VALIDATION OF FARMERS' PRACTICE OF ORGANIC MANURING IN OKRA
(*Abelmoschus esculentus* (L.) Moench)

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench)"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench)"** is a bonafide record of research work done independently by **Ms. Ankita Singh** under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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AFFECTIONATELY DEDICATED TO DEPARTMENT OF OLERICULTURE AND MY LOVING PARENTS

INTRODUCTION

1. INTRODUCTION

Organic farming is a concept or approach to make agriculture near to nature, simple, sustainable and safe to the society. This concept is based on one universal fact that food is the basic need of living beings and it can only be produced through biological process, essentially with the help of nature. It is a system of farm design and management to create an ecosystem which can achieve sustainable productivity without the use of artificial external inputs such as chemicals, fertilizers and pesticides.

Organic agriculture has the potential to produce enough food on a global per capita basis to sustain the total human population without increasing the agriculture land base (IFOAM, 2011). Maintenance of good soil health and stability in production is inevitable to meet the global food requirement in the long run. By respecting the natural capacity of the ecosystem, organic farming aims to optimize the quality in all aspects of agriculture and environment. Bioaccumulation of hazardous chemicals through an ecological food chain to the higher tropic levels can be minimized by adopting organic farming. Since the basic aim is diversification of crops, much more secure income can be obtained than monoculture, thus the biodiversity is maintained and space utilization is done.

Organic agriculture considers the medium and long-term effect of agricultural interventions on the agro-ecosystem. It dramatically reduces off-farm inputs. It aims to produce food while establishing an ecological balance and to prevent soil degradation or pest havocs. Since soil is the "soul of infinite life", continued maintenance of good soil health is vital to agricultural production and nation's economy. Soil building practices such as crop rotations, inter-cropping, symbiotic associations, integration of legumes, returning cropping residues, cover crops, mulching and organic manures are central to organic practices which increase the return of carbon to the soil (Natarajan, 2003). The fibrous portions of the organic matter with its high carbon content promote soil aggregation, improve the permeability and aeration of clay soil, while its ability to absorb moisture helps in the granulation of sandy soils and improves their water holding capacity. The carbon in the organic matter is the source of energy for microbes, which helps in aggregation, encourages soil fauna and flora, improves soil formation and structure, creating more stable systems. In turn, nutrient and energy cycling is increased and the retentive abilities of the soil for nutrients and water are enhanced, compensating for the non-use of mineral fertilizers. Such management techniques also play an important role in soil erosion control. The length of time that the soil is exposed to erosive forces is decreased, soil biodiversity is increased and the nutrient losses are reduced, helping to maintain and enhance soil productivity.

Pollution of groundwater with synthetic fertilizers and pesticides is a major problem in chemical agriculture. But well managed organic systems with better nutrient retentive abilities, greatly reduce the risk of groundwater pollution. By reducing the dependency on agrochemicals, organic agriculture reduces the use of non-renewable energy.

Organic farming is both a philosophy and a system of agriculture. The objective of achieving environmental, social and economic sustainability lies at the heart of organic farming and the methods to achieve the same are the major factors determining the acceptability or otherwise of specific production practices. Rising awareness about the harmful effects of chemicals used in production, processing and preservation of food on health, has lead to an increased demand for organically grown foods (Swaminathan *et al.,* 2007).

Okra is specially valued for its tender and delicious fruits. India produces 67 per cent of the world's okra. Okra contributes 5.4 % of the total vegetables produced in India constituting an area 4.3 lakh ha. India exports okra (18.12 m t) to West Asia, Western Europe and the U.S. The demands are high overseas, but European

Maximum Residue Level (EMRL) is very low and hence India should be pragmatic and quick to encash the opportunities in the global market (NHB, 2011).

Organic farming movement in India suffers from lack of adequate institutional and scientific support in areas of research and extension though farmers have come forward with many challenging and inspiring organic nutrient management techniques which they claim to be very competitive. Finding new perspectives for reducing chemical inputs in agriculture and residues in food is one of the major priorities. Again, the natural resources are showing signs of fatigue and it is the right time to focus on efforts to restore the soil, water, vegetation and environment status and to increase the per unit productivity by rationalizing the use of organic inputs.

Hence, as a beginning, the present project is formulated to test scientifically the farmer innovations in organic nutrient management of okra.

The major objectives of the project are:

- To test and scientifically validate the farmer driven technologies in organic nutrient management in vegetables with special reference to okra.
- To work out the practical feasibility and financial viability of okra cultivation with organic sources of nutrients.
- To assess the crop response to organic management in terms of yield, shelf life and fruit quality and to initiate a standardization of package on nutrient management through organic means.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The demand for organic products is increasing day by day. But there is fear of reduction in productivity via organic means. It is imperative to maintain productivity to feed the growing population. The present study was formulated to scientifically validate the farmer driven organic nutrient management technologies in augmenting the yield and quality of okra. The pertinent literature on this aspect is reviewed under the following major heads.

1.1 Effect of organic manures on crop growth, yield and quality of vegetable crops

1.2 Farmers' innovations in organic vegetable cultivation

1.3 Effect of organic manures on physical, chemical and biological conditions of soil

1.4 Effect of organic manures on availability and uptake of nutrients by vegetable crops

1.1 EFFECT OF ORGANIC MANURES ON CROP GROWTH, YIELD AND QUALITY OF VEGETABLE CROPS

1.1.1 Growth and yield

In simple words, organic farming is the cultivation of crops by addition of organic inputs with an intention to minimize the use of chemical fertilizers and pesticides that are hazardous to the environment. Organic materials such as bio-digested slurry, poultry manure, green leaf manure and FYM can substitute for inorganic fertilizers to maintain productivity and environmental quality (Choudhary *et al.*, 2002)

Singh (2004) found that, in okra the treatment having FYM with other bulky organic manures gave the highest yield with good protein content, prolonged shelf life and highest net profit per unit area over other treatments. The treatment having bio-fertilizer with bulky organic manures produced okra fruits with highest vitamin C and lowest nitrate content.

