inoculants is presented in the Table 54. The application of AMF and *Trichoderma* together (B_5) in the soil resulted in less considerable loss (110.81 kg ha^{-1}).

Considering the O x B interactions (108.86 kg ha^{-1}), irrespective of all organic manures combination AMF and *Trichoderma* reduced the net loss. The net loss was the least in o_4b_2 combination among all interactions. Among FYM combination with microbial inoculants, FYM + AMF combinations resulted in higher net loss (117.30 kg ha^{-1}). Application of vermicompost, neemcake and green leaves with FYM and without microbial inoculants resulted in considerably higher net loss than their other combinations.

Table 53. Nutrient balance sheet P for first year (main and interaction effect)

Treatments	Initial Y (kg ha^{-1})	P addition A (kg ha^{-1})	P uptake B (kg ha^{-1})	Expected balance C (kg ha^{-1})	Available P status D (kg ha^{-1})	Net loss/gain (kg ha^{-1})
O_1	18.48	140	9.85	148.63	23.58	-125.05
O_2	19.04	140	9.28	149.76	23.33	-126.43
O_3	18.86	140	9.49	148.37	23.80	-125.57
O_4	17.92	140	9.51	148.41	24.27	-124.14
B_0	18.67	140	8.19	150.48	23.10	-127.38
B_1	19.17	140	9.84	149.33	23.82	-125.51
B_2	17.92	140	9.58	148.34	23.10	-125.24
B_3	18.67	140	10.53	148.14	24.97	-123.17
o_1b_0	17.92	140	8.11	149.81	22.40	-127.41
o_1b_1	18.67	140	11.58	147.09	23.40	-123.69
o_1b_2	17.92	140	8.80	149.12	22.40	-123.72
o_1b_3	19.41	140	10.91	148.50	26.13	-122.37
o_2b_0	19.41	140	8.11	151.30	22.40	-128.90
o_2b_1	18.67	140	9.95	148.72	22.40	-126.32
o_2b_2	18.67	140	9.50	149.17	23.33	-125.84
o_2b_3	19.41	140	9.55	149.86	25.20	-124.66
o_3b_0	18.67	140	8.41	150.26	23.33	-126.93
o_3b_1	20.16	140	9.07	151.09	25.20	-125.89
o_3b_2	17.92	140	8.98	148.94	22.40	-126.54
o_3b_3	18.67	140	11.50	147.17	24.27	-122.90
o_4b_0	18.67	140	8.12	150.55	24.27	-126.28
o_4b_1	18.67	140	8.75	149.92	24.27	-125.65
o_4b_2	17.17	140	11.03	146.14	24.27	-121.87
o_4b_3	17.17	140	10.14	147.03	24.27	-122.76
C_1	19.41	140	8.66	159.41	17.17	-142.24
C_2	19.41	-	6.45	12.76	9.95	-2.81

Table 54. Nutrient balance sheet P for second year (main and interaction effect)

Treatments	Initial Y (kg ha^{-1})	P addition A (kg ha^{-1})	P uptake B (kg ha^{-1})	Expected balance C (kg ha^{-1})	Available P status D (kg ha^{-1})	Net loss/gain (kg ha^{-1})
O_1	23.57	140	16.50	147.07	35.00	-112.07
O_2	23.33	140	13.94	149.39	34.07	-115.32
O_3	23.57	140	15.70	147.87	35.00	-112.87
O_4	23.57	140	15.42	148.15	36.40	-111.75
B_0	23.10	140	12.59	150.51	34.07	-116.44
B_1	23.57	140	15.40	148.17	35.70	-112.47
B_2	22.87	140	15.36	147.51	35.23	-112.28
B_3	24.50	140	18.22	146.28	35.47	-110.81
o_1b_0	22.40	140	12.35	150.05	33.60	-116.45
o_1b_1	23.33	140	20.56	142.77	35.47	-117.30
o_1b_2	22.40	140	13.86	148.54	35.47	-113.07
o_1b_3	26.13	140	19.22	146.91	35.47	-111.44
o_2b_0	22.40	140	12.17	150.23	32.67	-117.56
o_2b_1	22.40	140	12.57	149.83	33.60	-116.23
o_2b_2	23.33	140	15.30	148.03	34.53	-113.50
o_2b_3	25.20	140	15.73	149.47	35.47	-114.00
o_3b_0	23.33	140	13.07	150.26	35.53	-115.73
o_3b_1	25.20	140	14.78	150.42	36.40	-114.02
o_3b_2	22.40	140	14.22	148.18	35.53	-113.65
o_3b_3	23.33	140	20.73	142.60	34.53	-108.07
o_4b_0	24.27	140	12.75	151.52	35.47	-116.05
o_4b_1	23.33	140	13.69	149.64	37.33	-112.31
o_4b_2	23.33	140	18.07	145.26	36.40	-108.86
o_4b_3	23.33	140	17.18	146.15	36.40	-109.75
C_1	17.17	140	8.03	149.14	15.68	-133.46
C_2	9.71	-	4.75	4.96	8.21	+3.25

Among controls, higher net loss of phosphorus was observed in C_1 (133.46 kg ha^{-1}) while for C_2 (3.25 kg ha^{-1}) a net gain in phosphorus was observed during the second year of experimentation.

4.4.3 Balance sheet for available potassium

The nutrient balance sheet for available potassium for first and second year of experimentation is presented in Table 55 and 56. A net gain in available K was observed following the second year of experimentation. The magnitude of loss of potassium was comparatively lower than that for N and P.

During the first year of experimentation (Table 58) among organic manure treatments the net loss of available K was minimum for green leaves + FYM treated plots (O_4) followed by FYM (O_1). The net loss was the highest for neemcake treated plots (O_3).

Among microbial inoculants, the application of AMF and *Trichoderma* together resulted in lesser net loss (8.62 kg ha^{-1}) during first year. The net loss was less for *Trichoderma* than AMF plots. The soils which did not receive any microbial inoculants showed higher net loss of potassium (16.00 kg ha^{-1}).

The O x B interaction shows that o_1b_3 combination resulted in least loss of available K during first year (1.81 kg ha^{-1}). The combination of B_3 with all the organic manures resulted in lesser net loss. B_0 interaction with O_1, O_2, O_3 and O_4 produced higher net loss. Application of *Trichoderma* (B_2) with vermicompost (O_2) neemcake (O_3) and green leaves (O_4) reduced the net loss of available K compared to their combination with AMF.

Among controls, a net gain in available K was observed for C_2 while the loss of C_1 was the maximum among all the treatment combinations.

Table 56, reveals the nutrient balance sheet of the second year of experimentation. A net gain is available K was observed for all the treatments except C_1.

Table 55. Nutrient balance sheet K for first year (main and interaction effect)

Treatments	Initial Y (kg ha^{-1})	K addition A (kg ha^{-1})	K uptake B (kg ha^{-1})	Expected balance C (kg ha^{-1})	Available K status D (kg ha^{-1})	Net loss/gain (kg ha^{-1})
O_1	103.60	110	80.57	133.03	121.33	-11.70
O_2	106.40	110	79.93	136.47	122.27	-14.20
O_3	104.53	110	80.25	134.28	118.53	-15.75
O_4	100.80	110	80.27	130.53	120.40	-10.13
B_0	104.53	110	78.13	136.40	120.40	-16.00
B_1	105.47	110	80.79	134.68	120.40	-14.28
B_2	100.80	110	80.32	130.48	117.60	-12.88
B_3	104.54	110	81.79	132.75	124.13	-8.62
o_1b_0	100.80	110	77.92	132.88	115.73	-17.15
o_1b_1	104.53	110	83.11	131.42	119.47	-11.95
o_1b_2	100.80	110	79.19	131.61	115.73	-15.88
o_1b_3	108.27	110	82.06	136.21	134.40	-1.81
o_2b_0	108.27	110	77.77	140.50	123.20	-17.30
o_2b_1	104.53	110	81.08	133.45	115.73	-17.72
o_2b_2	104.53	110	80.35	134.18	123.20	-10.98
o_2b_3	108.27	110	80.50	137.77	126.93	-10.84
o_3b_0	104.53	110	78.56	135.97	119.47	-16.50
o_3b_1	108.27	110	79.90	138.37	123.20	-15.17
o_3b_2	100.80	110	79.56	131.24	115.73	-15.51
o_3b_3	104.53	110	82.98	131.55	115.73	-15.82
o_4b_0	104.53	110	78.25	136.28	123.20	-13.08
o_4b_1	104.53	110	79.05	135.48	123.20	-12.28
o_4b_2	97.07	110	82.16	124.91	115.73	-9.18
o_4b_3	97.07	110	81.61	125.46	119.47	-5.99
C_1	104.53	110	78.76	135.77	100.80	-34.97
C_2	108.27	-	63.50	44.77	59.73	+14.93

Table 56. Nutrient balance sheet K for second year (main and interaction effect)

Treatments	Initial Y (kg ha^{-1})	K addition A (kg ha^{-1})	K uptake B (kg ha^{-1})	Expected balance C (kg ha^{-1})	Available K status D (kg ha^{-1})	Net loss/gain (kg ha^{-1})
O_1	121.33	110	113.10	118.23	140.93	+22.70
O_2	122.27	110	109.87	122.40	142.80	+20.40
O_3	118.53	110	111.77	116.76	140.00	+23.24
O_4	120.40	110	111.17	119.23	145.60	+26.37
B_0	120.40	110	102.79	127.61	140.93	+13.32
B_1	120.40	110	113.52	116.88	142.80	+25.92
B_2	117.60	110	112.04	115.56	140.93	+25.37
B_3	124.13	110	117.56	116.57	144.67	+28.10
o_1b_0	115.73	110	102.60	123.13	138.13	+15.00
o_1b_1	119.47	110	121.45	108.08	141.87	+33.85
o_1b_2	115.73	110	108.44	117.29	138.13	+20.84
o_1b_3	134.40	110	119.90	124.50	145.60	+21.10
o_2b_0	123.20	110	99.76	133.40	141.87	+8.43
o_2b_1	115.73	110	115.61	110.12	141.87	+31.75
o_2b_2	123.20	110	111.78	121.42	141.87	+20.45
o_2b_3	126.93	110	112.31	124.62	145.60	+20.98
o_3b_0	119.47	110	105.12	124.35	138.13	+13.79
o_3b_1	123.20	110	110.78	122.42	141.87	+19.45
o_3b_2	115.73	110	109.52	116.21	138.13	+21.92
o_3b_3	115.73	110	121.64	104.09	141.87	+37.78
o_4b_0	123.20	110	103.66	129.54	145.60	+16.06
o_4b_1	123.20	110	106.22	126.98	145.60	+18.62
o_4b_2	115.73	110	118.42	107.31	145.60	+38.29
o_4b_3	119.47	110	116.38	113.09	145.60	+32.51
C_1	100.80	110	75.55	135.25	97.07	-38.18
C_2	56.00	-	48.28	7.72	44.80	+37.08

Among organic manure treatments the net gain was the highest for green leaves + FYM treatment, O_4 (26.37 kg ha^{-1}) and the least for vermicompost + FYM treatment, O_2 (20.40 kg ha^{-1}).

A distinct gain in the quantity of available K was observed in plots that received microbial application. Among microbial inoculants, application of AMF and *Trichoderma* together (B_3) resulted in higher net gain (28.10 kg ha^{-1}).

Among O x B interaction, the net gain was the highest for o_4b_2 combination (38.29 kg ha^{-1}) followed by o_3b_3 (37.78 kg ha^{-1}). The net gain was the least for o_2b_0 (8.43 kg ha^{-1}). For all the combinations of organic manures with B_0, the net gain was lower.

Between controls a net loss in available K was reported from C_1 while C_2 recorded a net gain in available K.

4.5 EFFECT OF ORGANIC MANURES MICROBIAL INOCULANTS AND THEIR INTERACTION ON PERCENTAGE OF PEST INCIDENCE

The effect of organic manures, microbial inoculants and their interaction on percentage of pest incidence at 60, 120, 180 and 240 DAP of both years of experimentation are presented in the Table 57.

The main effect of organic manures did not make any difference in the pest incidence at most of the stages except at 120 and 180 DAP of first year of experimentation. At 120 DAP, the percentage of pest incidence was the highest for FYM treated plants (14.50 %) followed by green leaves + FYM treated plants (9.29 %). The percentage of incidence of pest was 14.50 per cent for 120 DAP, which decreased to 3.93 per cent at 180 DAP. However the least percentage of pest incidence was noted from vermicompost + FYM treated plots (5.93 at 120 DAP and 1.28 at 180 DAP).

The percentage of pest incidence was not influenced by the application of different microbial inoculants.

The interaction O x B did not show any differences in percentage of pest incidence at all the stages of growth on both the years.

Table 57. Effect of organic manures, microbial inoculants and their interaction on the percentage of pest incidence

Treatments	60 DAP		120 DAP		180 DAP		240 DAP	
	I year	II year	I year	II year	I year	II year	I year	II year
O_1	5.62 (2.57)	1.74 (1.66)	14.5 (3.94)	5.92 (2.63)	3.93 (2.22)	1.56 (1.60)	0.81 (1.34)	0.38 (1.17)
O_2	3.25 (2.06)	1.30 (1.52)	5.93 (2.63)	3.99 (2.23)	1.28 (1.51)	0.58 (1.26)	0.18 (1.09)	0.00 (1.00)
O_3	2.33 (1.82)	1.81 (1.34)	7.70 (2.95)	3.70 (2.17)	2.64 (1.91)	1.04 (1.43)	0.37 (1.17)	0.00 (1.00)
O_4	3.52 (2.13)	1.64 (1.63)	9.29 (3.21)	4.96 (2.44)	3.33 (2.08)	2.12 (1.77)	0.37 (1.17)	0.18 (1.09)
SE			0.28		0.17			
CD	NS	NS	0.81	NS	0.5	NS	NS	NS
B_0	3.25 (2.06)	1.30 (1.52)	9.37 (3.22)	4.85 (2.42)	3.43 (2.10)	1.04 (1.43)	0.58 (1.26)	0.18 (1.09)
B_1	2.86 (1.97)	1.47 (1.57)	7.78 (2.96)	4.36 (2.32)	2.85 (1.96)	1.47 (1.57)	0.18 (1.09)	0.00 (1.00)
B_2	4.59 (2.36)	1.30 (1.52)	9.21 (3.20)	4.14 (2.27)	2.23 (1.80)	1.74 (1.66)	0.58 (1.26)	0.37 (1.17)
B_3	3.81 (2.19)	1.37 (1.54)	10.22 (3.35)	5.11 (2.47)	2.43 (1.85)	0.96 (1.40)	0.37 (1.17)	0.00 (1.00)
CD	NS	NS	NS	NS	NS	NS	NS	NS
Interaction								
o_1b_0	5.11 (2.47)	1.85 (1.69)	12.38 (3.66)	6.01 (2.65)	4.07 (2.25)	1.85 (1.69)	0.81 (1.34)	0.81 (1.34)
o_1b_1	6.01 (2.65)	1.85 (1.69)	14.45 (3.93)	5.11 (2.47)	4.07 (2.25)	1.85 (1.69)	0.81 (1.34)	0.00 (1.00)
o_1b_2	7.23 (2.87)	1.85 (1.69)	21.81 (4.78)	6.98 (2.82)	5.11 (2.47)	1.85 (1.67)	1.85 (1.69)	0.81 (1.34)
o_1b_3	4.31 (2.30)	1.45 (1.56)	10.45 (3.38)	5.65 (2.58)	2.64 (1.91)	0.81 (1.34)	0.00 (1.00)	0.00 (1.00)
o_2b_0	3.53 (2.13)	0.81 (1.34)	8.77 (3.13)	5.11 (2.47)	3.53 (2.13)	0.81 (1.34)	0.81 (1.34)	0.00 (1.00)
o_2b_1	1.45 (1.56)	0.81 (1.34)	4.00 (2.24)	2.64 (1.91)	1.45 (1.56)	0.81 (1.34)	0.00 (1.00)	0.00 (1.00)
o_2b_2	5.11 (2.47)	0.85 (1.69)	2.64 (1.91)	2.64 (1.91)	0.00 (1.00)	0.81 (1.34)	0.00 (1.00)	0.00 (1.00)
o_2b_3	3.34 (2.08)	1.85 (1.69)	9.65 (3.26)	6.01 (2.65)	0.81 (1.34)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
o_3b_0	2.03 (1.74)	0.81 (1.34)	7.04 ()	2.64 (1.91)	2.64 (1.91)	0.81 (1.34)	0.81 (1.34)	0.00 (1.00)
o_3b_1	1.45 (1.56)	0.81 (1.34)	6.34 (2.30)	2.64 (1.91)	2.94 (1.91)	0.81 (1.34)	0.00 (1.00)	0.00 (1.00)
o_3b_2	1.85 (1.69)	0.81 (1.34)	6.01 (2.65)	4.89 (2.43)	1.85 (1.69)	0.81 (1.34)	0.00 (1.00)	0.00 (1.00)
o_3b_3	4.31 (2.30)	0.81 (1.34)	11.37 (3.52)	4.89 (2.43)	3.53 (2.13)	1.85 (1.69)	0.81 (1.34)	0.00 (1.00)
o_4b_0	2.64 (1.91)	1.85 (1.69)	9.63 (3.26)	6.01 (2.65)	3.53 (2.13)	1.91 (1.34)	0.00 (1.00)	0.00 (1.00)

Table 57. continued…

o_4b_1	3.34 (2.08)	2.64 (1.91)	7.34 (2.89)	7.85 (2.98)	3.53 (2.13)	2.64 (1.91)	0.00 (1.00)	0.00 (1.00)
o_4b_2	4.89 (2.43)	0.81 (1.34)	10.92 (3.45)	2.64 (1.91)	3.13 (2.03)	4.07 (2.25)	0.81 (1.34)	0.81 (1.34)
o_4b_3	3.34 (2.08)	1.45 (1.56)	9.45 (3.23)	4.00 (2.24)	3.13 (2.03)	1.45 (1.56)	0.81 (0.34)	0.00 (1.00)
CD	NS	NS	NS	NS	NS	NS	NS	NS
C_1	5.21 (2.47)	5.21 (2.47)	8.33 (2.88)	8.33 (2.88)	2.08 (1.69)	2.08 (1.69)	1.04 (1.34)	1.04 (1.34)
C_2	5.21 (2.47)	3.13 (2.03)	8.33 (2.88)	7.29 (8.87)	6.25 (2.65)	6.25 (2.65)	1.04 (1.34)	1.04 (1.34)
Control vs Treated	NS	S*	NS	NS	NS	S*	NS	NS
C_1 vs C_2	NS	NS	NS	NS	NS	NS	NS	NS

NS-Non significant
*Significant at 5 % level

Transformed data in parenthesis

The percentage of pest incidence did not show any variation between the controls.

The comparison of organic treatments with controls showed significant difference at 60 and 180 DAP of second year. While for the remaining periods, no variation in percentage of pest incidence was noticed.

4.6 EFFECT OF ORGANIC MANURES, MICROBIAL INOCULANTS AND THEIR INTERACTION ON NEMATODE POPULATION OF THE SOIL BEFORE AND AFTER THE EXPERIMENT

The population of nematode estimated from the soil before planting the rhizome and after the first and second year of experimentation are presented in the Table 58.

The pretreatment population of root knot nematode (*Meloidogyne incognita*) was low. The population level ranged from 0 to 79 per 100 g of the sample per plot and the average per treatment ranged from 0.76 to 66.35. This level of nematode population was not significant enough to cause any economic damage. However after the first year and second year of experiment, the population was assessed and found a decreasing trend.

4.7. EFFECT OF ORGANIC MANURES, MICROBIAL INOCULANTS AND THEIR INTERACTIONS ON THE TERMINAL RESIDUES OF PESTICIDES

The level of residues of mancozeb and malathion and dimethoate were below detectable level in control C_1.

4.8 ECONOMICS OF ORGANIC MANURES AND FERTILIZER APPLICATION

The economics of organic manures and fertilizer application are presented in Table 59 and 60 for the first and second year of experimentation.