Taiwo *et al.* (2003) reported application of 5 t ha^{-1} of organic based manures led to significant increase in the number of okra pods when compared to inorganic fertilizers. Among liquid manures, the combined application of Beejamrut + Jeevamrut + Panchagavya and Panchagavya alone recorded higher uptake of N, P and K in chilli plants (Boomiraj, 2005). Comparison of soil, plant and yield parameters of okra grown under organic and conventional systems showed that leaf area index, plant height and fruit yield and quality were higher in the organic system compared to the conventional system.

According to Ogunlela *et al.* (2005), average pod weight and length were increased by cattle manure application in okra. Application of manure @ 6 t ha^{-1} gave the highest pod weight while 12 t ha^{-1} produced the highest weight of seeds per pod. Leaf calcium and pod nitrogen were slightly higher for cattle manure when applied earlier at the rate of 12 t ha^{-1} than applied late. Higher yield obtained from the cotton seed cake (25 % N) and poultry manure (75 % N) might be attributed to the better decomposition, higher availability of essential plant nutrients, rapid mineralization and more balanced ratio from poultry manure. The investigation done by Mali *et al.* (2005) in cucumber revealed that the maximum growth, maximum yield and earliness with best keeping quality were obtained from combined application of dhaincha and bulky organic manures as compared to inorganic fertilizers. The study conducted during the years 2005-2006 at Indian Grassland and Fodder Research Institute, Jhansi, revealed that all the jaivic and vedic krishi inputs like Amritpani, Panchagavya and Gomuthra improved the crop productivity, soil microbial population and soil biological activity (Sadanandan and Drand, 2006).

Sable *et al.* (2007) reported studies on tomato var. Parbhani Yashshri at MAU, Parbhani and studied the effect of organic sources of nutrients on growth and yield of tomato on a slightly alkaline soil. Results revealed that organic mode of plant nutrition through various combinations of neemcake and vermicompost was found superior to chemical fertilizers alone. A higher number of branches and fruit yield with the neem cake and 50 per cent N through vermicompost were recorded.

Facknath and Hurree (2008) reported that available nitrogen and potassium were higher in the organic plot. Application of organic manures like FYM and compost and other organic manures like panchagavya significantly increased the plant height, LAI, DMP, number of branches plant^{-1} and root nodules plant^{-1} over control in all the kharif, rabi and zaid seasons in soyabean.

Shekhar and Rajashree (2009) reported that the application of FYM @ 20 t ha^{-1} recorded the highest number of fruits per plant (37), fruit weight (38.3 g) and yield (42.3 t ha^{-1}) in cowpea. Studies done by Pimentala *et al.* (1984), comparing organic and inorganic grain production system, had also shown that organic farming was more energy efficient. Brinjal was grown organically using pot culture by Patil *et al.* (2009) where the soil was amended organically using oxygenated peptone (containing oxygen, peptone and silicate based inert filler compound) for soil conditioning. He also reported that the enzyme activity of catalase, peroxidase and polyphenol oxidase was improved. Better shelf life, superior taste and better shining of fruit increased its marketability.

Sangeetha and Ganesan (2010) reported beneficial effects on seed germination and yield in greengram by the application of organic inputs like cow dung, goat dung, poultry manure, leaf compost and FYM. Studies were conducted by (Ramassamy, 2010) on the comparative effects of Vermicompost (VC), Farm yard manure (FYM), Seaweed (*Hypnea muciformis* Lamour) and Liquid Fertilizer (SLF) individually and in combination on morphology and yield in okra variety Kumuda 501. The increased leaf area index and better fruit weight were obtained in VC and VC + SLF treatments.

1.1.2 Quality of vegetables

Lower level of nitrates and higher content of vitamin C were reported from organically grown vegetables and have anti-carcinogenic impact on humans. Organic vegetables more readily comply with food requirements of infants and small babies and should be recommended for baby foods (Rembialkowska, 2003).

Gennaro and Quaglia (2003) reported higher average vitamin C content in organic vegetables especially tomato, lettuce, spinach and cabbage. They also reported higher content of phosphorous, magnesium and lower nitrates in organically grown potatoes, carrot, lettuce, spinach, and cabbage. When an acceptability test was conducted, the panelists preferred organically grown okra soup to the chemically grown variant when they assessed the colour, taste, texture, flavour and drawness.

Thybo *et al.* (2006) reported higher dry matter, TSS, citric acids and volatile components in tomato as compared to those obtained from chemical farming. Significant differences were recorded in fruit quality characteristics like colour, brix, pH, acidity, lycopene and phenolic compounds between the organic and inorganically grown tomatoes.

Thimma (2006) conducted an experiment to study the effect of organic manures on growth, yield and quality of chilli under Northern Transition Zone of Karnataka, University of Agricultural Sciences, Dharwad. The quality parameters like oleoresin per cent increased by 13.89, 6.60, 3.70 and 2.30 per cent with application of poultry manure @ 7.50 t ha^{-1}, vermicompost @ 10 t ha^{-1}, FYM (50 %) + vermicompost (50 %), FYM (50 %) + neem cake (50 %), respectively over RDF alone. The extractable colour value also increased by 2.90 to 6.00 per cent with application of FYM (50 %) + poultry manure (50 %), FYM (50 %) + neem cake (50 %) over RDF alone.

Organic products stand out as having higher levels of secondary plant compounds and vitamin C and have more nutritional value. Organic produce has double the flavonoids, an important antioxidant (Dugan, 2007). The organic tomato fruits contained more dry matter, total and reducing sugars, vitamin C, total flavones and beta-carotene, but less lycopene in comparison to conventionally grown tomatoes (Hallmann *et al.*, 2007). The levels of quercetin and kaempferol in organic tomatoes [115.5 and 63.3 mg g^{-1} of dry matter (DM)] were 79 and 97 % higher than those in conventional tomatoes (64.6 and 32.06 mg g^{-1} of DM, respectively) (Alyson *et al.*, 2007). Increased water availability caused an accumulation of reducing sugars in potato tubers only in organic farming, whereas such accumulation was not observed under conventional farming in potato tubers (Maggio *et al.*, 2008).

The crude fibre content of okra var. Arka Anamika fruits under organic manures treatment was also less when compared to control (Shekhar and Rajashree, 2009). Sweet peppers grown under organic culture were reported to have high levels of phenolic compounds, and peroxidase and capsidiol activity that contributed to disease resistance (Francisco *et al.*, 2008).

As far as quality in terms of dry matter, vitamin C and total carotenoids in lettuce are concerned, maximum dry matter content (8.76 % and 10.30 %), vitamin C content (57.72 mg/100 g and 45.62 mg/100 g) and total carotenoids (3.88 mg/100g and 3.43 mg/100 g) were recorded with the sole application of vermicompost @ 6 t ha^{-1} during autumn and spring season, respectively. Among the integrated treatments of organic and inorganic fertilizers, application of 50 per cent recommended fertilizer dose + 3 tonnes vermicompost ha^{-1} registered higher values for dry matter content, vitamin C content and total carotenoids (Mujahid and Gupta, 2010). Organic food are a simple way to reduce an individual toxin burden of pesticides and food additives. It ensures high quality, which other conventional foods cannot commit (Pandey, 2010).

1.1.3 Mulching

Mulching is an agricultural technique that involves placing organic or synthetic material on soil around the plants to provide a favorable environment for growth and production. The beneficial effects of mulch on conservation of soil moisture, lowering of soil temperature, suppression of weed growth were reported by several workers. Use of mulching not only checks the weed growth but also enhances the interval of irrigation scheduling resulting in saving of water (Shijini, 2010).

Kumar (1998) reported that mulched crop of bhindi recorded significantly higher levels of fruit set i.e., on an average 88.1 per cent. The growth characters like mean plants height, green leaves, number of fruiting branches, LAI, yield attributes like number of flowers per plant, number of fruits, total fruit weight etc. were higher in mulched situation than in unmulched situation. A field experiment was conducted to elucidate the effects of mulches on winter fresh market tomato yield and quality. Soil organic C increased when OMs were applied compared with the plastic mulch (PM) (Tu *et al.*, 2006).

Awodoyin *et al.*, 2007 observed that mulches are effective in weed control and conservation of soil moisture and these improvements of crop growing environment resulted in increased growth and fruit yield in tomato. Cover crops and organic mulches (OMs) have been reported as a means to reduce inputs and increase soil quality. Sandal *et al.* (2007) reported that on application of organic wastes as mulch in standing okra crop during the recede of monsoon improved the hydrothermal properties and resulted in higher marketable yields.

Bahadur *et al.* (2009) on irrigation scheduling and mulching in bhindi, it was revealed that in mulched plots the estimated total water applied was 278 mm and 395 mm in non mulched plots. The mulched plants exhibited remarkably higher WUE (466.6 kg ha^{-1} cm^{-1}) and water saving (29.6 %) than non mulched plants. Baiju *et al.* (2010) reported that by the application of green mulch of mixed species, a steady and intermediate rate of nutrient release can be assured which is important for soil fertility management and plant uptake.

Vollmer and Creamer (2010) reported that mulches for no-till organic production of onions gave 50 per cent more yield in onion. Mulching conserves moisture during drought periods and completely checks the growth of weeds and reduces the incidence of soil borne diseases in rainy season in trailing tomato.

Mehta et al. (2010) suggested application of straw mulch also increases the available phosphorus and potassium in the soil. Due to mulching with paddy straw higher tuber yield was recorded in potato crop in the rainfed conditions of Northern Karnataka when limited water was available for cultivation. Paddy straw mulch has shown to reduce soil moisture evaporation losses (Kumar *et al.*, 2010).

1.1.4 FYM

Sittirungsun *et al.* (2001) conducted experiment at Hokkaido in Japan to study the influence of farmyard manure on the yield and quality of Pak-choi (*Brassica chinensis*) and Japanese radish (*Raphanus sativus*) grown without application of chemicals. They reported that nitrate nitrogen concentration of the vegetables decreased with decrease in N application, whereas, the total sugar content increased. Ascorbic acid content increased with application of farmyard manure.

Among the different treatments consisting of farmyard manure, microbial culture, processed city waste, oil cake pellets and vermicompost, FYM produced the best rice with finest cooking and milling quality. The protein content and total minerals of okra fruit increased under the FYM treatment (Bhadoria *et al.*, 2002). A field experiment was conducted at Bhubaneshwar by Khanda and Mohapatra (2003) to study effect of FYM on *Amaranthus hypocondriacus* and maximum yield was obtained (7.7 q ha^{-1}) on application of 5 t of FYM.