During the first year it is evident that application of FYM and AMF together (o_1b_1) resulted in higher net return (Rs.1,99,450 ha^{-1}). The

Table 58.Effect of organic manures, microbial inoculants and their interactions on the population build up of nematodes in the soil

Treatment	Before the experiment	After the first year	After the second year
o_1b_0	2.33	1.18	0.72
o_1b_1	3.20	1.27	0.42
o_1b_2	7.40	5.17	3.41
o_1b_3	4.35	2.00	0.33
o_2b_0	7.35	4.17	2.39
o_2b_1	2.50	0.47	0.22
o_2b_2	2.98	1.42	0.54
o_2b_3	3.20	1.40	0.26
o_3b_0	6.62	1.31	0.34
o_3b_1	0.76	0.42	0.24
o_3b_2	66.35	32.14	12.43
o_3b_3	4.12	1.39	0.62
o_4b_0	0.69	0.41	0.39
o_4b_1	2.75	0.51	0.23
o_4b_2	3.33	2.65	1.20
o_4b_3	12.33	3.33	0.50
C_1	4.25	3.31	3.16
C_2	3.18	2.19	2.23

Table 59. Economics of cultivation (first year)

Treatment	Fresh yield, t ha^{-1}	Value	Cost	Profit	B:C
o_1b_0	13.16	329000	179400	149600	1.84
o_1b_1	15.58	389500	190050	199450	2.05
o_1b_2	14.42	360500	199050	161450	1.81
o_1b_3	15.31	382750	209700	173050	1.83
o_2b_0	12.91	322750	189167	133583	1.71
o_2b_1	14.89	372250	199817	172433	1.86
o_2b_2	14.74	368500	208817	163433	1.76
o_2b_3	14.74	368500	219467	149033	1.68
o_3b_0	13.78	344500	183020	161480	1.88
o_3b_1	14.58	364500	193670	170830	1.88
o_3b_2	14.46	361500	202670	158830	1.78
o_3b_3	15.56	389000	211576	177424	1.84
o_4b_0	13.48	337000	187256	151394	1.80
o_4b_1	14.32	358000	197906	161744	1.81
o_4b_2	15.36	384000	206256	177744	1.86
o_4b_3	15.04	376000	217556	160094	1.73
C_1	13.93	278600	169900	108700	1.64
C_2	9.62	192400	127800	64600	1.51

Table 60. Economics of cultivation (second year)

Treatment	Fresh yield, t ha^{-1}	Value	Cost	Profit	B:C
o_1b_0	18.30	457500	173275	284225	2.64
o_1b_1	22.74	568500	183925	384575	3.09
o_1b_2	19.34	483500	192925	290575	2.51
o_1b_3	22.09	552250	203575	348675	2.71
o_2b_0	17.98	449500	186108	263392	2.42
o_2b_1	21.15	528750	196758	331992	2.69
o_2b_2	20.32	508000	205758	302242	2.47
o_2b_3	20.66	516500	216408	300092	2.39
o_3b_0	18.86	471500	177527	293973	2.66
o_3b_1	20.12	503000	188177	314823	2.67
o_3b_2	19.67	491750	197177	294573	2.49
o_3b_3	22.97	574250	207827	366423	2.76
o_4b_0	18.59	464750	180162	284588	2.58
o_4b_1	19.10	477500	190812	286688	2.50
o_4b_2	21.97	549250	199812	349438	2.75
o_4b_3	21.54	538500	210462	328038	2.56
C_1	12.31	246200	165775	80425	1.48
C_2	6.69	133800	123675	10125	1.08

application of FYM + green leaves together with *Trichoderma* (o_4b_2) as well as the FYM + neem cake + AMF + *Trichoderma* (o_3b_3) produced a net return of Rs.1,77,744 ha^{-1} and Rs.1,77,424 ha^{-1} respectively. The B:C ratio of the above treatments were 2.05, 1.86 and 1.84 respectively. However the control C_1 and C_2 produced a B:C ratio of 1.64 and 1.51 respectively which resulted in a gain of Rs.1,08,700 ha^{-1} and Rs.64,600 ha^{-1}.

For the second year of experimentation the net return was generally higher than the first year of experimentation. Like the first year, the net return of o_1b_1 was the highest (Rs.3,84,575 ha^{-1}) for second year of experimentation also. The B:C ratio was 3.09. The next highest return was from o_3b_3 (Rs.3,66,423 ha^{-1}) followed by o_4b_2 (Rs.3,49,438 ha^{-1}). However the least profit was from the control C_2 (Rs.10,125 ha^{-1}). All the organic treatments produced a higher net return than the controls.

Discussion

5. DISCUSSION

The effect of different organic manures, microbial inoculants and their interaction on the growth, yield and quality of ginger over two years of experimentation are discussed in this chapter.

5.1 PLANT CHARACTERS

5.1.1 Effect of organic manures, microbial inoculants and their interaction on growth characters

5.1.1.1 Height of the plant

During both the years the general trend was that the application of organic manures favoured plant height (Table 4) except at 180 DAP. Among organic manures, maximum plant height was recorded by plants which received FYM on both the years. A similar effect of FYM was noticed by many workers like Cerna (1980), Valsikova and Ivanic (1982) in capsicum, Sahota (1993) in potato and Arunkumar (2000) in Amaranthus. Vidyadharan (2000) also observed increased plant height by the highest level of FYM tried in arrowroot. The effect of neemcake on plant height was also significantly superior though shorter than the effect of FYM. According to Singh and Sitaramaiah (1963) application of oilcake increased plant height in bhindi. The plant height produced due to neemcake was on par with package of practices recommendation of Kerala Agricultural University according to Sharu (2000).

Application of microbial inoculants also significantly influenced the plant height. The plant height was the highest for B_3 among microbial inoculants which indicate that application of AMF and *Trichoderma* together resulted in longer plants than their individual application. The application of AMF and *Trichoderma* together resulted in increased plant height in wheat (Kumar *et al*., 1993) and marigold (Calvet *et al*., 1993). An increase in plant height of pepper as a result of AMF application was reported by Thomas and Ghai (1988); Sivaprasad *et al*. (1992) and

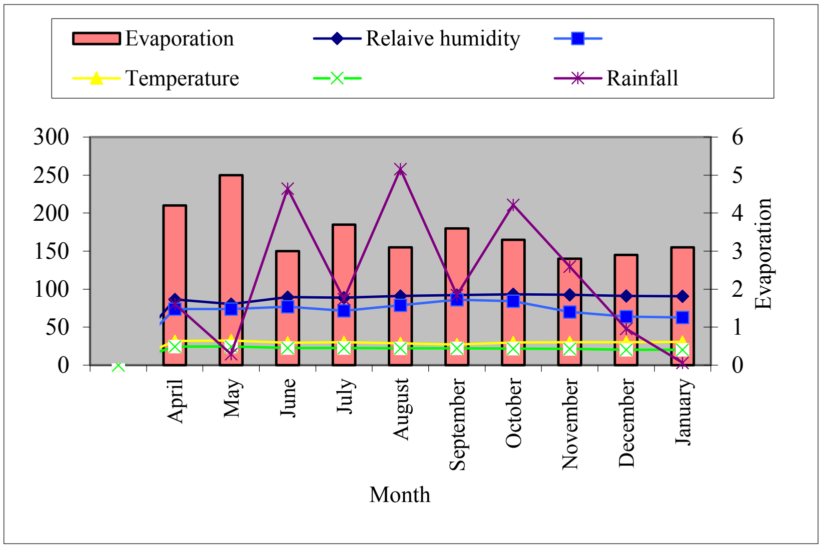


Fig. 1a. Weather parameter during first year of experiment (2000-2001)

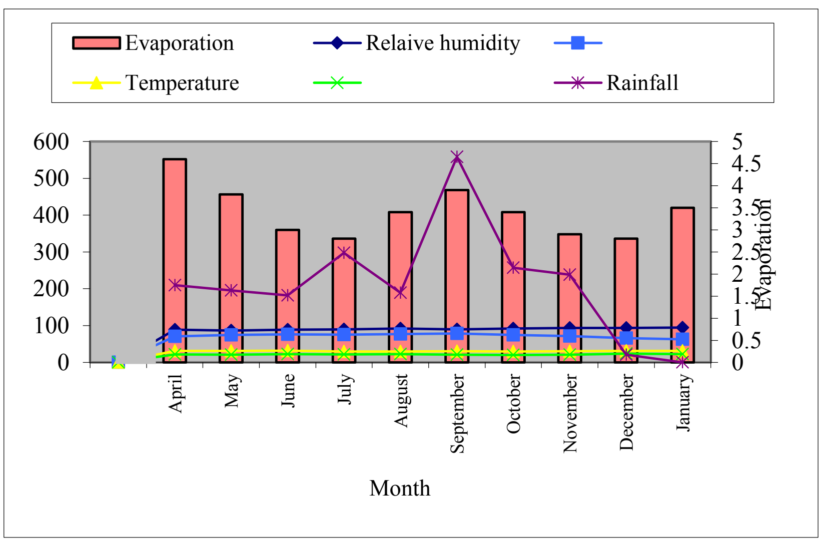


Fig. 1b. Weather parameter during second year of experiment (2001-2002)

Anandaraj and Sarma (1994). Similar effects were also noticed in cardamom seedlings (Thomas *et al*., 1989) and ginger (Sivaprasad, 1993). The effect of *Trichoderma* on growth enhancement was also noticed by Joseph (1997) in ginger.

The combination of organic manures and biofertilizers significantly influenced the plant height as evident from the interaction effects. Treatments combination, o_1b_1 and o_3b_3 produced plants with higher plant height during the first year while o_3b_3 resulted in longer plants in the second year of study and were significantly superior to other combinations on both years. The combinations of AMF with FYM and AMF + *Trichoderma* with FYM + neemcake might have resulted in the efficient release as well as uptake of nutrients which might have resulted in higher plant heights (Table 4).

The controls varied significantly from the treatments at all stages. The shortest plants were produced by absolute control (C_2). The plant heights produced by C_1 differed significantly from the treated plants as evident at all growth stages. However longer plants were produced by the application of organic manures like FYM, vermicompost, neemcake and green leaves in combination with AMF and *Trichoderma* and these plants were longer than those plants treated as per package of practices recommendation of Kerala Agricultural University (C_1) and absolute control (C_2). Thamburaj (1994) compared inorganically and organically grown tomato plants and observed taller plants in organically treated ones.

5.1.1.2 Number of tillers

Tiller production was found to be influenced by organic manure application at later stages of growth of second year *ie.,* 120, 180 and 240 DAP and at final harvest (240 DAP) of first year (Table 5). At these significant stages higher tiller production was noticed in FYM treated plants. A similar observation was noted in turmeric by Rakhee (2002) where higher tiller production was observed during the early stages of growth of FYM treated plots and it was on par with coirpith compost treatment during the later stages of growth. FYM act as nutrient reservoir and upon decomposition produces organic acids, thereby adsorbed ions are released slowly for the entire growth (Nimje and Jagdishseth, 1988). Among organic manures, least tiller production was observed in vermicompost treated plots. Vermicompost is a composted material and the nutrients available in it might be easily made available to plants. Since ginger is a crop which remains in the field for quite long period, the effect of vermicompost was not that much effective as other type of organic manures and this might have resulted in lesser growth characters during the later stages of growth.

The significant effect of microbial inoculants on tiller production was observed on all stages except 60 DAP of second year. The tiller production was generally higher in AMF + *Trichoderma* combination than their individual application except at 60 DAP of first year. Nath and Korla (2000) observed better tiller and leaf production per plant over normal dose of NPK and control in ginger due to the effect of biofertilizers. The application of AMF + *Trichoderma* might have mobilized more available nutrients than their individual application resulting in more tiller production.

The interaction between organic manures and microbial inoculants was significant at most of the stages except at 60 DAP in second year. The combination enhanced the production of tillers with higher tiller production for treatments like o_1b_1 and o_3b_3 on both years of study.

Treatments differed significantly from the control at all stages of growth. This result is in conformity with the results obtained by Sharma and Mitra (1990) in rice. However Subbiah *et al*. (1983) was of the view that incorporation of organic residues did not influence the tiller production per square metre in rice. The tiller production for C_2, absolute control was the least. Since no manures or fertilizers were applied to C_2, the tiller production was limited on both years. The tiller production of C_1, *ie.*, the treatments where package of practices recommendation of Kerala

Agricultural University was carried out produced higher tiller production compared to all Ob_0 combinations during the first year of experimentation. This indicates that application of organic manure alone (Ob_0 combination) was significantly inferior compared to the package of practices recommendation of Kerala Agricultural University for the production of tillers. Hence the tiller production of all the treatment combination except Ob_0 combination compared to C_1 might be due to the combined effect of organic manures and microbial inoculants in increasing the tiller production. On the second year of experimentation, the number of tillers produced by package of practices recommendation of Kerala Agricultural University treated plants were far lower than all the organic and microbial inoculant combinations. The higher number of tiller production witnessed during the second year, in organic microbial inoculant treatments might be due to the residual effect of these treatments. The residual effect of organic manures was described by many researchers (Gaur, 1982; Kadam, 2000; Sharu, 2000; Patidar and Mali, 2002).

5.1.1.3 Number of leaves

The main effects of organic manures on the number of leaves were significant at all the growth stages of first year of experimentation and during the later stages of second year of experimentation (180 and 240 DAP) (Table 6). Among organic manures, application of FYM produced significantly higher number of leaves at all stages of growth. A similar effect was reported by Sahota (1993) in potato and Arunkumar (2000) in amaranthus. The higher number of tillers under FYM treatment might have resulted in higher number of leaves. The increased supply of nutrients, higher microbial population and improved soil structure might have favoured the production of more tillers.

The application of different microbial inoculants also influenced the number of leaf production. Higher number of leaves were observed from the treatment where AMF + *Trichoderma* were applied. Govindan and Nair (1985) observed higher number of leaves in cocoa due to *Azospirillum* inoculation. Thomas and Ghai (1988) observed higher number of leaves on inoculation with different AMF in pepper. Similar reports were reported by Sivaprasad *et al*. (1992), Anandaraj and Sarma (1994) and Ashithraj (2001) in pepper, Sreeramulu and Bagyaraj (1999) in cardamom and Sivaprasad (1993) in ginger. Arbuscular mycorrhizal fungi are known to form mutualistic symbiotic association with many crop plants of economic importance and help in better crop growth through increased uptake of diffusion limited nutrients particularly P and have synergistic effect on other beneficial microoganism (Ikram, 1990). The effect of *Trichoderma* on growth enhancement was reported by Joseph (1997). Hence the higher production of tiller under AMF + *Trichoderma* treatment might have resulted in higher leaf production.

The combination of organic manures and microbial inoculants also influenced the leaf production. Unlike other combinations of AMF, FYM+AMF as well as FYM + neemcake + AMF + *Trichoderma* resulted in higher production of leaves. Higher leaf production corresponded to he higher tiller production during these stages. The leaf production was the least for FYM + vermicompost + no microbial inoculants treatments on both the years of study. The corresponding tiller production for the treatment at all growth stages was also the least leading to lower leaf production.

The number of leaves produced by the treatments varied significantly from the controls at all stages of growth on both the years. The leaves produced by plants that followed package of practices recommendation of Kerala Agricultural University (C_1) as well as absolute control (C_2) differed significantly from the treatments. The application of organic manures as well as microbial inoculants produced more tillers which resulted in more number of leaves than the application of inorganic fertilizers along with FYM as well as with absolute control. The lowest leaf production was thus observed from absolute control (C_2) where the number of tiller production was also the lowest. In absolute control, the plant growth was solely dependent on the nutrients present in the soil and no external nutrients were applied hence the limited supply of nutrient might have led to lower tiller production resulting in lower leaf production on both years.

5.1.2 Correlation of growth character in relation to green ginger and dry ginger yield

5.1.2.1 Height of the plant

In the present investigation, important biometrical characters of ginger were correlated with yield. The correlation studies had shown significant positive association between plant height and green ginger and dry ginger yield on both the years (Table 7 and Table 8). The number of tiller production as well as leaf production were also related with plant height. Significant correlation was noticed between plant height and tiller as well as leaf production on both years of study. Genetic variability and heritability for fourteen characters were studied by Mohanty and Sarma (1979) in 28 cultivars of ginger. Significant positive genotypic and phenotypic correlation with the number of leaves, plant height and leaf breadth with rhizome yield were observed by them. In ginger, path coefficient analysis revealed that the phenotypic correlation between yield of rhizomes and height of pseudostem was quite high and so also the direct effect of height towards the correlation (Ratnambal, 1979). It was also found that the length of leaves had a high positive correlation between plant height and final yield. Multiple regression analysis in ginger was studied (Ratnambal *et al.,* 1980). The phenotypic correlation between yield and height was quite high as revealed form the study.

In this study also, among different organic manures involved, application of FYM (O_1) resulted in higher plant height and higher yield on both years of study. The application of AMF + *Trichoderma* (B_3) also produced longer plants resulting in higher plant yield on both years among microbial inoculants. Among organic manure microbial inoculant interaction the treatment combination FYM + AMF produced longest plants during the first year of study (Table 4) resulting in highest yield. The treatment o_3b_3 produced longest plants leading to higher rhizome yield during the second year. Thus from the above investigation it can be concluded that plant height in ginger is an important morphological character using which selection for yield could be made.

5.1.2.2 Number of tillers

The correlation of number of tillers of ginger with green and dry ginger yield were studied for two years (Table 7 and Table 8). It has been found that the number of tillers were related to green ginger and dry ginger yield as well as plant height and number of leaves. In turmeric an analysis of intercorrelation among the morphological characters and yield revealed that number of tillers, plant height and number of fingers had significant correlation with yield (Nair *et al.,* 1980). The important morphological characters of thirty ginger cultivars had been correlated with yield (Sreekumar *et al*., 1980). The correlation studies had shown significant positive association between plant height vs rhizome weight, tiller number vs rhizome weight. The intercorrelation result of the present study thus reveals that higher number of tiller production is an indication of higher rhizome yield. Ginger plant which produced higher number of tillers (Table 5) resulted in higher rhizome yield (Table 25).

5.1.2.3 Number of leaves

The intercorrelation of number of leaf production with green ginger, dry ginger, plant height and number of tillers showed significant positive correlation on both years of study (Table 7 and Table 8). Mohanty and Sarma (1979) studied genetic variability and heritability of fourteen character in 28 cultivars of ginger. The study indicated positive genotypic and phenotypic correlations with the number of leaves and rhizome yield. Qualitative and quantitative attributes of ginger cultivars were also studied

(Sreekumar *et al.,* 1980). The results of correlation studies had shown positive correlation between leaf number vs rhizome yield.

The two year experiment revealed significantly positive correlation of number of leaves with rhizome yield. Thus higher leaf production is an indication of higher rhizome yield. The more number of leaves produced might have resulted in more production of photosynthates resulting in higher yield. The highest rhizome yield under o_1b_1 for first year and o_3b_3 for second year corresponds to the highest leaf production under these treatments for the corresponding years. Thus number of leaves is also an important growth character for the selection of better cultivar of ginger producing higher yield.

5.1.3 Effect of organic manures, microbial inoculants and their interaction on root characters

5.1.3.1 Root length

The application of different organic manures did not influence the root length at most of the stages (Table 9). This shows that different organic manures have similar effect on root length. However significant difference in root length was noticed in 60 and 180 DAP at first year and 240 DAP at second year. The higher root length at these significant stages were observed from FYM treated plants. A similar observation was made by Singh *et al*. (2000) in rice-wheat system. According to Tandon (1994) FYM serves as a buffer against fluctuations in moisture availability and promoted better root growth. Thus the better soil conditions provided by FYM might have resulted in more root length.

Unlike organic manures, application of microbial inoculants influenced the root length at all stages of growth on both the year of experimentation. The application of AMF and *Trichoderma* together have resulted in higher root length followed by the AMF application. The application of 50 kg P_2O_5 per hectare alone and along with VAM augmented the root length by 47.8 per cent and 50.7 per cent respectively over the control (Nair and Gupta, 1999). According to Kumar *et al.* (1993) combination of AMF and *Trichoderma* resulted in higher root length in wheat, AMF establish beneficial association with roots of the growing crops. VAM increases root absorbing surface and reaches outside the root depletion zones and helps in the uptake of nutrients like phosphorus and zinc and increases the growth of associated plants by producing auxin. The possible reason that could be ascribed for better root growth was due to the role of P in cell division, energy production and construction of various cellular components. Moreover, P ions help in active transport of nutrients by over riding the opposing forces of osmotic equilibrium (Wallingford, 1991).

The organic manure microbial inoculant interaction also significantly influenced the root length. Among the combination, o_1b_1 produced significantly longer roots. At 180 and 240 DAP of first year and at all growth stages of second year of study o_3b_3 resulted in longer roots. AMF in combination with all organic manures as well as *Trichoderma* produced significantly longer roots. It has been reported that anatomical and morphological changes occur in the root system such as increased lignification, of root cells and the microbial changes in the mycorrhizosphere (Sivaprasad, 2002) as a result of AMF application. These might have resulted in longer roots due to AMF application. Apart from that, the application of organic manures as well as *Trichoderma* might have a synergistic effect to the activity of AMF which might have resulted in longer root length.

The root length of the treatments varied significantly from the control throughout on both the years of experimentation. However individual comparison of the control shows that the effect was more evident only during the second year of experimentation when C_1 was compared with treatments as a whole. Among the controls, the root length produced by C_1 was far longer than C_2 and was significantly different. The availability of nutrients from fertilizers as well as FYM might have resulted in longer roots in C_1 compared to C_2.

5.1.3.2 Root spread

The main effect of organic manures on root spread was significant only in 120 DAP and 240 DAP of first year and 120 and 180 DAP of second year of experimentation (Table 10). At 120 and 240 DAP of first year and 120 and 180 DAP of second year of experimentation, FYM treated plants produced more root spread. Issac (1995) reported highest root spread in bhindi due to application of FYM along with inorganic fertilizers. According to Rakhee (2002) root spread in turmeric was significant only at 6 MAP and it was highest for coirpith compost which was on par with vermicompost treatment.

The effect of microbial inoculants on root spread was significant at all stages of growth on both the years. Higher root spread in AMF + *Trichoderma* as well as AMF alone might be due to the favourable factors which resulted due to the application of AMF and *Trichoderma*.

The organic manure microbial inoculants also produced significant difference in root spread at all stages except at 240 DAP of second year of experimentation. Among the combinations, FYM + AMF and FYM + neem cake + AMF + *Trichoderma* recorded higher root spread on first and second year of study respectively. The conditions available under o_1b_1 and o_3b_3 might have contributed to the favourable spread of the root under these treatments.

The treatments when compared with the controls also showed significant variation. All the organic manure microbial inoculant combinations resulted in higher root spread than the control C_1 and C_2. However, the application of organic manures alone (o_1b_0, o_2b_0. o_3b_0 and o_4b_0) generally showed lower root spread or more or less comparable with C_1 during the first year. During the second year of experimentation, all the treatments resulted in more root spread than C_1 and C_2. The microbial inoculants might have provided a better physical environment for the root spread during both the years.

5.1.3.3 Root weight

Root weight varied significantly due to application of different organic manures at 120 and 240 DAP of both the years (Table 11). Not much variation in the root weight was observed during these stages also. Various organic manures thus could not make any significantly large difference in the root weights.

The effect of microbial inoculants on root weight was significant at all stages except at 180 DAP of first year. AMF and *Trichoderma* when applied together resulted in higher root weight. The effect of microbial inoculants on root weight was thus clear from the comparison with B_0 values. The higher root weight in maize plants was observed due to AMF inoculation (Kothari *et al.*, 1990). In black pepper *Trichoderma* application increased root weight (Anith and Manomohandas, 2001). The higher root production due to AMF and *Trichoderma* might be due to the small quantities of hormones including auxins produced by AMF and *Trichoderma*. Higher root spread resulted in these combination also might have contributed to the higher root weight.

The interaction O x B were significant at all stages except at 60 DAP of second year and 180 DAP of first year. Among the combinations, o_1b_1 and o_3b_3 resulted in significantly higher root weights and were almost stable throughout the growth stages on both the years of experimentation. The applications of organic manures and microbial inoculants, AMF and *Trichoderma* together might have resulted in higher root production due to involvement of AMF.

Significant difference in the root dry weight was noticed when the treatments and controls were compared. The controls C_1 and C_2 when compared individually with the treatments, varied significantly except at 180 DAP of first year of experimentation when C_1 was compared with the treatments. The interactions involving AMF and *Trichoderma* produced significantly higher weight compared to controls C_1 and unfertilized C_2. This could be attributed to better physical environment offering least mechanical resistance for elongation, increasing root absorbing surface due to AMF and higher nutrient status resulting in better root proliferation and finally leading to higher root dry weight. This is supported by the finding of Gajri *et al*. (1997) and Singh *et al*. (2000).

5.1.3.4 Root volume

The application of different organic sources influenced the root volume as revealed from the Table 12 at all stages except at 120 DAP of first year. Among organic manures O_1 produced higher root volume. This might be due to the better physical environment provided by FYM application which resulted in higher root length, root spread and root weight leading to better root volume. Rakhee (2002) observed better root volume in turmeric due to FYM and coirpith compost application.

Microbial inoculants significantly influenced the root volume at all stages of growth on both the years. Significant increase in root volume due to combination of AMF and *Trichoderma* as well as AMF alone was observed throughout the experiment. Increase in root production due to AMF was reported by Barea and Azcon (1982); Nair and Gupta (1999) and Ashithraj (2001). The beneficial effect of AMF in increasing root-absorbing surface leading to improved uptake of elements like P, Zn and Cu as well as production of plant hormones might have resulted in higher root production leading to higher root volume.

The interaction effects also showed significant variation in root volume at all growth stages on both the year of experimentation. The favourable condition due to organic manure microbial interaction especially the use of AMF might have resulted in the more root mass leading to more root volume. The application of AMF increased the root absorbing surface and reach outside the root depletion zone. The production of auxins due to

AMF application and the increased uptake of nutrients like P and Zn, which is required for the development of roots might also have contributed to the production of more roots resulting in increased root volume.

The variation in root volume was significant at most of the stages of growth when the treatments and controls were compared. The results indicated non-significance at 60 and 180 DAP of first year when treatments were compared with C_1. At harvest, the root volume of treatment was significantly different from the controls C_1 and C_2. This might be due to the higher roots produced by the treatments which is indicated by higher roots weights of the treatments on both years. However with C_2, significance was noted on all stages of growth. The variation in root volume was evident between the controls also. The effect of organic manure microbial inoculation on root volume was more pronounced due to the influence of AMF, as evident from the results.

5.1.4 Correlation of root characters in relation to green ginger and dry ginger yield

5.1.4.1 Root length

The root length showed a significant positive correlation with green and dry ginger yield on both years of study. A significant positive correlation was also noticed between root length vs root spread, root length vs root weight and root length vs root volume on two years of experimentation (Table 13 and Table 14). The application of organic manures and microbial inoculants might have provided better soil physical environment for better root length, root spread, root weight and root volume resulting in higher uptake of the available nutrients and water leading to more rhizome yield.

5.1.4.2 Root spread

Root spread showed a significant positive correlation with green ginger and dry ginger on both years of experimentation. Root length, root weight and root volume also show a significant positive correlation with root spread on two years of study (Table 13 and Table 14).

Increased root spread may be due to the better soil characteristics provided by the organic manures and microbial inoculants. The better soil characters as well as better nutrient availability due to root colonization by AMF might also have helped in more root spread for treatment involving AMF.

5.1.4.3 Root weight

Root weight of two years of experimentation was intercorrelated with green ginger, dry ginger, root length, root spread and root volume (Table 13 and Table 14) and a significant positive correlation was noticed on both years of study.

The higher root length and root spread might have resulted in higher root volume and root dry weight and hence positive correlation. The correlation results also reveals that root weight is thus an indication of higher rhizome yield.

5.1.4.4 Root volume

Root volume also showed a significant positive correlation with green ginger, dry ginger, root length, root spread and root weight for two years of experimentation and the correlation coefficients are expressed (Table 13 and Table 14).

In the treatment combination higher root volume was seen associated with higher green ginger, dry ginger, root length, root spread and root weight. This might be because when root length was increased, root volume was also increased. Similarly the increase in root spread as well as root weight also resulted in increase in the root volume. Hence the root volume showed positive correlation with root length, root spread and root weight.

5.1.5 Effect of organic manures, microbial inoculants and their interaction on physiological characters

5.1.5.1 Dry matter production

The dry matter production varied significantly due to the application of different organic manures at almost all stages except at 240 DAP of second year of experimentation (Table 15). At all these stages, the DMP

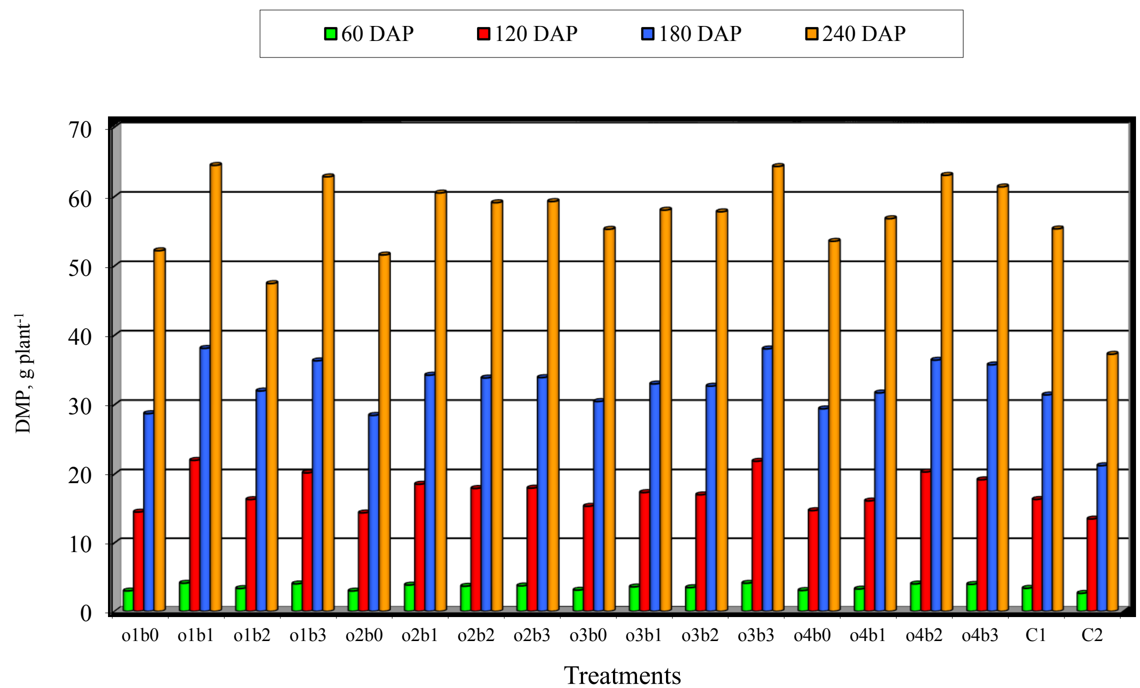


Fig. 3. Dry matter production of ginger as influenced by organic manure, microbial inoculant interaction on 00-01

was the highest under FYM treatment. The positive influence of FYM on plant height, tillers, leaves, root mass as well as rhizomes have resulted in the high dry matter production. This is an indication of the favourable effect of FYM on growth and yield of ginger. Similar results indicating the favourable effect of FYM on increasing DMP on bhindi (Senthil kumar and Sekar, 1998) and turmeric (Rakhee, 2002) were reported.

The different microbial inoculants significantly influenced the dry matter production at all stages of growth on both the years of experimentation. The effect on DMP was more pronounced by the application of AMF + *Trichoderma*. According to Kandiannan (1998) the biofertilizer inoculation enhanced the dry matter production and leaf nutrient content of black pepper. The combined application of three biofertilizers *viz.,* Azospirillum, phosphobacteria and AMF recorded maximum drymatter production at 18 months after planting compared to control (Kandiannan, 1998). Similarly the higher DMP due to AMF and *Trichoderma* was due to the higher tiller, leaf, root mass as well as rhizome production at these stages.

The interaction between organic manure and microbial inoculants also resulted in significant difference in dry matter production at all growth stages on both the years of experimentation. Among the combinations, higher DMP was recorded from o_1b_1 during the first year and from o_3b_3 during the second year of experimentation. However both the treatments were on par on both the years. The higher rhizome weight (Table 25) as well as shoot weight (Table 27) have resulted in higher DMP at these stages.

The dry matter production of treatments varied significantly from the controls. The variation was evident when the controls, C_1 and C_2 were also compared. There are reports that addition of organic matter enhanced the growth and biomass of the pepper vines (Sivakumar and Wahid, 1994). The beneficial effect of organic amendments in increasing the growth parameters were also reported by Pushpa (1996) in tomato and Anitha

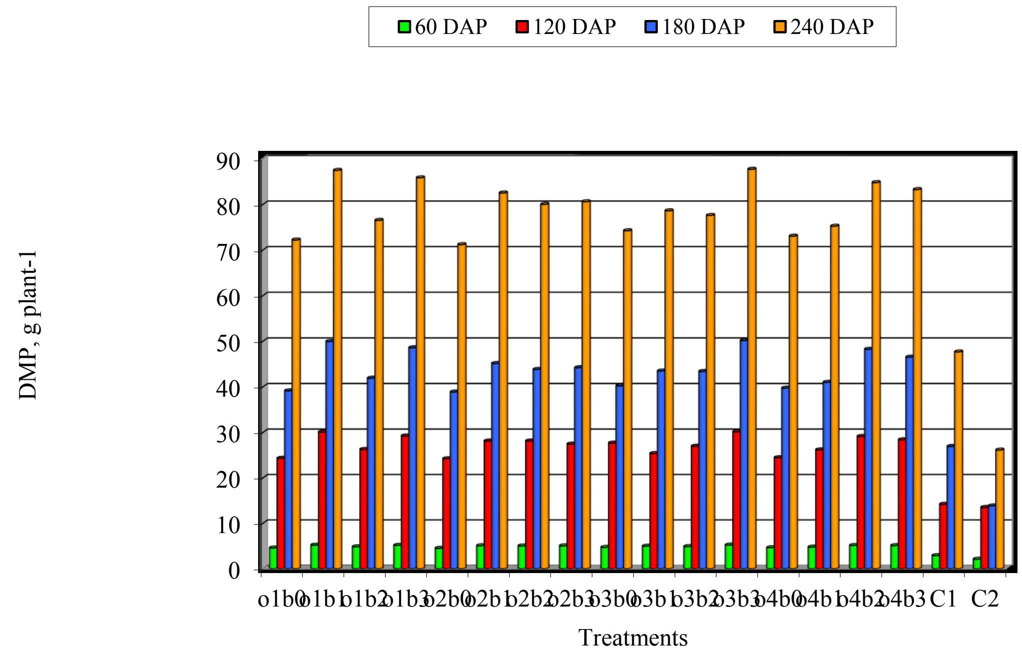


Fig. 4. Dry matter production of ginger as influenced by organic manure microbial interaction on 01-02

(1997) in chilli. Evans (1975) explained that roots and tubers continue cell division and growth during storage. The photosynthesis prior to storage phase determines storage capacity and generates reserves that may be mobilized during the storage phase. The demand for assimilates for storage in turn has a pronounced stimulant effect on the rate of photosynthesis. Similarly in this study a balance was maintained between these two inter related processes in plants supplied with organic manure microbial inoculant combination compared to controls, which resulted in higher DMP of the treatments.

The results of pooled mean of DMP at 240 DAP reveals significant difference for the main effect of treatments involving microbial inoculants. However no variation in DMP was noticed when organic manures as well as organic manure microbial inoculant interactions of first year was compared with the second year. In general, the DMP of the treatments at first year was significantly different from the second year. Higher DMP at the second year of experimentation may be due to the residual effect of organic manures and microbial inoculants of the first year resulting in more availability of nutrients for the second year of experimentation.

5.1.5.2 Crop growth rate

The effect of organic manures on crop growth rate was significant only during 60-120 DAP of first and second year as well as on 120-180 DAP of second year (Table 16). Non-significant CGR at final harvest of both the years indicate that different organic manures produced similar effects on crop growth rate.

The microbial inoculants significantly influenced the crop growth rate at all the stages of growth on both the years. The application of AMF and *Trichoderma* together resulted in higher CGR. The beneficial effect of biofertilizers on physiological characters of amaranthus was described by Niranjana (1998). Higher dry matter accumulation due to higher LAI resulted in higher CGR in amaranthus.

The interaction between organic manures and microbial inoculants was significant at most of the stages except at 120-180 DAP of first year. In general for both years of study, among the interactions maximum crop growth rate was observed in o_1b_3 and o_3b_3 combinations. This may be due to the more uptake of nutrients for crop nourishment, which resulted in more LAI (Table 19) and DMP (Table 15) and finally higher CGR. Thus with FYM, AMF alone was significant for better crop growth rate while with neemcake, FYM + AMF + *Trichoderma* contributed to better crop growth rate.

The crop growth rate observed in treatments was significantly different from the controls. The higher CGR among treatment compared to controls might be due to the enhanced supply of nutrients, better physical environment and better growth leading to higher LAI (Table 19), which resulted in greater rate of dry matter production per unit leaf area (NAR) (Table 17) as well as greater rate of dry matter production per unit ground area (CGR). While C_1 differed from the treatments at all stages except at 120-180 DAP, C_2 showed significant variation at all stages of growth on both the years. The LAI as well as DMP was the least under absolute control, which might be due to the poor nutrient availability under these conditions, which led to lower rate of dry matter production per unit ground area (CGR).

The pooled data reveals difference between the CGR of first and second year. But the CGR shown by the influence of organic manures, microbial inoculants as well as their interaction during the first year did not vary significantly from the second year which reveals that the application of organic manure, microbial inoculants and their interaction could not make a significant difference in the crop growth rate between the two years.

5.1.5.3 Net assimilation rate

The net assimilation rate varied significantly due to the different organic manure treatment only during 60-120 DAP of first and second year and 120-180 DAP of second year (Table 17). At final harvest, the net assimilation rate was not influenced by the different organic manures on both the years. All the different organic manures applied showed similar effect.

The effects of microbial inoculants on net assimilation rate produced significant difference at almost all stages of growth except at 180-240 DAP of both the years. The significant effect of biofertilizers on NAR of peas was reported by Vimala and Natarajan (2002).

The interaction effect of organic manure and microbial inoculants varied significantly at almost all stages except during the final phase (180-240 DAP) of both the years. Among the combinations, o_1b_1 and o_3b_3 resulted in significantly higher NAR and were on par at the significant stages on both the years. A decrease in NAR towards final phase compared to the initial stage of growth was noted. This trend is in accordance with the postulation of Watson (1958) that as leaf area ratio falls with advancing age the rate of respiration per unit leaf area tends to increase and hence NAR decreases, independently of any change in the rate of photosynthesis or respiration per unit dry weight.

The treatments when compared with the controls showed significant variation at all stages of growth on both the years. This might be due to the beneficial effect of organic microbial inoculant interaction, which resulted in higher rate of dry matter production per unit photosynthesizing area. Individual comparison of C_1 with the treatments indicated significantly different values of NAR at all stages of growth during the second year and at final stage (180-240 DAP) of first year of experimentation. The NAR of controls C_1 as well as C_2 varied significantly. The lower uptake of nutrients might have resulted in significantly lower rate of dry matter production per unit photosynthesizing area.

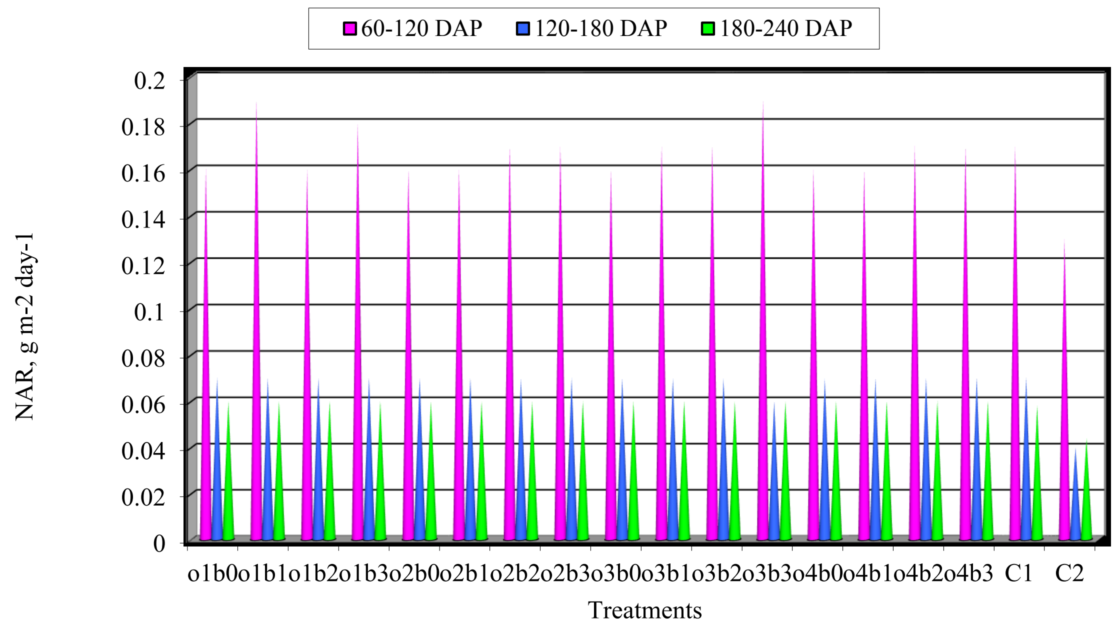


Fig. 5. Net assimilation rate as influenced by organic manure microbial interaction on 00-01

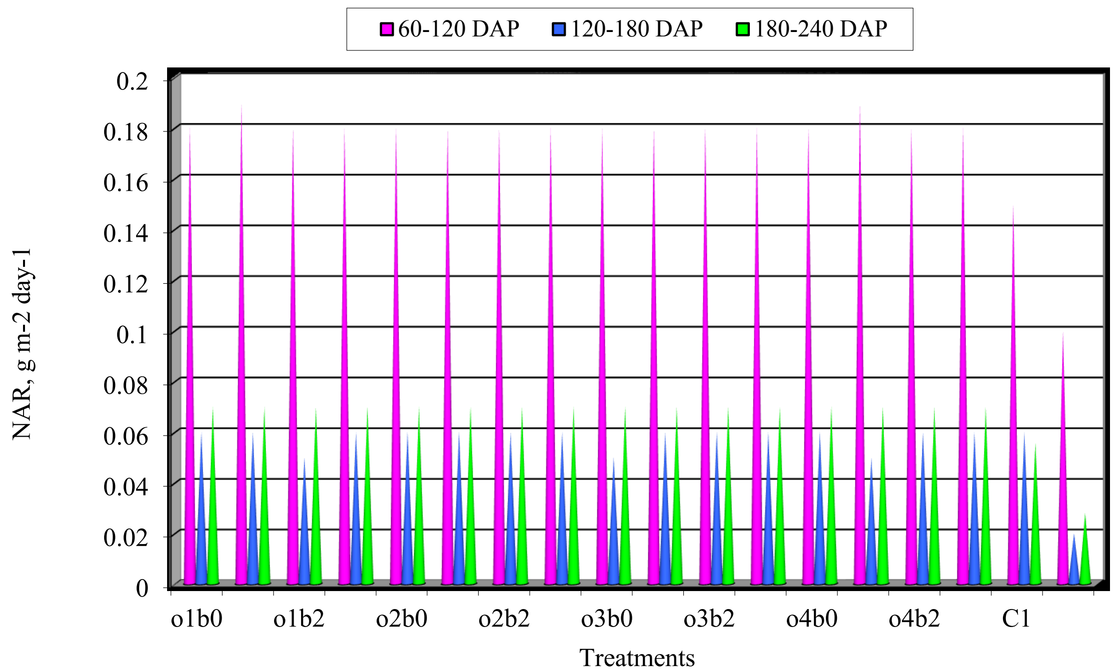


Fig. 6. Net assimilation rate as influenced by organic manure microbial interaction on 01-02

The pooled analysis revealed that in general the NAR of first year was significantly different from the NAR of second year but the NAR due to the main effects of organic manure, microbial inoculants and their interaction of first year was not different from the second year which indicates that the dry matter production per unit photosynthesizing area of the treatment during the first year was not significantly different from the corresponding treatment of second year.