Sareedha *et al.* (2007) reported that application of FYM 25 t ha^{-1} along with foliar spray of vermiwash (1:5 dilution) produced best gherkin fruits, with 4.9 cm length, 4.18 cm girth, with average yield of 409 g per plant.Vasmate *et al.* (2007) reported that the different levels of application of organic manure in coriander imparted significant influence on growth parameters like number of leaves, secondary branches, and spread.

According to Prabhakaran (2008) application of poultry manure increased the yield and fruit size in crops like tomato, papaya, strawberry and potato and a dose of even 40 t ha^{-1} is economical. Shekhar and Rajashree (2009) conducted a field experiments were conducted to study the influence of different organic manures on the growth, yield and quality of okra var. Arka Anamika. The results showed that FYM @ 20 t ha^{-1} recorded the highest yield of 10.39 t ha^{-1} with a BC ratio of 3.56. Among the organic manures tested, FYM produced maximum fruit yield and biomass.. The uptake of N, P and K and micro-nutrient in FYM treatment was significantly superior to all other commercial manuring and CF (Rakshit, 2009).

Increasing amounts of organic manure increased the yield of both leeks and celery. However, the C:N ratio of green manures determined the yield response, and from these experiments it was concluded that the C:N ratio has to be below and preferably below 12, if a quick response if needed (Nygaard *et al.*, 2010).

1.1.5 Poultry manure

Srivastava (1998) reported that the production of potato was better when poultry manure was the source of nutrition. He realized 28 kg tubers when poultry manure was the source of one kg nitrogen whereas only 15 kg tubers was realized when FYM was the source. Yanwang *et al.* (2002) reported that the application of cattle waste and poultry waste composts released approximately 31.5 and 51.3 per cent nitrogen, respectively and had decreased nitrate leaching to deeper soil layers. The field trial in Sweden by Stintzing *et al.,* 2002 showed that the pelleted broiler manure gave a better effect on yield in lettuce than stored broiler manure. In Nigeria application of 8 t ha^{-1} of poultry manure was found to be optimum as yield of okra increased by 49 per cent over control (Odeleye *et al.*, 2005).

Zhou-Dongmei *et al.* (2005) obtained rapid growth and high Cu and Zn uptake by radish (*Raphanus sativus* L.) and pakchoi (*Brassica chinensis* L.) due to application of poultry manure. The characteristics of poultry manure are influenced by bird species, age, diet, health, farm management and environment. The total N and P content of poultry manure and litters are among the highest of all animal manures.

The effects of organic manures and N levels on the growth and yield of okra var. Varsha Uphar were investigated in Jobner, Rajasthan. Plant height, node number per plant and branches per plant were increased by the application of both inorganic and organic forms of N. Among the organic sources, PM stimulated better response than FYM and VC at different levels and combinations. Improved growth was noticed for plants under PM. Fruit number, length and girthand total yield were influenced significantly by the application of PM in combination with urea than the combinations of FYM and VC with urea. The highest mean weight of fruits per plant was recorded under PM. The highest quality was obtained under PM (Yadav *et al.,* 2006).

In Nammakal a field trial was done with different combinations of FYM and poultry manure in cassava, along with inorganic manures. The study revealed that all the organic manurial treatments resulted in higher uptake of all the nutrients, higher tuber yield and higher soil nutrient status than the control Amanullah *et al.* (2007).

Poultry manure @ 4 t ha^{-1} gave significant increase in fruit yield (20.1 %) in okra. The leaf nutrient content was also increased with increasing rates of poultry manure (Omotoso and Shittu, 2008). Prasanthrajan *et al.* (2009) observed drastic increase in microbial population and enzyme activity in soil of Coimbatore by the application of poultry manure @ 12 t ha^{-1}. Poultry manure was the most economical in the study on organic nutrient scheduling for okra and cowpea conducted by Geethakumari *et al.,* 2010. In Egypt, it was recorded that the plant growth and yield were greater with poultry manure as compared to plant residues (El-Kader *et al.*, 2010).

1.1.6 Vermicompost

Kumaran *et al.* (1998) showed that the use of organic manure, like FYM and vermicompost combined with recommended dose of inorganic fertilizers showed better performance in terms of growth and fruit yield of tomato.

Tomar *et al.* (1998) indicated that brinjal and carrot plants recorded maximum yield with soil amended with FYM and vermicompost compared to unamended soil.

In an experiment, conducted by Renuka and Ravishankar (2001) in tomato, the application of biogas slurry + FYM, vermicompost alone have recorded maximum fruit size, more number of fruits per plant, while inorganic fertilizers (NPK) recorded the minimum fruit size. It is inferred that tomato crop would respond well to the application of organic manures either in combination with FYM or alone. Further, organic manure application helped to maintain the soil health.

Reddy and Reddy (2005) reported that the yield of onion increased significantly with increasing level of vermicompost (from 10 to 30 t ha^{-1}) and nitrogen fertilizer from 50 to 200 kg ha^{-1}. Vermicompost is a highly nutritive organic fertilizer and plant growth promoter, with high porosity, aeration, drainage and water holding capacity. It contains most of the nutrients in available form and is rich in microbial population and diversity.

Yadav and Vijayakumari (2006) conducted an experiment to evaluate the effect of vermicompost and inorganic fertilizers on the yield parameters of chilli and found that higher number of fruits per plant, fruit weight, fruit length and fruit diameter were obtained by applying vermicompost alone. Vermicompost works as a soil conditioner and its continued application leads to total improvement in the quality of soil (Sinha *et al.*, 2009). The fruit yield increased to 13.51 tonns, fruit number 18.36 plant^{-1}, fruit weight 18 g, fruit length 12.26 cm and fruit thicknes 1.89 cm in okra by the application of vermicompost, as reported by Bairwa *et al.* (2009).

Sutaria *et al.* (2010) reported that organic farming could be adopted by applying enriched compost @ 6 t ha^{-1} or vermicompost @ 2 t ha^{-1} alone prepared from the farm residue for maintaining soil fertility and obtaining good quality products. Application of vermicompost along with organic manures resulted in earlier flowering, increased fruit size, number of fruits and yield in tomato and chilli (Prabhu *et al.*, 2010).

1.1.7 Panchagavya

Panchagavya has got reference in the scripts of Vedas (divine scripts of Indian wisdom) and Vrkshayurveda (Vrskha means plant and ayurveda means health system). The texts on Vrskhayurveda revealed that at field level the farmers certain organic liquids,, and it also defined certain plant growth stimulants; among them Panchagavya was an important one that enhanced the biological efficiency of crop plants and quality of fruits and vegetables (Natarajan, 2003). The positive effect of panchagavya on growth and productivity of crops has been reviewed and documented by Somasundaram *et al.* (2003).

Microbial flora of soil plays an important role in soil health. The microorganisms present in the rhizosphere environment around the roots influence the plant growth and crop yield. The beneficial microorganisms from panchagavya and their establishment in the soil improved the sustainability of agriculture (Swaminathan *et al.*, 2007).

Beaulah (2001) reported that the secondary nutrients, micronutrients and macronutrients contents of leaves and pods of annual moringa were superior under poultry manure + neem cake + panchagavya treatments. Higher nutrient uptake and nutrient use efficiency in both main and ratoon crops of annual moringa were also observed. Similarly, the quality parameters *viz.*, crude fibre, protein, ascorbic acid, carotene content and shelf life were also higher under organic manure applied as panchagavya spray (Beaulah *et al.*, 2002). In an experiment conducted by Jayashankar *et al.* (2002) it was found that 3 per cent spray of panchagavya on field bean increased fruit production and LAI after a week of application.

Panchagavya is having feeding deterrent action (Natarajan, 2003). Application of Panchagavya increased number of flower and fruit production in moringa (Beaulah, 2001). Panchagavya was tested for different crops such as turmeric, paddy, onion, gingely, sugarcane, banana, vegetables and curry leaf and it was found that it enhanced the growth, vigour, resistance to pest and diseases and keeping quality (Natarajan, 2003). Pathak and Ram (2004) reported increase in soil fertility when panchagavya was applied as foliar spray.

Panchagavya and vermicompost combination have given the highest pod yield in french bean variety Ooty 2, which was 36 per cent higher than the conventional method (Selvaraj, 2003). Increase in yield of sunflower, maize and greengram (Somasundaram *et al.*, 2003) and French bean (Selvaraj, 2003) was also observed with panchagavya spray. Similar findings were reported by Boomiraj (2005) wherein increase in fruit weight of bhendi was found due to Panchagavya spray.

Varied reasons have been attributed to the superiority and efficiency of panchagavya by several workers in various crops (Beaulah, 2001 and Natarajan, 2003). Beaulah (2001) explained that the proportion and activity of beneficial microbes were at a higher rate during fermentation resulting in synthesis of growth promoting substances beneficial for crop plants.Presence of macro (N. P, K and Ca) and micro (Zn, Fe, Cu, Mn) nutrients were observed in panchagavya. When sprayed the chemolithotrops and autotropic nitrifiers (ammonifiers and nitrifiers) present in panchagavya, colonize in the leaves which increase the ammonia uptake and enhance the total N supply (Papen *et al.,* 2002).

Panchagavya applied @ 3 per cent spray at 0, 30, 50 days after sowing in rice (Ramanathan, 2006) recorded significantly higher grain yield (5430.00 kg ha^{-1}) over no Panchagavya spray (4990.0 kg ha^{-1}). Panchagavya @ 3 per cent spray 4 times, for bhendi, augmented the yield level in poultry manure (10.27 t ha^{-1}) treated plots and the yield was comparable to that of inorganic (10.39 t ha^{-1}) (Louduraj *et al.,* 2005). Microbial populations (*viz*., bacteria, fungi and actinomycetes) were significantly higher in treatments supplemented with organic manures in combination of beejamrut + jeevamrut or beejamrut + jeevamrut + Panchagavya over RDF + FYM and treatments with fermented organics alone. Similarly enzymatic activities *viz*., phosphatase & dehydrogenaze were significantly higher with supplementation of organic manures + fermented organics. These enhanced biological activities helped in enhancing the soybean crop yield (Babalad, 2005)

Hannah *et al.* (2005) noticed that spraying Panchagavya produced tastier banana fruits. A field experiment was conducted at TNAU, Coimbatore during Feb-May 2003 with an objective to evaluate the impact of organic and inorganic sources of nutrients, panchagavya spray and botanical spray on growth, yield and economics of bhendi. Application of poultry manure @ 21 ha^{-1} with panchagavya foliar spray (3%) four times at 30, 45, 60 and 75 days after sowing, recorded bhendi fruit yield of

10.27 t ha^{-1} and net returns of Rs. 46,440 ha^{-1}, hence basal application of poultry manure along with foliar spray of panchagavya is the best organic approach to soil and crop management for eco-friendly bhendi production (Boomiraj and Lourduraj, 2006).