5.1.5.4 Relative growth rate

The main effect of various organic manures showed significant difference only during the initial phase of both the years (Table 18). The effect was insignificant for the remaining phases. Suja (2001) reported same relative growth rate value for all organic manure treatments in white yam intercropped in coconut garden.

The variation in relative growth rate due to microbial inoculants was significant only at 60-120 DAP of second year and 180-240 DAP of first year. This indicates that microbial inoculants could influence the relative growth rate only at the final stages of harvest at the first year of experimentation. At the second year of experimentation, the rate of dry matter accumulation per unit plant material (relative growth rate) was influenced by microbial inoculants only at the initial stage (60-120 DAP).

The organic manure microbial interaction also did not influence the relative growth rate during most of the stages. The effect was significantly different only during the initial phase and 120-180 DAP of second year.

Similarly, the relative growth rate of treatments varied significantly from the control only during second year of experimentation for all stages except at 180-240 DAP of second year when C_1 was compared with the treatments. During first year, the application of various organic manure microbial inoculant treatment did not make any significant difference in relative growth rate compared to the plants treated as per package of practices recommendation of Kerala Agricultural University. For C_2

significance was observed in most of the stages of first year except at 120-180 DAP and 180-240 DAP and all stages of second year. The rate of dry matter accumulation per unit plant material due to organic manure, microbial inoculants and their interaction was the same for both the year of experimentation.

5.1.5.5 Leaf area index

The effect of organic manures on leaf area index was significant during the initial stages of growth (Table 19). At final harvest the leaf area index did not vary consistently between different organic manures.

The different microbial inoculants influenced the leaf area index at all stages of growth on both the years. Among the inoculants, the application of AMF and *Trichoderma* together resulted in significantly higher leaf area index. The influence of biofertilizers on leaf area index in peas was described by Vimala and Natarajan (2002).

The interaction between organic manures and microbial inoculants significantly affected the leaf area index. Among the combinations, significantly higher leaf area index were produced by o_1b_1 and o_3b_3 on both the years. The enhanced leaf production and higher photosynthetic leaf area produced under these treatments have resulted in the higher leaf area index. The superiority of FYM in enhancing leaf area index in amaranthus was reported by Arunkumar (2000).

The treatments differed significantly from the controls during all the periods on both the years. The controls, C_1 as well as C_2 varied significantly from the treatments. Longer leaf size coupled with more number of functional leaves retained per plant with treatments could have resulted in higher leaf area index.

The leaf area index as a result of the application of organic manures and microbial interaction during first year and second year of study did not differ significantly. However the leaf area index due to application of microbial inoculants alone varied significantly between the years. The leaf area index was higher during the second year of experimentation. Apparently higher production of leaves as well as increased leaf area on the second year of experimentation might have resulted in the higher leaf area index.

5.1.5.6 Leaf area duration

Leaf area duration was significantly influenced by the application of different organic manures (Table 20). Significantly higher leaf area duration was observed from FYM treatments. Rakhee (2002) also reported increased leaf area duration under FYM treatments. Higher leaf area duration might be due to the higher LAI as well as the longer retention of the leaves area over the period.

The effect of different microbial inoculants on leaf area duration was also significantly different at all stages of growth during both the years. The application of *Trichoderma* and AMF together resulted in significantly higher leaf area duration. The influence of microbial inoculants on leaf area duration was evident as the leaf area duration value of B_0 treatments (without microbial inoculants) was very low.

The interaction effects on leaf area duration were also significant at all stages of growth on both the years. Among the treatments o_1b_1 and o_3b_3 recorded significantly higher leaf area duration and was on par at all phases of growth on both the years. The higher leaf area duration at these stages might be due to the higher nutrient uptake by these treatments, which have resulted in more number of leaf production as well as increased retention of leaves leading to increased leaf area for photosynthesis and thus higher leaf area duration. The application of organic manures as well as microbial inoculants together was more effective than the individual application of organic manures (o_1b_0, 0_2b_0, o_3b_0 and o_4b_0).

The leaf area duration of treatments differed significantly from the controls. The control C_1 as well as C_2 showed significant variation from the treatments at all the phases of growth on both the years. The leaf area duration of C_2 was the least. Thus might be due to the least leaf area index due to lower intake of nutrients. The early degradation of photosynthetic leaf area might also have contributed to the lower leaf area duration.

The pooled mean revealed significant variation between the leaf area duration of first and second year of experimentation for different microbial treatments. The application of different organic manures however did not produce any variation in leaf area duration between the years. This might be because the application of different organic manures did not produce any variation in leaf area index, but the microbial inoculants showed significantly different leaf area index.

5.1.5.7 Harvest index

The application of different organic manures did not produce any significant difference in harvest index (Table 21). This shows that the efficiency of translocation of assimilates to economic part was almost similar under different organic manures.

The application of microbial inoculants resulted in significantly different harvest index at all stages during the first year of experimentation and only at 120 DAP of second year. The effect of AMF and *Trichoderma* in the translocation of assimilates to the rhizomes was higher than without their application (B_0). This might have resulted in significantly different harvest index. At final harvest, on the second year the harvest index was not significant showing that the effect was similar at these stages.

The organic manure microbial inoculant interaction did not influence the harvest index at later stages. The effect was significant only at 120 DAP of both the years. The results reveal that the translocation of assimilates to the rhizome was the same under different interactions.

The harvest index of treatments varied significantly from the controls C_1 and C_2 at 120 DAP of first year. However the variation in harvest index of C_1 was significantly different from the treatment at initial period of both the years (120 DAP). But C_2 (absolute control) varied from the treatments at initial 120 DAP as well as at harvest stage (240 DAP) on both the years. The assimilate transfer for the treatments was superior compared to the absolute control where the rhizome yield was also low. Maheswarappa *et al*. (2000) reported that in galangal intercropped in coconut garden, among organic manures, FYM + NPK, FYM and vermicompost had significantly higher HI compared to composted coirpith and NPK alone. Higher harvest index was mainly attributed to better translocation of dry matter into rhizomes as reflected in higher rhizome dry weight.

The pooled mean of harvest index at 240 DAP indicated no significant difference between the years due to organic manures, microbial inoculants and their interaction.

5.1.5.8 Root shoot ratio

Application of different organic manures did not influence root shoot ratio at most of the stages on both the years (Table 22). The significance was observed only at 180 DAP of first year. This was an indication that the different organic manures applied could not produce proportionate variation in root shoot dry weight.

The application of different microbial inoculants produced significant variation in root shoot ratio. VAM influence the partitioning of phytomass between shoot and root (Smith, 1980). Lower root shoot ratios with VAM colonization have been reported by Puccini *et al*. (1988) and by Berta *et al*. (1990). According to them relatively less of the photosynthates are allocated to the roots and hence the root shoot ratio is usually lower in VAM plants.

Significant variation in root shoot ratio was reported in organic manure microbial inoculant interaction at final harvest and 120 DAP of first year and 180 DAP of second year. As growth advanced the root shoot ratio decreased. This might be because of the less allocation of photosynthates to the root at later stages of growth, where most of the assimilates might have been translocated to add to economic part.

The root shoot ratio of treatments varied significantly from the controls, C_1 and C_2 at 180 and 240 DAP of both years. C_1 varied significantly from the treatments at almost all stages except at 120 DAP of first year. This result explains the beneficial effect of treatments over plants treated with package of practices recommendation of Kerala Agricultural University as well as absolute control in increasing root shoot ratio. While the application of organic manures produced similar effects on root shoot ratio, the microbial inoculants made a significant effect on root shoot ratio. This might be mainly due to the influence of AMF. AMF increases the root absorbing surface by producing external mycelium, which extended over the root and increased root branching. This might have resulted in the more root dry weights resulting in different root shoot ratio as a result of microbial inoculant application.

5.1.6 Correlation of physiological character in relation to green ginger and dry ginger yield

5.1.6.1 Dry matter production

The intercorrelation results indicated a significant positive correlation between dry matter production and green ginger yield, dry ginger yield, CGR, NAR, LAI, LAD and HI on both years (Table 23 and Table 24). The results also indicated a significant negative correlation between DMP and RGR on both years and DMP and root shoot ratio on first year. The dry matter production is contributed by shoot and rhizome weight. The increased vegetative growth resulted in significantly higher yield. The CGR, NAR, LAI, LAD and HI were superior for treatments which produced higher DMP and yield. Hence a significant positive correlation was noticed.

5.1.6.2 Crop growth rate

The crop growth rate showed a significant positive correlation with green ginger yield, dry ginger yield, DMP, NAR, LAI, LAD, and HI on both years (Table 23 and Table 24). The crop growth rate was higher for treatments with higher green ginger yield, dry ginger yield, DMP, NAR, LAI, LAD and HI and hence positive correlation. The relative growth rate remained almost constant for treatments producing higher as well as lower crop growth. Hence a negative correlation was noticed with CGR and RGR.

5.1.6.3 Net assimilation rate

Net assimilation rate showed a significant positive correlation with green ginger yield, dry ginger yield, dry matter production, CGR, LAD and HI during the first year (Table 23 and Table 24). This shows that more the net assimilation rate more will be the DMP, CGR, LAD, HI leading to higher yield. During the second year a significant positive correlation was noticed between net assimilation rate and green ginger yield, dry ginger yield, dry matter production, crop growth rate, leaf area index, harvest index and root shoot ratio.

5.1.6.4 Relative growth rate

The intercorrelation results revealed a significant negative correlation when relative growth rate correlated with green ginger yield, dry ginger yield, DMP, CGR, LAD and HI during the first and second year (Table 23 and Table 24). During the second year a significant negative correlation existed between RGR and LAI and RS ratio. The results indicate that lower the relative growth rate, higher will be the DMP, CGR, LAD, HI and green and dry ginger yield.

5.1.6.5 Leaf area index

Leaf area index produced a significant positive correlation with green ginger yield, dry ginger yield, dry matter production, crop growth rate, net assimilation rate and harvest index on two years (Table 23 and Table 24). When the leaf area index increased, the DMP, CGR, NAR as well as HI was found to increase resulting in increasing green and dry ginger yield.

5.1.6.6 Leaf area duration

The leaf area duration showed a significant positive correlation when correlated with green ginger yield, dry ginger yield, DMP, CGR, LAD, LAI and HI on both years (Table 23 and Table 24) which indicate that direct correlation exists between LAD and these characters. However a significant negative correlation was also noticed between LAD and RGR in both years.

5.1.6.7 Harvest index

The harvest index showed a significant positive correlation with green ginger, dry ginger yield, dry matter production, crop growth rate, NAR, LAI and LAD on both years (Table 23 and Table 24). The increased vegetative growth resulted in higher yield and higher harvest index. Higher the HI, more will be the CGR, NAR, LAI and LAD and hence significant positive correlation.

5.1.6.8 Root shoot ratio

Root shoot ratio represented a significant negative correlation with green ginger yield, dry ginger yield, DMP, CGR and LAD during the first year (Table 23). However the RS ratio was non significant between NAR, RGR, LAI and HI at the first year of study. During the second year a significant positive correlation was observed between RS ratio and green ginger, dry ginger yield, DMP, CGR, LAI, LAD and HI (Table 24). Between RS ratio and RGR a significant negative correlation was noticed.

5.1.7 Effect of organic manures, microbial inoculants and their interaction on yield and yield components

5.1.7.1 Green ginger yield

The different sources of organic manures influenced the green ginger yield at the early stages of rhizome production and at 180 DAP of second year (Table 25). However, the application of different organic manures did not show any variation in green ginger yield at final harvest on both the years. The result implies the similar effect of various organic manures on green ginger yield of ginger. According to Suja (2001) the application of different organic manures produced similar effects on white yam yield.

The significant effect of AMF and *Trichoderma* on green ginger yield was evident throughout the growth stages. Among inoculants, the combination of AMF and *Trichoderma* in the field resulted in significantly higher yield compared to their individual application. Joseph (1997) recorded maximum rhizome yield in ginger plants inoculated with *Trichoderma viride* and AMF. The AMF inoculation may increase the growth due to increased absorption of P, Zn and Cu (Swaminathan and Verma, 1979; Krishna and Bagyaraj, 1991). *Trichoderma* always plays an important role in the promotion of plant growth and yield (Sivaprasad, 2002) by producing plant hormones and enzymes. In the present study the application of AMF and *Trichoderma* together (B_3) increased the rhizome yield on both years of study which reveals the synergistic effect on yield.

The interaction of organic manures and microbial inoculants significantly influenced the green ginger yield at all stages of growth on both the years. Though organic manures exerted similar influence on green ginger yield at harvest, they interacted significantly with microbial inoculants and resulted in higher yields due to the favourable main effect of microbial inoculants. Treatments, o_1b_1 and o_3b_3 were on par on both the years at all stages of growth. At final harvest, on both the years, o_4b_2 was also on par with o_1b_1 and o_3b_3. Thus the organic manure treatments *viz.,* FYM + AMF, FYM + neemcake + AMF + *Trichoderma* as well as FYM + green leaves + *Trichoderma* was effective in contributing to yield. The higher yield under these treatment may be due to the higher uptake of N, P and K (Table 48) leading to production of more leaves (Table 6) resulting in the accumulation of more photosynthates and their further efficient translocation to the rhizome contributing to yield. Among organic manure microbial interaction, the rhizome yield was the lowest under o_2b_0 treatment for both years of study. The vermicompost is actually the decomposed products and the nutrients are readily available. The net loss of nutrient, N, P and K was the highest for o_2b_0 treatment on both years of experimentation as revealed from Table 51, Table 52, Table 53, Table 54 and Table 55. A net gain of K as revealed from Table 44 for the second year of experimentation was also the least for o_2b_0 combination. Thus when vermicompost was applied alone, (o_2b_0) without any microbial inoculants, the loss of nutrient was also high which might be due to the readily available nature of nutrients in vermicompost. Hence o_2b_0 treatment resulted in significantly lower yield compared to o_1b_0, o_3b_0 and o_4b_0 but the application of AMF along with vermicompost produced more yield. The increased root extension due to AMF might have resulted in harvesting more nutrient leading to higher yield. Application of FYM alone resulted in higher yield in yam (Mohankumar and Nair, 1979), amorphophallus (Patel and Mehta, 1987), turmeric (Bai and Augustin, 1998) and in arrowroot (Vidhyadharan, 2000). Application of neemcake at the rate of 1 t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990). Sadanandan and Hamza (1996) reported that application of organic cakes increased the yield in ginger. The nutrient management study for white yam revealed that application of FYM, coirpith compost and *in situ* green manuring using sunhemp produced similar effects in promoting weight, length and girth of tubers (Suja, 2001).

The green ginger yield of treatments varied significantly from the controls, C_2 at all stages of growth on both years. Generally higher yield was observed from the treatments compared to controls. The green ginger yield of C_1 differed from the treatment for all the growth stages of second year of experimentation. However during the first year of study at 180 and 240 DAP there was no significant difference between C_1 and treatments. Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure treatment was reported by Gaur *et al*. (1984). The organic manure microbial inoculant interaction had influenced various physical parameters of the soil and improved the nutrient availability to the plants. As a result of this, higher nutrient uptake resulted leading to better crop growth, greater leaf area, better translocation of nutrients and finally higher rhizome yield. Ginger is an exhausting crop and benefits greatly from the application of manures. The package of practices recommendation of Kerala Agricultural University recommends 30 t ha^{-1} of FYM or compost and 75:50:50 kg NPK ha-1. Aiyadurai (1966) reported N at 50-100 kg ha^{-1} had significantly increased the yield of ginger by 18-32 per cent. Nair (1969) recommended 60 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K for better yield of ginger under Kerala conditions. Nair and Verma (1970) reported that the highest yield of 43 t of green ginger ha was obtained with 100 kg N, 100 kg P_2O_5, 100 kg K_2O ha^{-1}. Studies conducted by Kerala Agricultural University, Vellanikkara revealed that NPK dose of 80:30:40 kg ha^{-1} was optimum. Recently it was found that the yield of ginger was more when 20 tonne of FYM and 125 kg N, 40 kg P_2O_5 and 80 kg K_2O were applied (Shanmugavelu *et al*., 2002). The application of 75:50:50 kg NPK ha^{-1} and FYM 30 t ha^{-1} (C_1) was not thus sufficient to maximize the yield as revealed from the experiment.

The pooled data reveals that the application of microbial inoculants as well as organic manure microbial inoculant interaction resulted in a significantly higher green ginger yield during the second year compared to the first year. However the green ginger yield of C_1 as well as C_2 was lower than the corresponding yield obtained during the first year. The residual effect of organic manures also might have contributed to the higher yield at second year under treatments. Organic manures and phosphatic fertilizers have carry over effect on the succeeding crops. According to Gaur (1982) about less than 30 per cent of nitrogen and small fraction of phosphorus and potash in organic manure may become available to immediate crop and rest to subsequent crops.

5.1.7.2 Dry ginger yield

The variation in dry ginger yield due to application of different organic manures was significant at all stages of growth on both the years. The variation was significantly higher for FYM treated plants (Table 26). The effect of FYM in increasing yield was reported in many crops like yam (Mohankumar and Nair, 1979) amorphophallus (Patel and Mehta, 1987), turmeric (Balashanmugham *et al*., 1989), Kacholam (Bai and Augustin, 1998), arrowroot (Vidhyadharan, 2000) and betel vine (Arulmozhiyam *et al*., 2002). FYM serves as a good source of almost all plant nutrients. The physical conditions brought about by their addition, higher microbial population and dehydrogenase activity may have influenced the nutrient uptake, chlorophyll synthesis, plant growth and finally yield (Maheswarappa *et al*., 2000).

Neemcake application along with FYM also improved the yield. The influence of neemcake on yield of ginger was reported. Application of neemcake @ 1 tonne per ha before planting gave maximum yield in ginger (KAU, 1990). However the vermicompost treatment resulted in lower yield. Among organic manure combination the uptake of (59.57 kg ha^{-1}, 82.84 kg ha^{-1} for first and second year) P (9.28 kg ha^{-1}, 14.99 kg ha^{-1} for first

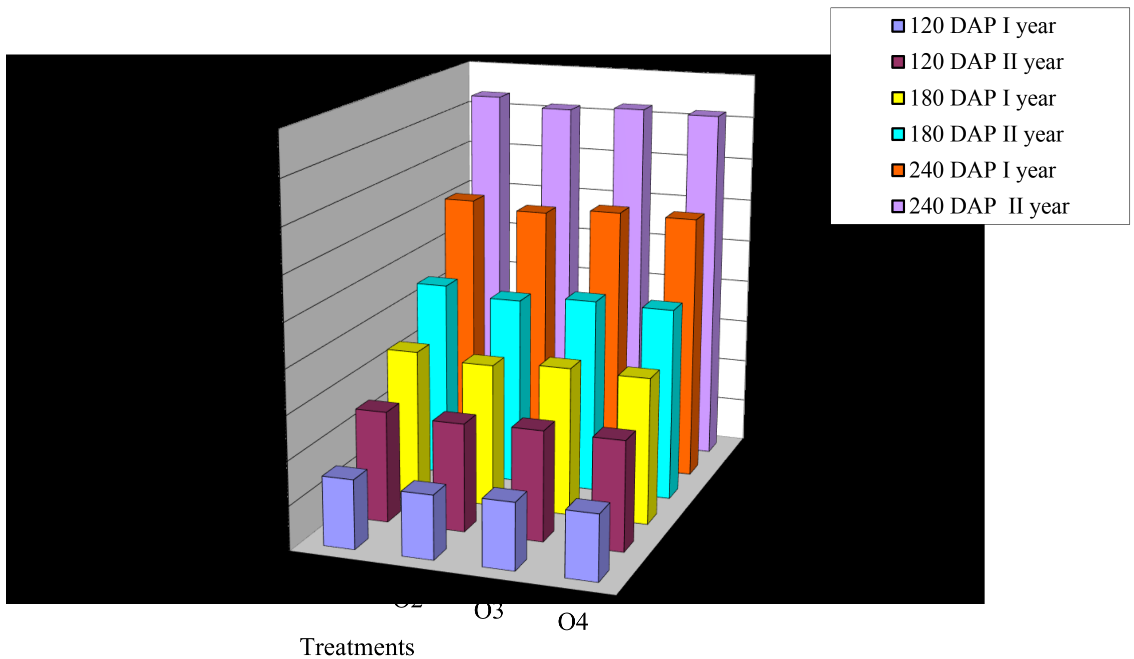


Fig. 7. .Dry yield of ginger as influenced by organic manures on 00-01 and 01-02

and second year) and K (79.92 kg ha^{-1}, 109.87 kg ha^{-1} for first and second year) was the least for vermicompost combinations (Table 48). The lower uptake of N, P and K might have contributed to the lower yield under O_2.