Guava yield was maximum (38.88 kg $tree^{-1}$), with Panchgavaya. TSS was maximum (12.0° Brix) with Panchgavaya, while ascorbic acid was more (165 mg 100 g $fruit^{-1}$) with FYM treated plants (Ram and Pathak, 2006).

Swaminathan *et al.* (2007) reported that the ultimate product had total N (302.00 mg kg^{-1}), total P (219.00 mg kg^{-1}), total K (355.00 mg kg^{-1}), total organic carbon (0.80 %), bacteria (34 x 106 cfu/ml), fungi (22 x 104 cfu/ml), Actinomycetes (3 x 102 cfu/ml), Zn (0.26 mg kg^{-1}), Fe (0.83 mg kg^{-1}), Mn (0.23 mg kg^{-1}), Cu (0.20 mg kg^{-1}), pH of 6.02 and electrical conductivity 3.02 dSm^{-1}. Increased nitrogen uptake at all growth stages of maize, sunflower and green gram was observed under biogas slurry with Panchagavya. Higher yield of maize and sunflower were recorded under biogas slurry with Panchagavya. Grain yield of greengram was higher under recommended fertilizer treatments but it was comparable to biogas slurry with *Panchagavya*. Among all the organic sources tried, biogas slurry + Panchagavya spray proved to be better than others (Somasundaram *et al.*, 2007).

Swaminathan *et al.* (2007) concluded that application of panchagavya at 3 per cent as foliar spray on 15, 25, and 40 DAS on black gram recorded the highest grain yield of 1195 kg ha^{-1}. According to Sebastian and Lourduraj (2007) foliar fertilization with panchagavya has been used as a means of supplying supplemental doses of minor and major nutrients, plant hormones, stimulants and other beneficial substances. Panchagavya enhanced the biological efficiency of crop plants and the quality of fruits and vegetables. It possessed the properties of both fertilizer and bio-pesticide and increased the economic yield of crops such as rice, green gram, sunflower, turmeric, moringa and coleus.

1.1.7 Fish amino acid

Fish silage is an excellent protein product of high biological value for animal feeding, which can be produced from dead fish, sub-utilized species and by-products from marine fishing, commercial fish waste and industrial residues. These are considered as low quality raw materials, that if not used may cause environmental, health, and economical problems. During silage processing, enzymes found in muscles hydrolyze proteins and nitrogen becomes more soluble. Proteins are hydrolyzed to free amino acids, thus making silage the most available amino acid source for protein biosynthesis (Espe *et al.*, 1989).

Commercial marine fish waste, commercial freshwater fish waste, and tilapia filleting residue were used to produce fish amino acid (Rose *et al.*, 2003). Abhilash (2011) reported 20 per cent more yield in red amaranthus and confirmed boost in growth and colour when fish amino acid was given as foliar spray.

1.1.8 Amrutha Pani

Pathak and Ram (2004) observed that in Rishi krishi, a system of agriculture in Maharashtra, Amrutha Pani was used to treat the seeds and for spraying on field crops to maintain soil fertility and crop yield.

Sethuraman (2004) found that Amrutha Pani when given through irrigation water increased the soil fertility and the soil biological activity. It acted as a nutrient, growth promoter and increased soil enzyme activity which led to high yield. Rajareega (2008) observed that when 500 l ha^{-1} was applied, it acted as a nutrient and growth promoter and essential soil micro organisms were increased.

Selvaraj *et al.* (2006) reported that Amrutha Pani invigorates the living soil and converts dead soil into living one. When the soil is damp, it should be drenched with Amrutha Pani between the rows and not directly on the plants. While planting seedlings of crops such as chilli, tobacco or fruit trees, the small amount of water, which is needed to wet the area around the plants, should be Amrutha Pani. Yelleshkumar *et al.* (2008) found that dipping mangostone in Amrutha Pani (3 % for 3 hours) ensured the highest germination and succesfull graft union.

1.1.10 Oil cakes

Reddy and Reddy (2005) reported that farmers found that bulky organic manures like oilcakes are rich in nitrogen and are important concentrated organic manures, also known as organic nitrogen fertilizer. (Guar, 1979) reported that oil cake if added to soil leads to increased soil activity, and gave a better crop response in Vasmate *et al.* (2007) observed increase in yield due to application of oil cakes in coriander.

Field experiments on okra crop cv. Arka Anamika were set up in an acid alluvial sandy loam soil to evaluate relative efficacy of organic manures in improving productivity. Uptake of N, P and K and micro-nutrient in oil cake applied treatment was significantly superior to all other commercial manuring and CF (Amitava and Debashish, 2008).

Maheswari and Harpriya (2008) observed that application of groundnut oilcake@ 250 kg ha^{-1} for four times recorded maximum number of fruits, highest fruit length, maximum fruit girth and highest dry fruit yield of hot pepper.

1.1.11 Fermented plant extracts

Neem formulations in cow urine are very effective against a number of insects and pest in chickpea (Bajpai and Sengal, 2000). According to Sachan and Lal (1990) explored the utility of neem as a potential source for managing the pod borer complex of pigeon pea. Similarly Perries (1985) observed cow urine and cow dung have been reported to be effective for insect control and plant growth. Application of *Vitex* *negundo*, neem, *Clerodendron* gave a good amount of yield and field was free of pest incidence (Barapatre and Lingappa, 2003). Soil amendments with leaf extracts of calotropis (*Calotropis procera*), datura (*Datura fastuosa*) and neem (*Azadirachta indica*) significantly reduced root-knot infection caused by *Meloidogyne javanica* and improved growth of okra.