The influence of various microbial inoculants on the dry ginger yield was significant throughout the growth stages of both the years. AMF + *Trichoderma* enhanced the dry ginger yield at all stages of growth on both the years. The influence of AMF in increasing yield was described by Khaliq *et al*. (2001) in peppermint. The application of *Trichoderma viride* and AMF together resulted in maximum yield in ginger (Joseph, 1997). The increased growth of plants inoculated with AMF may be attributed to the improved phosphate uptake and better availability of other elements especially Zn and Cu (Swaminathan and Verma, 1979; Krishna *et al*., 1982). The influence of hormones (Allen *et al*., 1982) as well as anatomical and morphological changes in the root system such as increased lignification, root branching, the meristematic and nuclear activities of root cells (Sivaprasad, 2002) might have helped in better absorption and transport of nutrients which might have resulted in higher yield. *Trichoderma* also plays an important role in the promotion of plant growth and yield (Sivaprasad, 2002). *Trichoderma* influence the growth by producing plant hormones and enzymes. The physical, chemical and biological barrier hosted against pathogen by *Trichoderma* might also have contributed to the yield. It has been reported that Azotobacter, Azospirillum, phosphate solubilising bacteria along with mycorrhizal colonization exerts synergistic effect on plant growth (Azcon *et al*., 1976; Bagyaraj and Menge, 1978; Raj *et al*., 1981). Similarly the application of AMF and *Trichoderma* might have resulted in synergistic effect which enhanced the yield.

All the interaction effects were significant in both the years. During both the years, FYM + AMF (o_1b_1) as well as FYM + neemcake + AMF + *Trichoderma* (o_3b_3) resulted in higher and similar effect. The combined application of neemcake (150 kg ha^{-1}) along with seed treatment using *Trichoderma viride* recorded maximum yield in fenugreek (IISR,

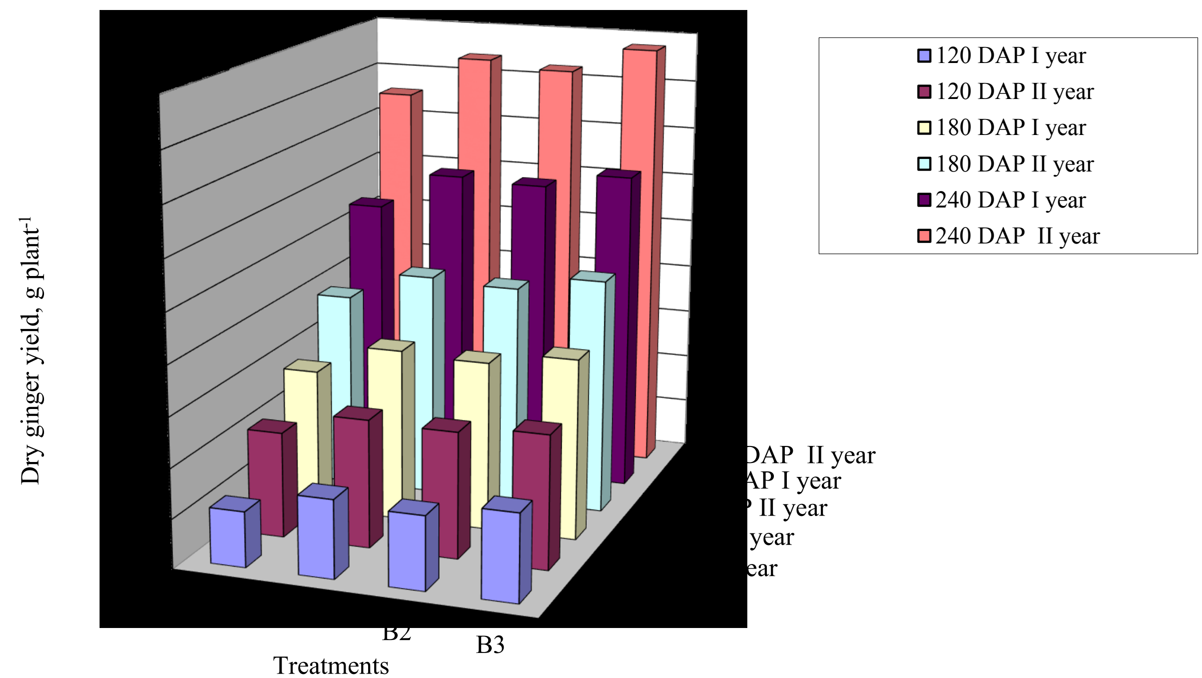
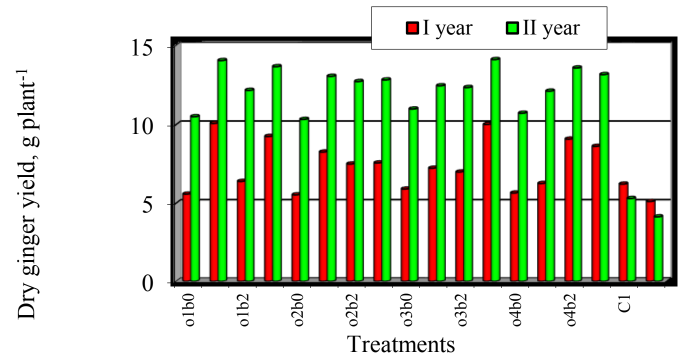


Fig.. 8 . Dry yield of ginger as influenced by microbial inoculants on 00-01 and 01-02

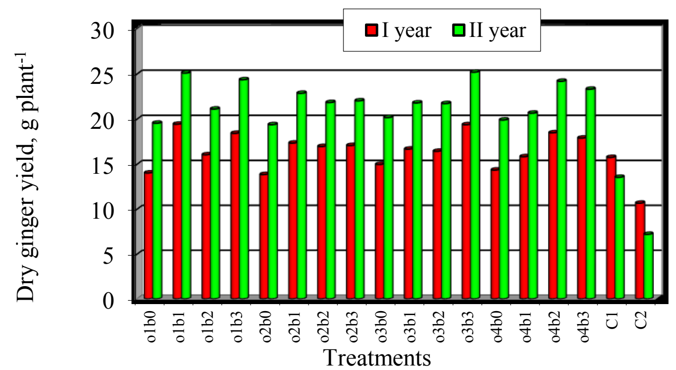
1998). The application of organic manures alone (o_1b_0, o_2b_0, o_3b_0 and o_4b_0) resulted in lower yield compared to other organic manure microbial inoculants interactions indicating the importance of microbial inoculants along with organic manures. The use of organic amendments or manures usually favours the growth of antagonists than pathogens as reported by Davide (1990). The yield under vermicompost microbial inoculant combination was comparatively lower than any other organic microbial inoculant combinations. As revealed from Table 51, 52, 53, 54 and 55, the net loss of nutrient for both years of experimentation was higher for o_2b_0 combination. During the second year of study, a net gain of K was noticed for all treatment except controls, C_1 and C_2. The net gain of K was also the least for o_2b_0 treatment (Table 56) during the second year. Hence when vermicompost + FYM was applied (o_2b_0) the loss of nutrients was high which might be because of the easy availability of nutrients. Thus vermicompost + FYM could not produce a better effect on yield compared to other organic manure treatment combination (o_1b_0, o_3b_0 and o_4b_0). However among the vermicompost combinations AMF resulted in increasing the yield. The AMF application along with vermicompost and FYM might have involved in harnessing more nutrients from the nearby areas and its uptake resulting in better yield among the vermicompost microbial inoculant combination.

The treatments differed from the controls at most of the stages of growth on both the years. Increase in yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984). However the effect of C_1 when compared individually with the treatments was not significant at 6 and 8 MAP for the first year. The effect was significant for the remaining periods. The yield under absolute control (C_2) was very low.

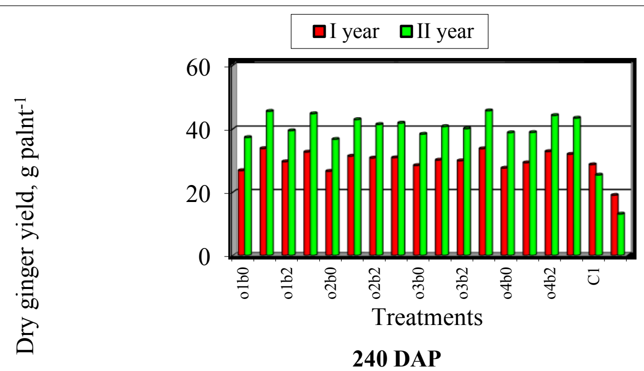
The pooled data reveals significant difference in dry ginger yield of first and second year for microbial inoculant treatments only. The effect of organic manure treatment, as well as interaction effect of first year was



120 DAP



180 DAP



240 DAP

Fig. 9. Dry yield of ginger as influenced by organic manure microbial inoculant on 00-01 and 01-02

not different from the second year. However, the yearly mean indicates significant difference between first and second year of experimentation. Significantly higher yield (41.24 t ha^{-1}) was observed during the second year compared to first year (30.43 t ha^{-1}). The increased yield of treatments during the second year can be accounted to greater uptake of N, P and K (Table 48), mobilized from the manures during the current as well as previous seasons and the resultant highest biomass accumulation and further diversion to rhizomes. For the controls C_1 and C_2, the dry ginger yield of the second year of experimentation was comparatively lower than the first year. The uptake of N, P and K on the second year of experimentation was lower than the first year for C_1 and C_2. The net loss of N and K was more during the second year of experiment for C_2 (Table 51, 52, 53 and 54) resulting in lower uptake compared to first year. The less yield under C_1, during the second year of study could be attributed to this.

5.1.7.3 Shoot yield

The application of different sources of organic manures significantly influenced the shoot yield at most of the stages except at 120 and 240 DAP of first and second year of experimentation (Table 27). Rakhee (2002) also observed no difference in shoot yield between various organic as well as inorganic treatments in turmeric at harvest. At all stages of growth except at 120 and 240 DAP of first and second year of experimentation highest shoot yield was obtained from FYM treatments compared to other organic manures. The highest shoot yield in FYM (O_1) was mainly due to highest tillers and leaves under that treatment. The lower tiller as well as leaf production resulted in less shoot yield for O_2.

The influence of microbial inoculants in shoot yield was significant in both the years at all stages of growth. The application of AMF and *Trichoderma* together resulted in higher shoot yield. The AMF and *Trichoderma* when applied together resulted in the production of more tillers and leaves which may be due to the more nutrient mobilization under these treatments. The higher tiller and leaf production hence resulted in more shoot yield under B_3.

The organic manure microbial inoculant interaction produced significant difference in shoot yield at all stages of growth on both the years. Treatments o_1b_1 (FYM + AMF) was on par with o_3b_3 (FYM + Neemcake + AMF + *Trichoderma*). The treatment o_4b_2 (FYM + green leaves + *Trichoderma*) also resulted in superior shoot yield followed by o_1b_1 and o_3b_3 on both years at 240 DAP. The higher vegetative growth as indicated by higher number of tillers and leaves under the above treatments resulted in higher shoot yield.

Treatments showed significant variation in shoot yield compared to controls, C_1 and C_2 at most of the stages of growth on both the years. This was because of the higher shoot growth of treatments compared to controls. The control C_1, differed from the treatments at all stages except at 120 DAP on first year. The difference was not much evident during the initial stage (120 DAP) but as growth advanced the shoot growth of treatments was comparatively higher than the plants where package of practices recommendation of Kerala Agricultural University was followed. However for C_2, the shoot growth was less because of the low intake of nutrients. Variation in shoot yield was significant between the controls also at all stages of growth on both the years.

5.1.7.4 Bulking rate

The main effect of organic manures on bulking rate was significant only during the initial stage of rhizome formation (120 – 180 DAP) at second year only (Table 28). However during the later stages (180 – 240 DAP) of both the years the bulking rate produced by different organic manures did not vary. The non-significant bulking rate might be due to the non-significant NAR during those periods.

The bulking rate was significantly influenced by different microbial inoculants. The application of microbial inoculants resulted in accumulation of more dry matter in the rhizome. The effect was more pronounced when AMF and *Trichoderma* were applied together leading to higher bulking rate.

The organic manure microbial inoculant interaction was significant at all periods except 120-180 DAP of first year of experimentation. Among the treatment combinations, at final harvest of first year FYM + AMF, FYM + AMF + *Trichoderma*, FYM + neemcake + AMF + *Trichoderma*, FYM + green leaves + *Trichoderma* and FYM + green leaves + AMF + *Trichoderma* produced significantly higher and similar increasing effect in dry matter accumulation in the rhizomes.

During the second year of experimentation highest bulking rate at harvest was observed in treatment involving FYM + neemcake + AMF + *Trichoderma*.

The bulking rate of treatments varied significantly from the controls at most of the stages of growth on both the years. The control C_1 when compared individually with the treatments also showed significant difference in bulking rate at all stages except at 120-180 DAP of first year. However, C_2 varied significantly from the treatments at all stages of growth on both the years.

The pooled analysis reveals that organic manures as well as organic manure microbial inoculant interaction did not produce variation in bulking rate of first and second year of the corresponding treatments. However the microbial inoculant applied at first year produced significant effect on the bulking rate of second year also. At 180-240 DAP, the bulking rate of B_3 was 0.24 which increased to 0.34 showing significant difference.

5.1.7.5 Rhizome spread

The significant effect of organic manures on rhizome spread was evident throughout the second year and at the initial (120 DAP) stage of rhizome formation of first year (Table 29). A similar study made by Rakhee (2002) in turmeric using various organic, inorganic as well as treatment using package of practices recommendation of Kerala Agricultural University reported significant difference in rhizome spread only at 8 MAP.

The different microbial inoculants significantly affected the rhizome spread of both the years. The rhizome spread due to application of AMF + *Trichoderma* was significantly superior than the individual application of microbial inoculants. AMF and *Trichoderma* together also favoured higher root spread, which might have helped in more accumulation of photosynthates and congenial spread of rhizome.

Rhizome spread varied significantly for organic manure microbial treatments during all stages except at 240 DAP of first year. The results indicate that the rhizome spread was influenced by organic manure microbial inoculant application. During first year rhizome spread recorded was highest under o_1b_1 while for second year it was the highest under o_3b_3 treatment. The highest yield was also recorded for these treatments, which indicates the role of rhizome spread on yield determination.

The treatments differed from controls at all stages of growth on both the years. The controls (C_1 and C_2) differed from the treatments at all stages of growth on both years. Rhizome spread recorded among controls also showed significant variation. The least rhizome spread was recorded from C_2 where the rhizome yield was also the least.

5.1.7.6 Rhizome thickness

The influence of organic manures on rhizome thickness was significant at the later stages (180-240 DAP) of second year and at 180 DAP of first year (Table 30).

The influence of different microbial inoculants on rhizome thickness was significant on 6 and 8 MAP on both the years. Among microbial inoculants, the application of AMF and *Trichoderma* together produced significantly thicker rhizomes. The combined application might have mobilized more nutrients, which resulted in accumulation of higher carbohydrates, represented by higher rhizome thickness.

The organic manure microbial inoculant interaction produced significantly different values in rhizome thickness at the later stages of growth. This is an indication that rhizome thickness occurs more during these periods. Among the interactions, the o_1b_1 produced thicker rhizomes during first year, while during the second year thicker rhizomes were resulted from o_3b_3. Higher yields were also reported from these treatments, which indicates rhizome thickness as a function of yield.

Significant difference between the rhizome thickness of treatments and controls were noted throughout the growth period on both the years. C_1 varied from the treatments at all stages except at 120 DAP of first year of experimentation. The interaction in rhizome thickness between C_2 and treatments was evident throughout the growth periods. This might be due to the low nutrient availability under C_2, which resulted in lower rhizome thickness.

5.1.8 Correlation of yield characters in relation to green ginger and dry ginger yield

5.1.8.1 Green ginger yield

A significant positive correlation exists between green ginger yield vs dry ginger yield, green ginger yield vs shoot weight, green ginger yield vs bulking rate, green ginger yield vs rhizome spread and green ginger yield vs rhizome thickness revealed from two years of experimentation (Table 31 and Table 32).

More the green ginger yield more was the dry ginger yield. The increase in dry weight of rhizome per plant per day (bulking rate) is also directly dependent in the green ginger yield and hence significant positive correlation. Increasing thickness as well as the spread of rhizome also was found to be a factor contributing to green ginger yield thus indicating positive correlation.

5.1.8.2 Dry ginger yield

The significant positive correlation results were noticed when dry ginger yield was correlated with green ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness (Table 31 and Table 32).

The results obviously indicate the direct relation of dry ginger yield and green ginger yield. Increase in dry weight of rhizome per plant per day (bulking rate) is a yield contributing factor and hence positive correlation. Higher vegetative growth resulted in accumulation of more photosynthates contributing to more yield being indicated by more spread and thickness of rhizomes as revealed from the above results.

5.1.8.3 Shoot weight

The significant positive correlation was noticed between shoot weight and green ginger yield, dry ginger yield, bulking rate, rhizome spread and rhizome thickness on both years of experimentation (Table 31 and Table 32).

The tillers and leaves constitute shoot weight. Higher shoot weight which may be due to the higher tiller and leaf production might have resulted in more leaf area leading to higher production of photosynthates resulting in more green and dry ginger. Increased bulking rate, rhizome spread and rhizome thickness were also noticed with increase in shoot weight which might be due to the increased green and dry ginger yield.

5.1.8.4 Bulking rate

Bulking rate had a significant positive correlation with green ginger yield, dry ginger yield, shoot weight, rhizome spread and rhizome thickness on both years of study. The increase in dry weight of rhizome per plant per day was evidently correlated with green ginger yield, dry ginger yield, rhizome spread and rhizome thickness. The results revealed that higher shoot weight (Table 27) resulted in higher rhizome yield which might be due to the increased dry weight of the rhizome per plant per day and hence a significant positive correlation.

5.1.8.5 Rhizome spread

The significant positive correlation was noticed between rhizome spread vs green ginger, rhizome spread vs dry ginger, rhizome spread vs shoot weight, rhizome spread vs bulking rate and rhizome spread vs rhizome thickness on two years of experimentation (Table 31 and Table 32). A similar observation of higher rhizome spread with higher dry ginger yield at 240 DAP was noticed (Sreekala and Jayachandran, 2001). This may be an indication that rhizome spread increase with increase in green ginger yield. Higher the shoot weight higher will be the leaf area resulting in photosynthates leading to higher rhizome spread, rhizome thickness and finally higher rhizome yield.

5.1.8.6 Rhizome thickness

Rhizome thickness showed a significant positive correlation with green ginger, dry ginger, shoot weight, bulking rate and rhizome spread on both years of experimentation (Table 31and Table 32).

During the first year of study highest rhizome thickness (2.51 cm) was noticed from o_1b_1 treatment among the interaction and the least from o_2b_0 (2.09 cm). The highest green ginger yield, dry ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness were also noticed from o_1b_1 combination. Similarly the least green ginger yield, dry ginger yield, shoot weight, rhizome spread and rhizome thickness were noticed in o_2b_0 among the interactions. This explains the positive correlation between rhizome thickness and other yield contributing characters.

5.1.9 Effect of organic manures, microbial inoculants and their interaction on quality aspects

5.1.9.1 Volatile oil

As presented in the Table 33 the volatile oil of ginger was significantly influenced by different organic manure application on all the stages of first year of experimentation. During the second year, the effect was significant at 6 MAP only. The highest volatile oil content was also noticed at six month after planting and hence the significance may be more evident at that stage on both years of experimentation. At all the significant stages, use of FYM resulted in higher volatile oil content. According to Rakhee (2002) application of coirpith compost and FYM resulted in volatile oil content of 5.37 and 5.33 per cent respectively in turmeric.

The influence of different microbial inoculants on volatile oil content was significant on both the year of experimentation. The combined application of AMF and *Trichoderma* produced significantly higher volatile oil content than their individual application. The treatments where no microbial inoculants were applied (B_0) resulted in least volatile oil content. The influence of AMF on increasing the volatile oil content in cymbopogon was explained by Ratti and Janardhan (1996).

The volatile oil content of ginger was influenced by organic manure microbial inoculant interaction only at the initial stage (120 DAP) on both the years. However, the interaction was not significant during most of the period and at final harvest.

The treatments varied significantly from the controls, C_1 and C_2 at all stages of growth on both years. However, individual comparison of C_1 and C_2 with treatments also showed significant variation at all stages of growth on both years.

The influence of different organic manures and *Azospirillium* on growth, yield and quality of ginger revealed 15 per cent increase in essential oil content in treatments where 25 per cent of N was substituted through *Azospirillum* (FYM 30 t ha^{-1}+ *Azospirillum* 2.5 kg ha + 75 % N + full P and K) (KAU, 1999).

5.1.9.2 Non-volatile ether extract

The application of different organic manures did not make any variation in non-volatile ether extract (Table 34).

The non-volatile ether extract was significantly influenced by the application of different microbial inoculants. The combined application of AMF and *Trichoderma* increased the non-volatile ether extract while their individual application did not produce any significant variation.

The organic manure microbial inoculant interaction effects did not make any significant influence on the non-volatile ether extract.