Zarina *et al.* (2006) used fresh leaf extract from the following ten plants for the preparation of fermented leaf extract *Azadirachta indica* - 0.5 kg, *Adhatoda vasica, Calotropis gigantia, Nerium oleander, Vitex negundo,* Ipomea, *Parthenium hysterophorus, Ricinus communis, Vinca rosea, Pongamia glabra* and *Carica papaya* leaves 200 g each. Fresh leaf extract from all the above plants were collected and mixed with 0.5 kg cow dung, 0.5 litre of cow urine and it was added to 20 litre water in separate container. The mixture was kept undisturbed for about 30 days for complete fermentation. After 30 days the mixture was filtered and used @ 1.2 ml/l for two times. This treatment resulted in good yield and disease and pest resistance in sorghum. The results were also in close agreement with the reports on yield and pest resistance in sorghum by Shekharappa (2001).

Datura leaf extract was the best treatment, followed by neem and calotropis, in terms of increasing plant growth and reducing root gall development (Zarina *et al.*, 2006). Chalermwut *et al.* (2010) reported that farmers used fermented leaf extracts for higher yields in cole crops.

1.2. FARMERS' INNOVATIONS IN ORGANIC VEGETABLE CULTIVATION

Agriculture in India has a long history which dates back to the Neolithic age of 7500-6500 BC. In those days, the farming systems aimed at maintaining the livelihood of farmers on a sustainable basis, along with livestock, with minimum damage to the environment. In the past decades agricultural development focused on short term improvement of productivity based on external inputs resulting in neglect and improper use of local resources. This has resulted in damage to the environmental resources and indigenous knowledge and hence the agriculture can hardly be perceived as sustainable. During the present scenario all over the world, efforts are being made to work towards ecologically friendly agriculture. One such option is organic farming as it is a holistic approach which takes care of all the components of the system. It is nature based, environment friendly and sustainable, ensuring not only the requirement of the present but also ensures the conservation of resources for future. Organic farming has developed very rapidly in recent years. Indian agriculture has a better chance to convert to organic agriculture because the per capita and per ha consumption of chemical fertilizer and pesticides in the country is much lower than the global standards. In olden days, cattle based agriculture was widely practiced (Swaminathan , 2011).

In India many techniques were used in the past but most of them are not being practiced at present. There is a great need to validate many of these potentially useful techniques through research. The term indigenous technology which is being practiced is referred by different names. Warren (1989), called it as indigenous technology knowledge (ITK). Similarly, Gupta (1990) called the same as indigenous innovation.

In 1950, Martin of USA made a liquid catalyst (living water) from milking cow, using dung, sea water and yeast and it was claimed that it was capable of greening degraded land (Vivekanandan *et al.*, 1998). Cows ghee had been used in ancient and medieval times (Kautilya 321-296 BC and Someshwara Deve 1126 AD) for managing seedling health. The ghee contains vitamin A, vitamin B, calcium, fat and also glycosides, which protects cut wounds from infection. Cows curd is rich in microbes (*Lactobacillus*) that are responsible for fermentation and imparts resistance to crop plants.

Farmers used *Clerodendrum phlomidis* for imparting resistance against viral diseases (Nene, 1999). Milk, ghee and buttermilk have been used in agriculture for centuries. Glutamate, leucine and proline make up about 40 % of the total amino acids in milk. Milk is reported to contain plant growth promoters. A recent report (Kumar *et al.*, 2002) claimed that spraying with milk induced systemically acquired resistance (SAR) in chilli against leaf-curl virus. Milk (10 % aqueous suspension) has also been used effectively for controlling powdery mildews. Besides, milk has excellent sticker-spreader properties (Nene, 1999).

Seed priming with organics for enhancing yield of rain fed black gram was practiced by farmers and was tested by Chandramohan (2002) and came up with the result that it increased growth, dry matter, yield, and reduced soil born diseases. The organic growers of Tamil Nadu used panchagavya widely for various agricultural and horticultural crops (Natarajan, 2003). In jasmine, it ensures continuous flowering and in annual moringa it doubles the fruit yield besides giving resistance to pest and diseases (Somasundaram *et al.*, 2003). He also reported that yield attributes of Sunflower, Maize and Greengram were increased through folir spray of Panchagavya. Of late, farmers have started to use panchagavya for crop protection as it possessed feeding deterrent action (Natarajan, 2003). Increased crop yield due to panchagavya spray was reported by Selvaraj (2003) in French bean and Boomiraj (2005) in bhindi. Use of Panchagavya and Amrutha Pani was also practiced by farmers to enhance germination (Pathak and Ram, 2004) and (Natarajan, 2003).

According to Palekar (2006), Beejamrut was used by the organic farmers for seed or seedling treatment to increase the germination and growth of seedlings as it contains growth hormones and microbial load. According to Palekar (2006) and Vasanthkumar (2006) Jeevamrut is a fermented liquid containing enormous amount of microbial load which multiply and act as a soil tonic to enhance microbial activity in soil and ultimately ensuring the availability and uptake of nutrients by the crops. Amrutha Pani and vermiwash was used by some farmers in Tamil Nadu (India) as pest repellent, antifeedant and growth promoter Sebastian and Lourduraj (2007). Use of Panchagavya recorded maximum colour value (243.5 ASTA units in red fruits of chilli (Cv. Byadgi Dabbi)) (Kondapanaidu, 2009).