The treatments significantly differed from the controls, C_1 and C_2 at all stages of growth except at harvest during the first year. Organic manure and biofertilizer application in ginger revealed no variation in the oleoresin content between various treatments (KAU, 1999).

The above results indicate that different organic manure microbial inoculant application could not produce any significant change in non-volatile ether extract but the non-volatile ether extract of organic manure microbial inoculant treatments was significantly superior compared to plants treated with package of practices recommendation of Kerala Agricultural University treatment as well as absolute control on all the stages.

5.1.9.3 Starch

The applications of different organic manures influenced the starch content on all stages of growth on the second year of experimentation and only on 120 DAP of first year (Table 35).

The different microbial inoculants made a significant change in the starch content on both year of experimentation. The plots, which did not receive any microbial inoculants produced significantly higher starch content. However the starch content was less in plots, which received either individual or combined application of AMF and *Trichoderma*.

The different organic manure microbial inoculant interaction however did not influence the starch content of ginger. The starch content produced due to various organic manure microbial inoculant interactions was the same.

The starch content of the treatments varied significantly from the control on all stages of growth on the second year and at final harvest of first year. C_1 varied significantly from the treatments at all stages of growth. However, the control C_2 produced almost similar effect as treatments on all stages except at harvest of first year.

5.1.9.4 Crude fibre

The crude fibre content of ginger varied significantly due to application of various organic manures, microbial inoculants and their interaction (Table 36).

The application of different organic manures influenced the crude fibre content of ginger on all stages of growth on the second year of experimentation and at initial stage (120 DAP) of first year. FYM as well as FYM + neemcake resulted in lower starch content and hence better quality.

The influence of various microbial inoculant on the crude fibre content of ginger was almost similar. However Niranjana (1998) observed least crude fibre content in treatment, which received Azospirillum inoculation with 75 per cent package of practices recommendation of Kerala Agricultural University in amaranthus.

The organic manure microbial interaction could not make any significant impact on the crude fibre content of ginger. The various treatment combination resulted in similar crude fibre content.

The crude fibre content of treatments varied significantly from the control at all stages of growth. Arunkumar (2000) reported improved quality of amaranthus like vitamin C, crude fibre and protein due to various organic manures. The variation in crude fibre was evident between the plants treated as per package of practices recommendation of Kerala Agricultural University treatment (C_1) and absolute control (C_2).

The crude fibre content increased after each stage of growth producing highest crude fibre content at full maturity. Jogi *et al.*(1972) estimated the crude fibre content at different stages of maturity and observed that 1.89 per cent of crude fibre content at five months after planting increased to 5.76 per cent at full maturity. The average increase per day was 0.12 per cent during the whole ripening period. Fully matured ginger had crude fibre content about three times of the present at first ripening though increase in crude fibre content continued upto the last stage of ripening. Fibre cells are associated with vascular tissues throughout the rhizome development and developed progressively from the days of rhizome formation with ageing of the tissue. Further the rapid thickening of the fibre cells occur in the older portions of the well formed rhizomes (Whily, 1980)

5.1.10 Correlation of quality aspects in relation to green ginger and dry ginger yield

5.1.10.1 Volatile oil

Table 37 and Table 38 represents the intercorrelations of volatile oil with green and dry ginger, NVEE, starch and fibre on two years of study.

Significant positive correlations of volatile oil with green and dry ginger and NVEE on both year of experimentation was noticed from the results. However volatile oil content was found to be significantly negatively correlated with starch and crude fibre. Accumulation of starch and crude fibre decrease essential oil level as evidenced by significant negative correlation.

Essential oil is positively correlated with oleoresin content and negatively correlated with starch (Pruthi, 1989). The starch buildup during maturation evidently reduced the essential oil levels.

5.1.10.2 Non-volatile ether extract

The intercorrelation of NVEE with green and dry ginger yield, volatile oil, starch and crude fibre for two years of experimentation are presented in Table 37 and Table 38.

The non-volatile ether extract observed for two years of study was found to be significantly correlated to green and dry ginger yield, volatile oil, starch and crude fibre. A significant positive inter correlation was noticed between NVEE and green ginger yield, dry ginger yield and volatile oil.

The non-volatile ether extract shows a significant negative correlation with starch and crude fibre for two years of study. This it may be assumed that accumulation of starch and crude fibre decrease the non-volatile ether extract as evidenced by significant negative correlation.

The positive correlation of essential oil with oleoresin content was also reported by earlier studies (Pruthi, 1989). The positive correlation of essential oil with oleoresin is well found as the essential oil is an integral part of the oleoresin (Govindarajan, 1982). Pruthi (1989) also reported a negative correlation of oleoresin with starch and crude fibre in ginger.

5.1.10.3 Starch

The correlation of starch to green and dry ginger, volatile oil, NVEE and crude fibre for two years of experimentation are presented in Table 37 and Table 38.

The starch shows a significant positive correlation with crude fibre on both years of experimentation. However a significant negative intercorrelation was observed between starch and green ginger, dry ginger, volatile oil and NVEE on two years. The significant negative correlation between starch and green and dry ginger at 240 DAP on both years may be because of the lesser starch content observed in treatments which resulted in higher yield in both years. The treatment o_1b_1 resulted in higher green and dry ginger yield during first year (Table 25) but the starch yield was 42.43 per cent (Table 35). The least green and dry ginger was noticed from o_2b_0 (Table 26) while the starch content observed was 42.71 per cent (Table 35). The negative correlation of starch with essential oil and oleoresin content in ginger was also reported by Pruthi (1989). The positive correlation between starch and crude fibre content is well established (Pruthi, 1989). At maturity levels, higher starch content is observed (Table 35) compared to earlier stages. The higher starch might have resulted in higher crude fibre content which was indicated by their positive correlation.

5.1.10.4 Crude fibre

The correlation of crude fibre content with green and dry ginger, volatile oil, NVEE and starch content during the first and second year of study are presented in Table 37 and Table 38.

A significant positive correlation was noticed between crude fibre and starch on both years. With green ginger, dry ginger, volatile oil and NVEE a significant negative relation was observed. The positive correlation between crude fibre and starch may be explained as the build up of crude fibre due to accumulation of starch. A similar observation was also done by Pruthi (1989). The significant negative correlation between crude fibre and green and dry ginger may be due to the lower crude fibre content observed (Table 36) for the treatments producing higher green (Table 25) and dry ginger yield (Table 26). A significant negative relation was also noticed between crude fibre and volatile oil and crude fibre and NVEE. A reduction in oleoresin content due to accumulation of more starch and crude fibre at maturity levels was also observed by Pruthi (1989). The reduction is relative and is not caused by actual lowering of oleoresin content but by an increase in the various constituents of ginger such as starch and crude fibre which form the dry matter. Accumulation of starch and *in vitro* loss of volatiles decrease the essential oil content during ontogenesis of rhizomes.

5.2 SOIL CHARACTERS

5.2.1 Effect of organic manures, microbial inoculant and their interaction on soil physical properties

5.2.1.1 Bulk density

The application of different organic manures made a significant change in bulk density after the second year of experimentation for all the treatments (Table 39). However, the effect was evident after the first year of experimentation for green leaves treatment. Aravind (1987) reported that when farm yard manure was applied as an organic source of nitrogen, bulk density of soil lowered from 1.30 to 1.06 g cc^{-1} compared to the poultry manure application which lowered the same from 1.30 to 1.10 g cc^{-1}. Otu and Agboola (1991) reported that 14 per cent decrease in soil bulk density due to green leaf application. According to Maheswarappa (1999a) the bulk density decreased to 1.38 g cc^{-1} in FYM treatment from the initial value of 1.55 g cc^{-1}. There was no change in the bulk density under NPK treatment alone.

The 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.

There was significant variation in the bulk density between treatments and control, C_1. While the bulk density decreased for the treatments after the second year of experiment, the value increased for the control, C_1 and C_2 after two years of experimentation. More crop residues, higher organic matter content and better aggregation may be the possible reasons for decreased bulk density due to the application of organic treatments. These findings are in close conformity with those of Mishra and Sharma (1997). The bulk density of treatments, however did not differ significantly from the control, C_2.

5.2.1.2 Particle density

The application of different organic manures made a significant variation in the particle density after each experiment (Table 40). The variation in particle density was significant after the first year of experiment for O_1, O_3 and O_4. The effect of vermicompost treatment on particle density become significant only after the second year of experimentation. The higher crop residues and organic matter from FYM, green leaves + FYM and neemcake + FYM might be the reason for the significant changes in particle density after the first year of experiment itself.

The microbial inoculants as well as organic manure microbial inoculant interaction did not influence the particle density even after second year of experimentation.

The particle density of the soils that received treatments varied significantly from the controls, C_1 and C_2. The variation was significant between the controls also. The particle density of the treatments decreased after each experiment while it increased after each experiment in the case of controls. According to Brady (1994) organic matter stimulates the formation and stabilization of granular and crumb type aggregates, facilitates greater pore space and lowers the specific gravity of soils. A decrease in bulk density after the second year of experimentation due to organic manure application was also reported by Suja (2001) in white yam.

5.2.1.3 Water holding capacity

The water holding capacity of the soil before and after each experiment showed a significant influence by different organic manures, microbial inoculants and their interaction (Table 41).

The application of different organic manures significantly influenced the water holding capacity of the soil after the experiment. The FYM and green leaf + FYM treatments showed a significant increase in water holding capacity after first year of experimentation. However, the increase in water holding capacity was significant after the second year of experimentation for all the organic manure treatments. Increase in soil moisture retention due to addition of FYM was observed by Salter and Williams (1963) and Biswas *et al*. (1969).

The use of different microbial inoculants as well as their combination with organic manures could not influence the particle density after second year of experimentation.

The different treatments influence the water holding capacity of the soil and showed significant variation from the control, C_1. Manickam (1993) explained the better water conducting properties of the soil due to the action of gum compounds, polysaccharides and fulic acid compounds of organic matter on the soil structure. Hence the higher organic matter added by the treatment might have resulted in better water holding capacity. The water holding capacity of treatments and absolute control did not vary significantly.

5.2.1.4 Soil aggregate index

The application of organic manures, microbial inoculants and their interaction could not significantly change soil aggregate index over two years of experimentation (Table 42).

The soil aggregate index of treatment varied significantly from the control, C_1. The variation was significant between the controls also. The polysaccharides have an important role in soil aggregate formation and these can be of organic origin and hence higher aggregate index under treatments. However the soil aggregate index of control, C_2 did not differ significantly from the treatments.

5.2.2 Effect of organic manures, microbial inoculants and their interaction on the available nutrients of the soil

5.2.2.1 Available Nitrogen

The pooled data reveals that the application of different organic manures influenced the available N content of the soil (Table 43). Among the organic manures, the application of green leaves resulted in higher available N content followed by FYM treatment. This result is in conformity with the general finding that green manuring enhances available N content of soils (Russell, 1973; Singh *et al*., 1991; Singh *et al*. 1992). A similar effect of *in situ* green manuring using cowpea in cassava was observed (Prabhakar and Nair, 1987; Nayar *et al*., 1993).

The microbial inoculants also influenced the available K content. The application of AMF and *Trichoderma* together resulted in higher available N content followed by AMF application. The VAM inoculated papaya varieties showed significant increase in the N, P, K content compared to the control (Kennedy and Rangarajan, 2001). It may be possible that application of VAM and *Trichoderma* convert the unavailable nutrient from the rhizosphere soil to available form resulting in increased contents of nutrients.

The organic manure microbial inoculants significantly influenced the available N content of the soil. Among the interactions highest available N was noticed from o_4b_3 followed by o_1b_3. However, the lowest available N was observed from o_2b_1. Subbiah (1990) observed that when adequate amount of farmyard manure was added to the soil with biofertilizers, it improved biofertilizers efficiency and ultimately nutrient status of soil.

The application of organic manures significantly changed the available N content of the soil of the each year of experimentation. The application of microbial inoculants also significantly affected the available N content after each experimentation. However, the organic manure microbial interaction could not influence available N content after each experimentation. The available N content of the treatment varied significantly from the controls, C_1 and C_2. The variation was significant between the controls also.

The available N content of the soil decreased for the control C_1 as well as C_2 while for treatments it increased after each experimentation.

5.2.2.2 Available P

The pooled mean reveals that the application of different organic manure did not influence the available P (Table 44). The different microbial inoculants however influenced the available P. Among the treatments, application of AMF resulted in significantly higher available P. The effect

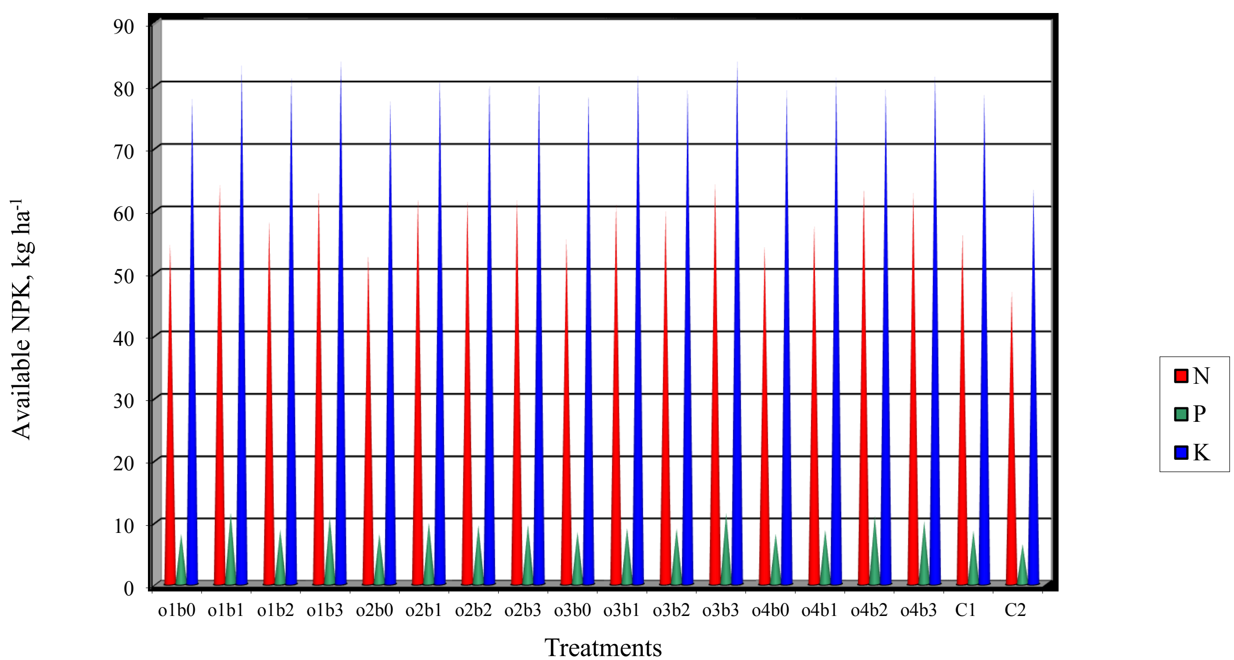


Fig. 10 Available N, P, K as ifnluenced by organic manure microbial inoculant interaction on 00-01 .

of four species of VAM fungi and P on leaf and soil mineral nutrient status of apple seedling was studied (Sharma *et al.*, 2002). All inoculated treatments had shown significantly higher P, Zn, Cu, Mn and Fe nutrients in soil over uninoculated control. The increased P availability might be due to the AMF mediated nutrient availability from the rhizosphere soil.

The organic manure microbial inoculant interaction also produced significantly different available P. Among the interactions significantly higher available P was observed from o_3b_1, and o_4b_1. This is the AMF combination with neem leaves + FYM and green leaves + FYM. AMF hyphae obtain their extra phosphate from liable pool rather than dissolving soluble phosphate. Subbiah (1990) reported that when adequate amount of farmyard manure was added with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of soil. The well developed root system due to AMF application coupled FYM and with green leaves and neem cake might have resulted in the utilization of insoluble phosphates and its subsequent mineralization and also the mineralisation of organically found P during the decomposition of manures would have enriched the pool. The available P of the soil changed significantly due to the different organic manure application after each year compared to the initial soil P status. However, the application of microbial inoculants as well as organic manure microbial inoculant interactions over the years did not affect significantly the available P content.

The available P content of the treatments varied significantly from the controls, C_1 and C_2. The available P noted due to treatments was significantly superior than the controls. Between the controls also the variation in available P was significant.

5.2.2.3 Available K

The different organic manure did not produce significant variation in available K content as revealed from the pooled data (Table 45).

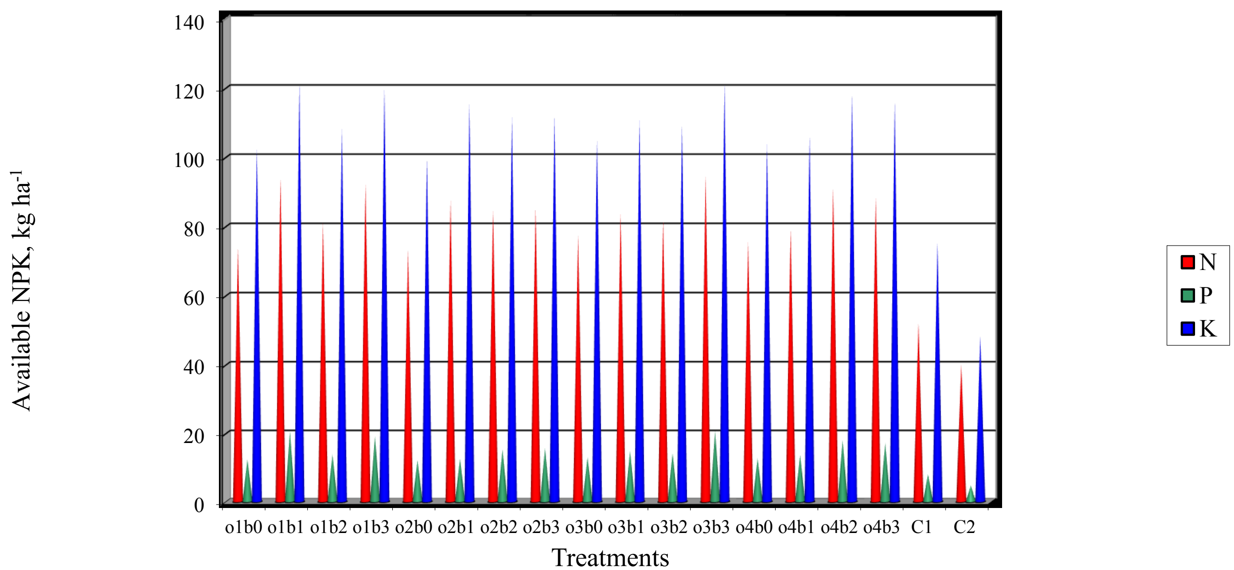


Fig. 11. Available N, P, K as influenced by organic manure microbial inoculant interaction on 01-02

Microbial inoculants significantly influenced the available K content. Application of AMF and *Trichoderma* resulted in significantly higher available K followed by application of AMF alone.

The available K content of soil was also influenced by organic manure microbial inoculant interaction. Among the interactions significantly higher available K was noticed from o_1b_3 and this might be due to the higher available K in the soil before the first year of experiment.

The variation in available K over the years due to various treatments like organic manures, microbial inoculants as well as their interaction was not significant over two years of experimentation.

The available K content of the treatments varied significantly from the controls, C_1 and C_2. There was a decrease in available K content of soil in C_1 and C_2 after each experiment. However for treatments after each experiment, a significant build up of available K status of the soil was observed. Srivastava (1985) observed a significant increase in available K content of soil due to application of different organic manures. Nayar *et al*. (1993) also observed a build up of available K in plants that received cowpea green manuring. A similar observation was also made by Suja (2001). An increase in K content of soil was also reported by Rakhee (2002) after the experiment using different organic manures, fertilizers alone and treatments that followed package of practices recommendation of Kerala Agricultural University in turmeric.

5.2.2.4 Organic carbon

The organic carbon content due to application of different organic manures showed significant variation as revealed from the pooled data (Table 46). The lower organic carbon content of O_4 (FYM + green leaves treatment) was due to the initial lower organic carbon status.

The significant variation due to application of different microbial inoculants was also observed. Higher organic carbon content in B_3 might be due to the beneficial effect contributed by the combined application of AMF and *Trichoderma*.

The organic manure microbial interaction produced significant variation in organic carbon content. Significantly superior organic carbon content was resulted from o_1b_1 and this was due to the high initial status of organic carbon.

The application of different organic manures, microbial inoculants and their interaction did not significantly affect the organic carbon.

The organic carbon content of the soil due to organic manure, microbial inoculants or their combined application on the first year of experimentation did not significantly differ from the second year of experimentation. Suja (2001) observed same effect on organic carbon content of soil due to various organic manures over years. Rakhee (2002) also observed no variation on organic carbon content due to different organic manure application.

The organic carbon content of treatments differed from the controls. While organic carbon content of treatments increased after each experiment from the initial status, there was a decline in organic carbon content of the controls, C_1 and C_2 after each experiment. The higher organic carbon under treatments may be due to higher organic matter addition. The organic matter addition under C_2 and C_1 was very less which resulted in a decline in organic carbon content.

5.2.2.5 Soil pH

The application of different organic manures as well as microbial inoculants did not significantly affect the soil pH. But the interaction of organic manures and microbial inoculants produced significant change in soil pH (Table 47).

No significant variation in soil pH was observed due to application of organic manure, microbial inoculants and their interaction over the two year of experimentation.

No significant variation in the soil pH was noticed between treatments and controls. A general decreasing soil pH after each experiment was noticed among treatments as well as for C_1. The decrease in soil pH may be due to the organic acids produced during the decomposition of organic manures as well as the enzyme and hormonal effect of microbial inoculants.

5.3 PLANT ANALYSIS

Effect of organic manures, microbial inoculants and their interaction on uptake of N, P and K on first and second year of experiment are discussed.

5.3.1 Effect of organic manures, microbial inoculants and their interaction on the uptake of nutrients

5.3.1.1 Uptake of N

The main effect of organic manures on the uptake of N was significant on both the years of experimentation (Table 48). Among the organic manure significantly higher uptake was observed from FYM (O_1) on both the years. The nutrient uptake is a function of dry matter production and significantly higher dry matter was observed from O_1.

The main effect of microbial inoculants also significantly influenced the uptake of N on both the years. The application of AMF and *Trichoderma* together resulted in higher uptake of N on both the years. The influence of microbial inoculants on the uptake of N was so evident, since the plant uptake of nitrogen was the least for the treatments, which did not receive any microbial inoculants. The next best alternative was the application of AMF alone. Higher uptake of N, K, Ca, Mg, Zn and 20 per cent increase in P content was observed in mycorrhizal papaya seedlings than non mycorrhizal (Gaddeda *et al.*, 1984).

The organic manure microbial inoculant interaction resulted in significant difference in the uptake of N during both the years. During the first year among various interactions higher uptake of N was noticed from o_1b_1 which also produced maximum dry matter production. Higher the N uptake, higher was the yield noticed in o_1b_1 during the first year. On the second year of experimentation highest uptake was observed from o_3b_3 which resulted in maximum dry matter production. The yield was also the highest for o_3b_3 treatments which might be due to the higher uptake of N. Organic manures together with microbial inoculants increased the availability of N, which might have resulted in the higher uptake of N.

The uptake of N by the treatments was significantly different from the control, C_1 and C_2, and the uptake was fairly higher for the treatments. The better availability of N under treatments might have influenced the higher N uptake. Deiz (1989) reported that nitrogen uptake by wheat was much greater in the manure, compost or peat treatments than inorganic control. The uptake of N due to organic manures, microbial inoculants, and their interaction during the first year differed significantly from the second year. For all the treatments, higher uptake was noticed in the second year of experiment. The availability of the soil N was also more under second year of experimentation. Better N uptake is commonly associated with adequate K fertilization. Nitrogen uptake occurs at the expense of energy from ATP, which requires potassium for its synthesis (Tisdale *et al*., 1995). The availability of K and its uptake during the second year was also higher for treatments compared to the controls.

5.3.1.2 Uptake of P

The use of different organic manures significantly affected the uptake of P on both the years (Table 48). FYM application resulted in higher uptake of P, followed by FYM + neemcake. The higher uptake of N and K was also noticed from FYM treatment. This treatment produced the highest yield among other organic manures.

The application of different microbial inoculants significantly influenced the uptake of P on both the years. The combination of AMF and *Trichoderma* resulted in significantly superior uptake of P, followed by the use of AMF alone. The beneficial effect of AMF on the mobilization of P was explained by many researchers (Mosse, 1973; Gaddeda *et al*., 1984; Thomas and Ghai, 1988; Sivaprasad *et al*., 1992; Thomas *et al*., 1994). The higher uptake of P which is less mobile by AMF may be thus attributed to greater volume of soil explored by the external AMF hyphae.

The P uptake was significantly influenced by organic manure microbial inoculant interaction on both the years. Among the interaction highest P uptake was noticed from o_1b_1 treatment during the first year and from o_3b_3 during the second year. The AMF was involved in both the treatments and might have mobilized more P resulting in higher P uptake.

The uptake of P due to organic manure microbial inoculants and their interaction on the first year differed significantly from the P uptake during the second year of experimentation. The uptake of P was higher during the second year than the first year of experimentation. This might be due to higher P made available by AMF during the first year of experimentation which resulted in more uptake throughout the second year.

Significant variation in the uptake of P was noticed between treatments and control. The uptake of P was the lowest for the controls during the second year. Higher uptake of P by the treatments involving farmyard manure alone at 48 t ha^{-1} substituting 59 per cent N and 25 per cent N through Azospirillum was reported (KAU, 1999). For the treatments where higher N uptake was noticed, the P uptake was also the highest. The higher rates of N increased protein biosynthesis leading to new tissue formation resulting in higher dry matter production. Protein biosynthesis involves ADP and ATP which are high energy phosphorus compounds. Thus the high P uptake may be related to N uptake and finally dry matter production.

5.3.1.3 Uptake of K

Among the different organic manures used, application of FYM resulted in significantly higher K uptake on both years of experimentation (Table 48). The N as well as the P uptake was the highest for FYM treatments. Thus among the different organic manures used the application of FYM was found to be the best for the uptake of more N, P and K leading to more yield.

The application of different microbial inoculants significantly affected the uptake of K on both the years. The combined application of AMF and *Trichoderma* enhanced the K uptake on both the years compared to their individual application. According to Joseph (1997) the combined use of AMF and *Trichoderma* in ginger increased K uptake. Kennedy and Rangarajan (2001) also found significant increase in the K content compared to the control in papaya varieties due to AMF inoculation.

There was significant variation in the uptake of K due to organic manure microbial inoculant interaction on both years. Among the interaction highest K uptake during first year was observed from o_1b_1 and during the second year from o_3b_3. Highest N as well as P uptake were also observed from these treatments. Better N uptake was usually associated with adequate K fertilization. N uptake occurs at the expense of energy from ATP which requires K for its synthesis (Tisdale *et al.,* 1995). Higher P uptake was also noticed with higher N uptake. .

The treatments varied significantly from the controls (C_1 and C_2) as revealed from the pooled result (Table 48). There was significant variation between the controls, C_1 and C_2 also.

The uptake of K by treatments during the first year varied significantly from the second year due to organic manure, microbial inoculants and their interaction. The higher uptake of treatments during the second year may be due to the residual K left through organic matter addition of the first year which resulted in higher K uptake.

5.3.4 Correlation of uptake of N, P and K in relation to green ginger and dry ginger yield

5.3.4.1 Uptake of N

The uptake of N showed significant positive correlation of green ginger yield, dry ginger yield with respect to uptake of P and K on both years of study (Table 49 and Table 50).

Higher the uptake of nitrogen resulted in increased vegetative growth resulting in increased production and storage of photosynthates in rhizomes which accounted for higher yield, representing a significant positive correlation. Increase in yield due to higher rates of N application in ginger was reported by many workers (Samad, 1953; Muralidharan *et al*., 1994; Ancy and Jayachandran, 1996; Ajithkumar, 1999). Higher N uptake might have resulted in higher ginger yield and hence significant positive correlation.

5.3.4.2 Uptake of P

The uptake of P showed significant positive correlation with green ginger yield, dry ginger yield, uptake of N and K (Table 49 and Table 50) on both years of experimentation.

Higher the uptake of P, higher was the yield noticed on both years. The higher uptake of P, resulting in higher yield is an indication of increased uptake with increased rates of phosphorus application (Ancy, 1992; Ajithkumar, 1999) in ginger. The N as well as K uptake was higher for the corresponding higher P uptake for both years of study and hence significant positive correlation.

5.3.4.3 Uptake of K

The intercorrelation studies indicated a significant positive correlation of uptake of K with green ginger yield, dry ginger yield, uptake of N and P on two years of experimentation (Table 49 and Table 50).

The higher uptake of K was noticed from treatments producing higher yield hence significant positive correlation. Positive influence of K application in increasing rhizome yield was reported by Singh *et al.* (1993).

The uptake of N also showed significant positive correlation with the uptake of P and K on both years of study which may be due to the beneficial effect of organic sources of fertilizers.

5.4 NUTRIENT BALANCE SHEET

5.4.1 Balance sheet for available nitrogen

Available N showed a net negative balance in both the years, however lower net losses were observed in the second year except for C_2 at second year (Table 51 and 52). The results support the finding of Sadanandan and Mahapatra (1973a). During the second year a gain in N was observed from C_2 (absolute control). The net loss or gain of N was arrived in the soil from the actual N balance or available N content of the soil. The soil of the experimental site was rated as low for available N content. The lower value of initial N status of first year as compared to the second year resulted in higher expected nutrient balance at the first year compared to the second year. The actual nutrient balance of first year was considerably higher which led to a higher loss of N in the first year. The net loss of N may be due to high mobility of N as well as rapid loss due to leaching and volatilization. However, at the commencement of second year, the available N content was slightly higher than that of the initial status of first year for treatments. This might be due to the residual effect of organic manures. This factor coupled with comparatively greater addition of nutrients through various organic treatments, slightly higher crop removal on account of higher yield, low nutrient loss during the second year resulted in comparatively lower net losses of available N in the organic treatments of second year.

Among the controls a higher loss of net N was noticed from C_1 during the second year compared to the first year. However for C_2, a gain of N was noticed during the second year.

Net gains of N in crop sequences involving legumes/green manures namely groundnut-jute-rice (Sadanandan and Mahapatra, 1973a), soybean-wheat (Raghuwanshi *et al.*, 1991) and dhaincha-wheat (Binodkumar *et al.*, 2000) was reported earlier.

Among the organic manure treatments apparently lower net loss of N in the experiment was observed in green leaves incorporated plot on both the years. A similar observation involving lower net loss of N was observed in sun hemp incorporated plots among all organic treatments by Suja (2001).

The net loss of N was less for B_3 treatments. For B_0 where no microbial inoculants were applied, the net loss of N was the highest which indicates the influence of microbial inoculants on the nitrogen availability and loss.

Among the interactions, the lower net losses during both the years were noticed on o_1b_1, o_1b_3, o_3b_3, o_4b_2 and o_4b_3. The microbial inoculant combination with FYM and green leaves generally reduced net loss of N. The uptake of N as well as yield was also higher for these treatments.

5.4.2 Balance sheet for available phosphorus

The balance sheet for available phosphorus reveals a deficit at both the years except for C_2 at second year (Table 53 and Table 54). Deficit balance sheet for available P for various treatments have been reported by Suja (2001). The rate of release of P from musooriphos (C_1) was also slow and whatever quantity that was released might have been absorbed by the crop and the remaining P might have existed in the unavailable form in the soil. Apart from this temporary conversion of mineralized inorganic form to organically bound ligands might have reduced the available P status to the present crop though the same is available in the long run (Russell, 1973). Hence the actual P balance could never been upto the expected P balance which is computed theoretically on the assumption that 100 per cent mineralisation of organic P takes place. Considerable decrements in net losses was observed in the second year since there was slight increase in the content of available P at the end of the second year compared to that at the start of the experiment. The net losses was comparatively less for most of the treatments compared to the control C_1 for both the years. A gain in P was noticed during the second year for absolute control, C_2. Though no addition of P was undertaken through manures and fertilizers in C_2, a gain P was noticed, which indicates that, the soil received the available P from any other source. This might be either due to the slow release of P to mineralizable form and also the P obtained from the mulched material as well as the addition of fallen clove leaves from the plantation.

Among organic manure treatments, the net losses was the minimum for green leaves (O_4) treatment of both the years. Suja (2001) also observed lower losses in sunhemp incorporated plots in both the seasons of white yam plots. The greater mineralisation of organically bound P consequent to decomposition of green leaves could have enriched the available pool of phosphorus and lowered the magnitude of net loss of P.

The application of different microbial inoculants reduced the net loss of P on both the years. The net loss was the least for AMF + *Trichoderma* application than the individual application of AMF as well as *Trichoderma*.

The organic manure microbial inoculants reduced the net loss as revealed from the Table 53 and Table 54 on both the years. The net loss was less for organic manure microbial treatments than the individual application of organic manures (o_1b_0, o_2b_0, o_3b_0 and o_4b_0).

The net loss was the highest for C_1 and least for C_2 among all the treatments. However, a gain in P was observed in the second year of experiment for plants of absolute control treatment.

5.4.3 Balance sheet for potassium

The balance sheet of potassium for both the years of study (Table 55 and Table 56) reveals a gain in K during the second year unlike N and P.

Among the organic manures, least net loss was obtained from green leaves treatment during the first year which also resulted in highest gain in K during the second year. The loss was the highest from neemcake treatment during first year. However, there was a gain during the second year. The gain in K was the least for vermicompost treatments during the second year.

The different microbial inoculants affected the net loss as well as net gain of K. The loss of K during the first year was the least when AMF and *Trichoderma* were applied together. However, the loss changed to a gain during the second year and the gain was the highest from B_3.

The O x B interactions showed lowest net losses from o_1b_3. The net loss was the highest from o_2b_1 during the first year. The gain in C_2 was observed from the first year itself. The gain in K during the second year was the highest from o_4b_2. However for controls C_1 and C_2 during the second year a net loss in K was noticed.

The available K status of the soil was in general enhanced for all of the treatments in the second year compared to the control. The available K status observed at the beginning of the second experiment was higher compared to the soil before the first year of experimentation. The actual K content of the soil was higher than theoretically expected K balance of the soil which indicate a gain in K.

In the second year incremental doses of N tended to increase the gain due to build up of available K.

5.5 EFFECT OF ORGANIC MANURES, MICROBIAL INOCULANTS AND THEIR INTERACTION ON PERCENTAGE OF PEST INCIDENCE

The application of organic manures significantly influenced the shoot borer attack at 4 and 6 MAP on the first year of experimentation (Table 57). At final harvest of first year, the shoot borer attack was controlled. However during the second year various organic manures could not produce any significant effect on shoot borer attack. During the first year the soil was suddenly exposed to a different type of package involving organic manure application, which exposed the plant to more shoot borer attack. However, during the second year of experimentation the soil adjusted itself and hence could resist the infection to a large extent. Among the organic manures percentage pest incidence was the highest among FYM treated plots. The least incidence was noticed from vermicompost treated plots followed by neemcake. Jiji (1997) observed that vermicompost was significantly superior over control with respect to the count of fungi and bacteria. Sharu (2000) found lowest incidence of bacterial wilt in plots treated with chemical fertilizers and neemcake.

The application of different microbial inoculants as well as organic manure microbial inoculants interaction did not influence the pest incidence at all stages of growth on both the years.

Significant difference in the shoot borer attack was noticed at 60 and 240 DAP of second year and 120 DAP of first year when the treatments were compared with the control.

Biological control methods using neem kernal oil, rouging and collection and destruction of various stages of pests were carried out for treatments.

For control C_1, application of dimethoate was practiced. During the initial period at 60 and 120 DAP the pest incidence was more under treatments. As the period advanced the pest attack was gradually reduced for the treatments. This might be because of the different biological control methods adopted for treatments.

5.6 EFFECT OF ORGANIC MANURE, MICROBIAL INOCULANT INTERACTION ON THE POPULATION BUILD UP OF NEMATODES IN THE SOIL

The population build up of nematode in the soil before the first year of study was very less and was not enough to cause economic damage

(Table 58). The population started decreasing after each experiment for all the treatments except for C_2 at second year. The beneficial effect of organic amendments and plant residues in reducing plant parasitic nematode populations have been explained by Singh and Sitaramaih (1973). Vats *et al*. (1998) also reported that application of organic manures like neemcake, poultry manure, spent compost, FYM and biogas slurry improved plant growth of cotton and led to reduction in root knot nematode populations.

5.7 EFFECT OF ORGANIC MANURE, MICROBIAL INOCULANTS AND THEIR INTERACTION ON THE TERMINAL RESIDUES OF PESTICIDES

No detectable level of residues of mancozeb, malathion and dimethoate were noticed. This may be due to the long interval between the application of pesticides and harvest.

5.8 ECONOMICS OF ORGANIC MANURES AND FERTILIZER APPLICATION

The economics of cultivation using organic manures, microbial inoculants, their combination, treatments using package of practices recommendation of Kerala Agricultural University as well as absolute control on first and second year of experiment revealed wide difference in economics (Table 59 and Table 60).

During the first year of experimentation, maximum profit was obtained from o_1b_1 followed by o_4b_2, with B:C ratios 2.05 and 1.86 respectively. The net profit from o_3b_3 treatment was also higher and the B:C ratio was 1.84. This shows that application of FYM + AMF, FYM + green leaves + *Trichoderma*, FYM + neem cake + AMf + *Trichoderma* resulted in higher profit. The combination of AMF as well as AMF + *Trichoderma* was effective with FYM. Application of FYM and neemcake with any of the microbial inoculants produced profit, but was significantly higher when both microbial inoculants were applied. Among green leaves, application of *Trichoderma* together with FYM produced maximum profit.

The cost of FYM was reasonably high compared to other manures, and also they constituted low nutrient availability, but even then use of microbial inoculants resulted in higher yield and compensated the cost involved. The higher cost of production of organic manure microbial combination is due to the bulky nature as well as low nutrient availability and also the labour involved in its application.

The results indicate that judicious selection of organic manures and microbial inoculants should be done utilizing the resource available in the farm. The recycling should be effectively practiced in organic farming, then the cost can further be reduced.

The profit of treatment using package of practices recommendation of Kerala Agricultural University was less compared to treatments. The yield as well as cost of production under C_1 was less compared to all organic manure microbial combination. A gain of Rs.64,600 ha^{-1} was reported from plant which did not receive any manures and fertilizers.

During the second year of experimentation the net profit was the highest under o_1b_1 followed by o_3b_3 and o_4b_2 (Table 60). The profit from vermicompost treatments was comparatively less, due to the more cost involved in the cultivation using vermicompost and also because the yield obtained was not sufficient to cover the cost involved. The B:C ratio was the highest for o_1b_1 (3.09) followed by o_3b_3 (2.76) and o_4b_2 (2.75). Among FYM combinations, o_1b_1 (FYM + AMF) as well as o_1b_3 (FYM + AMF + *Trichoderma*) were found to be more profitable treatments. This is an indication of the positive influence of FYM and microbial inoculants like AMF and *Trichoderma* in ginger cultivation. With green leaves, and FYM, *Trichoderma* resulted in maximum profit. This shows that *Trichoderma* acts effectively in green leaves FYM combination than any other organic manures.

The profit was comparatively lower for plant treated with package of practices recommendation of Kerala Agricultural University which might be due to the lower yield compared to organic manure microbial inoculant treatments. The absolute control (C_2) resulted in a gain of Rs.10,125 ha^{-1} only during the second year.

The organic manure microbial combination resulted in higher yield during the second year. This might be due to the residual effect of organic manure microbial combination, which resulted in higher yield. Moreover the labour cost involved for field preparation during the second year of cultivation was also less. However the treatment involving package of practices recommendation continuously in the same bed resulted in lower yield which might be due to the exhaustive nature of ginger cultivation. The same was the effect with absolute control also. The results of the experiment indicates that if we practice organic manure microbial combination for ginger cultivation, apart from higher yield the soil physical character will also improve.

In conclusion the study revealed the superior effect of organic manure microbial inoculant combinations in improving the growth, yield and quality of ginger grown as an intercrop in coconut garden. The FYM + AMF and FYM + neem cake + AMF + *Trichoderma*, FYM + green leaves + *Trichoderma* were found to be the best treatment. All organic manure microbial inoculant combinations resulted in higher yield compared to package of practices recommendation of Kerala Agricultural University. The beneficial effect of organic manure microbial inoculant combinations in soil physical and chemical properties was also appreciable. Cultivation of ginger in the same field reduced the pest attack probably due to organic farming practice. The organic farming was also more economic when it was continued during the subsequent year also.

Future line of work

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

2. The residual effect of the organic manure microbial inoculant combinations should be studied
3. Impact of organic farming practices for the intercrop to the main crop (coconut) has to be investigated.

Summary

6. SUMMARY

The results of the salient findings of the experiment are summarized below :

The influence of organic manures on growth characters like plant height was significant at all stages except at 180 DAP while for number of tillers the effect was insignificant at most of the stages except at 120 and 180 DAP of second year and 240 DAP of both years. The number of leaves was insignificant at 60 and 120 DAP of second year. The application of different microbial inoculants significantly influenced the height as well as leaf production at all growth stages on both years of experimentation. However the tiller production was insignificant at 60 DAP of second year. Among the organic manure microbial interaction, the effect on growth character were significantly superior for FYM + AMF and FYM + neem cake + AMF + *Trichoderma*. The controls, C_1 as well as C_2 differed significant from the treatments for the growth characters on both years of experimentation. Between the controls also, the difference was significant. Shortest plants, lower tiller and leaf production was observed from absolute control at all stages of growth on both years of experimentation.

Correlation studies revealed a significant positive intercorrelation among green ginger yield, dry ginger yield, plant height, number of tillers and number of leaves on both years of study.

The main effect of different organic manure did not significantly influence the root characters like root length, root spread and root weight at most of the stages. The root volume was significantly influenced by different organic manures except at 120 DAP of first year. The microbial inoculants as well as organic microbial inoculant interaction produced significant variation in root length, spread and volume. The root length, root spread, root weight and root volume of treatments differed significantly from C_1 at all stages of second year and from C_2 at both years of experimentation. Between the controls also the variation in root characters was significantly different.

The root character *viz*., root length, root spread, root weight, root volume and green and dry ginger yield were intercorrelated and results revealed a significant positive correlation among these characters on two years of study.

The physiological parameter DMP was higher for FYM, AMF + *Trichoderma* treatment during both the years at all stages of growth. Among the interaction, FYM + AMF and FYM + neem cake + AMF + *Trichoderma* resulted in higher DMP at all stages of growth on both the years. The treatments varied significantly from both the controls at all stages of growth on both years of experimentation.

The crop growth rate was significantly influenced by different microbial inoculants and organic manure microbial inoculant interaction. The CGR was significantly higher for AMF + *Trichoderma*, FYM + AMF and FYM + neem cake + AMF+ *Trichoderma* treatments. At final harvest the treatments varied significantly from the controls.

The NAR of treatments varied significantly from the controls C_1 and C_2 at final harvest, but the relative growth rate of treatments did not vary significantly from the control, C_1.

Application of AMF + *Trichoderma*, FYM + AMF and FYM + neem cake + AMF + *Trichoderma* treatments produced higher leaf area index. The leaf area index of treatments was significantly different from the leaf area index of controls, C_1 and C_2 at all stages of growth on both years.

The various organic manures, microbial inoculants as well as their interaction significantly influenced the leaf area duration at all stages of growth on both years of experimentation. The LAD produced by C_1 was also significantly different from C_2 at all growth stages on both the years. The LAD of first year was similar to that of the second year for various organic manure treatments. However the LAD of first year was significantly different from the second year for microbial inoculants as well as for organic manure microbial inoculant interaction.

The different organic manures applied produced similar effects on harvest index at all stages of growth on both the years. However the use of different microbial inoculants as well as organic manure microbial inoculant interaction produced significantly different harvest index at some of the growth stages on both the years. The harvest index of C_1 was significantly different from the treatments at 120 DAP of both the years. The control C_2 differed from the treatments at 120 and 240 DAP of both the years. However between the controls the harvest index was similar at all stages of growth, except at 240 DAP of first year.

The root shoot ratio of ginger was influenced by different organic manures only at 180 DAP of first year. The application of various microbial inoculants produced significantly different root shoot ratio at all stages of growth on both years. However the organic manure microbial inoculant interaction significantly influenced the root shoot ratio at 120 and 240 DAP of first year and 180 DAP of second year. The control C_1 differed from the treatments at all stages of growth except at 120 DAP of first year. The control C_2 differed from the treatments at all stages of growth except at 120 DAP of both years.

The physiological characters *viz*., DMP, CGR, LAI, LAD, HI and green and dry ginger yield showed significant positive intercorrelation results on two years while RGR showed significant negative correlation with these characters for both years.

The application of different organic manures could not produce significant difference in green ginger yield at 180 DAP of first year and 240 DAP of both the years and was superior for FYM treatment. The use of various microbial inoculants as well as organic manure microbial inoculant interactions produced significantly different green ginger yield at all stages of growth on both years and was the highest for AMF + *Trichoderma* treatment, FYM + AMF and FYM + neem cake + AMF + *Trichoderma*. The green ginger yield of the controls C_1 and C_2 differed significantly from the treatments at all stages of growth on both the years. The green ginger yield of first year was significantly different from that produced during second year due to microbial inoculant application, as well as due to organic manure microbial inoculant interaction.

However the different organic manures could not produce significant difference in green ginger yield between two years.

The dry ginger yield was significantly influenced by different organic manures, microbial inoculants as well as their interaction at all stages of growth in both the years. The treatments which resulted in higher ginger yield showed similar trend in dry ginger yield also.

Significant difference in shoot weight due to different organic manures was noticed at 120 and 180 DAP of second year and at 180 and 240 DAP of first year. The shoot weight of ginger was significantly affected by different microbial inoculants as well as organic manure microbial inoculant interaction. The control C_1 differed from the treatments at all stages except at 120 DAP of first year, while C_2 differed from the treatments at all stages of growth on both the years. The shoot weight of C_1 differed significantly from C_2 at all stages of growth on both the years.

The bulking rate of ginger was not influenced by different organic manures at most of the stages except at 120-180 DAP of both the years. Different microbial inoculants significantly influenced the bulking rate at all stages of growth on both the years. The bulking rate of ginger was significantly different for organic manure microbial inoculant interaction at all stages except at 120-180 DAP of first year. The treatments differed from the control C_1 at all stages except at 120-180 DAP of first year. The control differed from the treatments at all stages of growth on both years.

The rhizome spread due to different organic manure application produced significant difference at 120 DAP of two years of study, 180 DAP and of 240 DAP of second year. The rhizome spread was the higher for FYM treatments. The rhizome spread was higher for AMF + *Trichoderma* treatment, FYM + AMF and FYM + neem cake + AMF + *Trichoderma* treatments at all stages of growth on both years.

Organic manures significantly influenced the rhizome thickness at 180 DAP of first year and at 180 and 240 DAP of second year. The highest rhizome thickness was noticed from FYM treatment. The different microbial inoculants as well as organic manure microbial inoculant interaction significantly influenced the rhizome thickness at 180 and 240 DAP. The rhizome thickness was the highest for AMF + *Trichoderma* treatments and FYM + AMF and FYM + neem cake + AMF + *Trichoderma*. The rhizome thickness of treatments varied significantly from the controls C_1 and C_2.

The results of intercorrelation studies revealed significant positive correlation among green ginger yield, dry ginger yield, shoot weight, bulking rate, rhizome spread and rhizome thickness on two years of experimentation.

The volatile oil content was significantly influenced by various organic manures at all stages of first year and at 180 DAP of second year and the volatile oil content was the highest for FYM treatment. Among the different microbial inoculants, application of AMF + *Trichoderma* produced significantly higher volatile oil content. The volatile oil as well as non-volatile ether extract were significantly higher for treatments compared to controls, C_1 and C_2.

The starch as well as crude fibre content of the treatments varied significantly from the plant, which followed package of practices recommendation of Kerala Agricultural University.

The quality parameters *viz*., volatile oil and non-volatile ether extract showed significant positive correlation with green ginger and dry ginger yield. The starch and crude fibre content of ginger produced a significant negative correlation with respect to green ginger yield, dry ginger yield, volatile oil and non-volatile ether extract on two years of study.

A significant difference in the bulk density of the soil was observed when the treatments were compared with control, C_1. Between C_1 and C_2 and between C_2 and treatments no much variation in the bulk density was noticed. The bulk density of the soil showed a significant reduction after second year of experimentation when compared to the soil before the beginning of the first year of study for organic manure treatments. The application of microbial inoculants as well as organic manure microbial inoculant interaction could not significantly change the bulk density of the soil even after the second year of experimentation.

The particle density of the soil which received organic manure microbial inoculant treatments varied significantly from the controls C_1 as well as C_2. No variation was however noticed between the controls, C_1 and C_2. The application of different organic manures produced significant reduction in particle density after second year of study compared to the soil before the first year of study. The effect was more evident with the application of FYM + green leaves. The application of different microbial inoculants as well as organic manure microbial inoculant interaction did not make any influence in the particle density after each year of experimentation.

The water holding capacity of the soil due to the application of organic manures and microbial inoculants was significantly high compared to control C_1. Between the treatment and absolute control as well as between C_1 and C_2 also the water holding capacity did not vary. A significant increase in water holding capacity was noticed when the soil before the first year of experimentation was compared with the soil after the second year of experimentation due to application of different organic manures. The application of different microbial treatments and organic manure microbial inoculant interaction could not produce a significant change in the water holding capacity of soil over the two years of its application.

The soil aggregate index due to application of organic manure microbial inoculants produced significantly higher values compared to the control, C_1. No significant variation in soil aggregate index was noticed between treatments and C_2 and between C_1 and C_2. Different organic manures, microbial inoculants and their interaction did not make any significant change in the soil aggregate index over two years of study.

Organic manures as well as microbial inoculants significantly increased the available nitrogen content of the soil after each year of experimentation. Among the organic manures, FYM + green leaves treatment accumulated higher nitrogen content. The organic manure microbial inoculant interaction did not produce any significant variation in available nitrogen content after each year of study. The different organic manures increased the available phosphorus content after the first year of application itself. But the microbial inoculants as well as organic manure, microbial inoculant interaction did not produce any significant effect on the available phosphorus of the soil after each year of experiment. The available potassium content of soil due to organic manures, microbial inoculants and their interaction could not produce any significant change over the years.

The application of different organic manures, microbial inoculant and their interaction over two years did not influence the organic carbon content as well as the pH of the soil compared to the soil before the beginning of first year of experimentation.

The uptake of nitrogen, phosphorus and potassium by ginger plant was significantly influenced by different organic manures, microbial inoculants and their interaction. The organic manure treatment, FYM and microbial inoculants treatment AMF + *Trichoderma* resulted in higher uptake of nitrogen, phosphorus and potassium on both the years. The treatments FYM + AMF and FYM + neem cake + AMF + *Trichoderma* resulted in a significantly higher uptake of nitrogen, phosphorus and potassium on both years. The uptake of nitrogen, phosphorus and potassium by the treatments also differed significantly from the controls C_1 and C_2 on both years. The uptake of nitrogen, phosphorus and potassium was significantly different between the controls C_1 and C_2. The uptake of nitrogen, phosphorus and potassium due to organic manures, microbial inoculants and their interaction on the first year was significantly different from the second year of application.

The uptake N, P and K and green ginger yield and dry ginger yield were intercorrelated and significant positive correlation existed between these characters as revealed from the results of both years of experimentation.

The balance sheet for available nitrogen, phosphorus and potassium showed lower net loss in FYM + green leaves treatment on both years of study among different organic manures. The application of AMF +

Trichoderma reduced the net loss of N, P and K on both years. Among the O x B interaction, FYM + green leaves + AMF + *Trichoderma* combination resulted in least net loss during first year and FYM + green leaves + *Trichoderma* combination resulted in least net loss of nitrogen during second year. The loss of available P was the least for FYM + green leaves + *Trichoderma* treatment for both years. The loss of nitrogen was the highest for organic treatments. During the second year, a gain in nitrogen was observed in C_2 plots. The net loss of potassium was the least for FYM + AMF + *Trichoderma* treatment during the first year and FYM + green leaves + *Trichoderma* during the second year.

Various organic manures significantly influenced the percentage of pest incidence at 120 and 180 DAP of first year only. The percentage of pest incidence was not influenced by different microbial inoculants and organic manure, microbial inoculants interaction. A significant difference was noticed when the organic treatments were compared with the controls at 60 and 180 DAP of second year.

The nematode population of the soil before and after the first and second year of study was carried out. The population level was not significant enough to cause any economic damage.

The economics of cultivation during the first and second year showed higher net return for FYM + AMF. The net return for FYM + green leaves + *Trichoderma* as well as FYM + neemcake + AMF + *Trichoderma* was also higher for both years. The net return for control C_1 and C_2 was lower compared to other treatments. During the second year, the profit increased for organic manure microbial inoculant combination compared to the first year.

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*Originals not seen

EFFECT OF ORGANIC MANURES AND MICROBIAL INOCULANTS ON GROWTH, YIELD AND QUALITY OF GINGER

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ABSTRACT

Field experiments were conducted at College of Agriculture, Vellayani during April 2000 to January 2001 and April 2001 to January 2002 to assess the effect of organic manures and microbial inoculants on growth, yield and quality of ginger grown as intercrop in coconut garden, to evaluate its effect on the physical and chemical properties of the soil and to develop a suitable economic organic farming practice for producing export quality ginger free of pesticide residues.

Factorial combination of four organic manures (FYM, vermicompost, neemcake and green leaves) and four microbial inoculant treatment (no microbial inoculant, AMF, *Trichoderma*, AMF + *Trichoderma*) and two controls (package of practices recommendation of Kerala Agricultural university and absolute control) in RBD were studied. FYM @ 30 t ha^{-1} was applied uniformly to all plots except for absolute control. Organic manures were applied on nitrogen equivalent basis.

The main effects of organic manures, microbial inoculants and their interaction were studied. The application of FYM and AMF + *Trichoderma* increased plant height, number of tillers, number of leaves, root length, root spread, root weight, root volume, DMP, CGR, NAR, LAI, LAD, root shoot ratio, green ginger yield, dry ginger yield, shoot weight, bulking rate, rhizome spread, rhizome thickness, volatile oil, NVEE and uptake of N, P and K. The starch content as well as crude fibre content was less for FYM and AMF + *Trichoderma* treatment.

Soil physical characters *viz*., bulk density, particle density, water holding capacity and soil aggregate index were superior for FYM + green leaf treatment and AMF+ *Trichoderma* application. The available N, P and K content of the soil after the second year of experiment was higher for FYM + green leaves treatment and AMF + *Trichoderma* treatment. The organic carbon content of the soil was higher for FYM treatment.

The soil pH was found to decrease after each experiment for organic manures, microbial inoculants as well as their combinations.

Among organic manure microbial interaction, application of FYM + AMF and FYM + neemcake + AMF + *Trichoderma* promoted significant growth and physiological characters, favoured green ginger yield, dry ginger yield, shoot weight, bulking rate, rhizome spread, rhizome thickness, quality parameters *viz*., volatile oil and NVEE. The application of FYM + AMF and FYM + neem cake + AMF + *Trichoderma* enhanced crop uptake of N, P and K and at the same time resulted in appreciable build up of available N, P and K in the soil.

The balance sheet for available N, P, K indicated a deficit balance during first year for all treatment except for absolute control. A gain in soil potassium content was noticed during the second year of experiment for all organic manures, microbial inoculants and organic manure microbial inoculant combinations.

The shoot borer attack was higher during the first year for FYM treatment at four month after planting and six month after planting compared to the second year. The nematode population in the soil was not significant before and after the experiment to cause economic damage. The residue analysis of plants treated with mancozeb, malathion and dimethoate as per package of practices recommendation of Kerala Agricultural University revealed no detectable level of residues.

The FYM + AMF and FYM + neemcake + AMF + *Trichoderma* generated a higher profit during the first and second year.

All organic manure microbial inoculant combination (except FYM + no microbial inoculant, FYM + vermicompost + no microbial inoculant, FYM + neemcake + no microbial inoculant, FYM + green leaf + no microbial inoculant) produced significantly higher yield and profit compared to treatments as per the package of practice recommendation of Kerala Agricultural University.

Correlation of yield with plant height, number of leaves, number of tillers, root length, root spread, root weight, root volume, dry matter production, crop growth rate, leaf area index, leaf area duration, shoot weight, bulking rate, rhizome spread, rhizome thickness, volatile oil, oleoresin and uptake of N, P and K showed significant positive correlation, which is an indication that these characters can be used as a criteria for the selection of yield.

To sum up FYM + AMF and FYM + neemcake + AMF + *Trichoderma* can be used as organic manure microbial inoculant combination with equal efficiency for ginger intercropped in coconut garden.

The result of two year study revealed that application of organic manure microbial inoculant combination produced better yield and improvement in soil health and nutrition than the application of organic manures or microbial inoculants alone. Increase in the profitability during the second year and reduction in the intensity of pest attack indicates the feasibility of switching over from integrated farming to organic farming.

Appendices

APPENDIX I

Weather parameters during the crop period monthly averages

Sl. No.	Month	Relative humidity, %		Temperature, ^0C		Rainfall, mm	Evaporation, mm
		Max 7.22 am	Min 2.22 pm	Max	Min		
I	First year of experiment (2000-2001)						
	April	86.63	73.83	31.90	24.40	80.40	4.2
	May	80.33	73.73	32.40	24.60	14.40	5.0
	June	89.5	77.00	29.30	22.70	232.30	3.0
	July	88.65	71.71	30.10	22.40	87.0	3.7
	August	91.10	78.87	28.60	22.10	257.8	3.1
	September	92.07	86.07	27.30	22.30	92.2	3.6
	October	93.19	84.23	30.00	21.90	210.8	3.3
	November	92.57	69.90	30.20	21.30	129.7	2.8
	December	91.13	63.77	30.24	20.21	47.8	2.9
	January	90.60	62.90	30.50	20.40	3.2	3.1
II	Second year of experimentation (2001-2002)						
	April	88.60	70.40	31.30	21.90	209.6	4.6
	May	86.40	74.50	31.10	20.90	195.6	3.8
	June	88.60	76.40	31.80	22.22	182.5	3.0
	July	90.00	75.50	29.30	21.90	297.5	2.8
	August	91.90	77.10	30.00	22.50	189.10	3.4
	September	89.40	78.50	30.20	21.20	558.2	3.9
	October	92.00	74.70	30.00	20.20	256.9	3.4
	November	93.60	71.20	30.30	21.20	238.1	2.9
	December	93.50	66.30	30.90	23.80	20.6	2.8
	January	94.70	62.60	31.10	22.20	0	3.5

APPENDIX II

Nutrient addition through manures and fertilizers

Treatments	Nutrient addition (kg ha^{-1})					
	2000-2001			2001-2002		
	N	P	K	N	P	K
o_1b_0	195	140	110	195	140	110
o_1b_1	195	140	110	195	140	110
o_1b_2	195	140	110	195	140	110
o_1b_3	195	140	110	195	140	110
o_2b_0	195	140	110	195	140	110
o_2b_1	195	140	110	195	140	110
o_2b_2	195	140	110	195	140	110
o_2b_3	195	140	110	195	140	110
o_3b_0	195	140	110	195	140	110
o_3b_1	195	140	110	195	140	110
o_3b_2	195	140	110	195	140	110
o_3b_3	195	140	110	195	140	110
o_4b_0	195	140	110	195	140	110
o_4b_1	195	140	110	195	140	110
o_4b_2	195	140	110	195	140	110
o_4b_3	195	140	110	195	140	110
C_1	195	140	110	195	140	110
C_2	-	-	-	-	-	-

APPENDIX III

Average input costs and market price of produce

Sl. No.	Items	Cost
	INPUTS	
A.	**Labour charge**	
1.	Men and women	
	2000 April to June	Rs.151
	2000 July to September	Rs.150.50
	2000 October to November	Rs.160.00
	2000 December to January	Rs.170.00
	2001 April	Rs.175.00
	2001 May to July	Rs.170.00
	2001 August to 2002 January	Rs.175.00
B	**Cost of seeds**	
1.	Seed ginger	Rs.30 per kg
C.	**Cost of manures and fertilizers**	
1.	Farm yard manure	Rs.1000 per tonne of dried FYM
2.	Vermicompost	Rs.3 per kg
3.	Neemcake	Rs.8 per kg during the first year and Rs.9 per kg during the second year
4.	Green leaves	Rs.1 per kg
5.	AMF	Rs.30 per kg
6.	*Trichoderma*	Rs.60 per kg
7.	Ash	Rs.1 per kg
8.	Rock phosphate	Rs.2 per kg
D	**Cost of other items**	
1.	Coir for bed preparation	Rs.28 per kg
	OUTPUT	
1	Market price of fresh organic ginger	Rs.25 per kg of fresh ginger
2	Market price for inorganically cultivated ginger	Rs.20 per kg of fresh ginger

APPENDIX IV

Quantity of manures and fertilizers used based on the nutrient value (On N equivalent basis)

Components	Treatments							
1. O_1b combination	o_1b_0		o_1b_1		o_1b_2		o_1b_3	
	I year	II year	I year	II year	I year	II year	I year	II year
1. FYM (t/ha)	44.423	42.931	44.423	42.931	44.423	42.931	44.423	42.931
2. AMF g/rhizome bit	-	-	3	3	-	-	3	3
3.*Trichoderma* (g per pit)	-	-	-	-	3	3	3	3
II.. O_2b combination	o_2b_0		o_2b_1		o_2b_2		o_2b_3	
	I year	II year	I year	II year	I year	II year	I year	II year
1.FYM (t/ha)	30	30	30	30	30	30	30	30
2. VC (t/ha)	7.89	8.33	7.89	8.33	7.89	8.33	7.89	8.33
3. AMF /rhizome bit	-	-	3	3	-	-	3	3
4.*Trichoderma* (g per pit)	-	-	-	-	3	3	3	3
Ash (kg/ha)	1081	834	1081	834	1081	834	1081	834
III. O_3b combinations	o_3b_0		o_3b_1		o_3b_2		o_3b_3	
	I year	II year	I year	II year	I year	II year	I year	II year
1. FYM (t/ha)	30	30	30	30	30	30	30	30
2. NC (kg/ha)	1744	1595	1744	1595	1744	1595	1744	1595
3. AMF (g per rhizome bit)	-	-	3	3	-	-	3	3
4.*Trichoderma* (g per pit)	-	-	-	-	3	3	3	3
5. Ash (kg/ha)	2596	2573	2596	2573	2596	2573	2596	2573
6. Rock phosphate (kg/ha)	164	162	164	162	164	162	164	162
IV. O_4b combinations	o_4b_0		o_4b_1		o_4b_2		o_4b_3	
	I year	II year	I year	II year	I year	II year	I year	II year
1.FYM (t/ha)	30	30	30	30	30	30	30	30
2. GL (t/ha)	18.75	18.75	18.75	18.75	18.75	18.75	18.75	18.75
3.Ash (kg/ha)	2456	1137	2456	1137	2456	1137	2456	1137
4. AMF (g per rhizome bit)	-	-	3	3	-	-	3	3
5.*Trichoderma* (g per pit)	-	-	-	-	3	3	3	3

AMF-Arbucular Mycorrhizal Fung
FYM-Farm yard manure
GL-green leaves
NC-neem cake
VC-vermicompost