Gill and Prasad (2009) found that farmers still used traditional organic formulation, the best performing treatments were combinations of; non-edible oil cake (NEOC) + cow dung manure (CDM) + enriched compost (EC) at Raipur; farmyard manure (FYM) + NEOC at Ranchi; CDM + poultry manure (PM); EC + Vermicompost + green leaf manure (GLM) + neem cake(NC) at Dharwad; FYM + VC + NEOC at Jabalpur; FYM + crop residues(CR) + GLM in rice-red pumpkin and rice-cucumber, and VC + Glyricidia leaf manure in mango at Karjat; FYM + NEOC at Coimbatore; FYM+VC at Pantnagar; FYM+VC+CR-FYM at Ludiana; EC + VC + NEOC at Modipuram; FYM (+RP) + VC at Bajaura; and FYM + VC + NC at Calicut. At Dharwad, a schedule of seedling dipped with cow urine + dung slurry, botanical spray at 30 DAT, cow urine + 5 % NSKE spray at 45 DAT, Panchagavya 3 % + botanicals spray at 60 DAT, Buttermilk (20 %) + Panchagavya 3 % spray at 75 DAT, Botanicals + Buttermilk (20 %) spray at 90 DAT, 5 % NSKE + vermiwash spray at 110 DAT in chillies was found effective for high yield and resistance against fruit borer and leaf curl in chillies. Rice, wheat, pulses and vegetables were the prominent crops being grown under organic farming. Majority of organic farmers (62 %) were satisfied with organic farming and was practicing it mainly due to the perception that organic farming improves the soil health, environment and human health (69.5 %) (Aulakh *et al.*, 2009).

The majority of farmers were managing insect pest and diseases by using neem (azadirachtin) based products followed by extract of leaves of datura, akk (*calotropis*), cow's urine , Jeev amrit, onion + garlic extract and hing (asafoetida). Other biopesticides being used by some organic growers were *Trichoderma* and

Beauveria. Vermiwash, basically a nutritional source was also being used for pest management (Aulakh *et al.,* 2009).

Farmyard manure and vermicompost were the major organic manures being used followed by green manure and Jeev Amrit. Environment, human health and improved soil health were the major concerns to adopt organic farming. Lack of marketing facilities and difficulty in control of pest and diseases were the two most serious constraints in its adoption (Aulakh *et al.,* 2009).

The farmers in the case study perceived that they had improved their livelihoods over the long term by the conversion from conventional to organic farming. Reduced costs for external inputs and reduced labour requirements together with similar or higher yields and premium prices resulted in higher net-farm income. The conversion to organic farming reduced the reliance on credits and the risk of crop failure due to pests, diseases and droughts, thereby reducing vulnerability. In addition, the farmers mentioned enhanced natural assets, reduced risk of pesticide poisonings, improved food safety, higher levels of self-sufficiency, and the access to networks supporting knowledge exchange and political participation as important benefits of the conversion (Lukas and Cahn, 2008).

1.3. EFFECT OF ORGANIC MANURES ON PHYSICAL, CHEMICAL AND BIOLOGICAL CONDITIONS OF SOIL

1.3.1 Physio-chemical properties of Soil

In vertisol, application of 5 t each of FYM, sunhemp, subabul and sorghum stubbles for three successive years recorded organic carbon per cent of 0.68, 0.61, 0.66 and 0.53, respectively against the initial level of 0.48 per cent (Badanur *et al.*, 1994).

Hapse (1993) reported that the vermicompost application enhanced the organic carbon content of soil as compared to fertilizer alone. Chenkai (1993) reported that incorporation of organic residues not only reduced bulk density but also improved soil porosity and nutrient availability. The compactness of a soil is known to be related to its content of water and air, and to the temperature and the supply of nutrients.

Bellakki and Badanur (1994) observed a significant decrease in bulk density with incorporation of sorghum stubbles and subabul loppings @ 5 t ha^{-1} compared to that of only chemical fertilizers application. Similar results with incorporation of FYM and vermicompost as compared to only chemical fertilizer application were observed by Babalad (1999).

Mastiholi (1994) reported that after harvest of rabi sorghum organic carbon content of soil was more due to application of vermicompost than chemical fertilizers alone. Application of poultry manure has decreased bulk density, increased organic matter content of soil, total porosity and water infiltration capacity of soil (Obi and Ebo, 1995). Bulk density provides a correct overall picture of the physical conditions of a soil. Loosely packed soils, which have a lower bulk density, will usually have better aeration, better drainage, will be warm and will have a longer growing season (Saini, 1997).

Mathur (1997) observed that incorporation of 16 tonnes FYM accounted for highest increase in organic carbon content of soil. Itnal (1997) noticed that application of maize straw @ 5 t ha^{-1} and cotton residue reduced the bulk density from 1.3 g cm^{-3} in control to 1.04 and 1.11 g cm^{-3}, respectively. The bulk density was also reduced by combined application of FYM and inorganic fertilizers (Mishra and Sharma, 1997). Patil (1998) observed that, incorporation of FYM @ 2.5 t ha^{-1} and vermicompost @ 1.0 t ha^{-1} enhanced the soil moisture content compared to only fertilizer application in the vertisols of Bijapur.

Lal *et al.* (2000) reported that incorporation of organic wastes like lantana, water. Hyacinth, subabul leaves, lentil straw, maize stover and rice straw significantly increased pH of an acid clay loam soil. Srikanth *et al.* (2000) observed an increase in the organic carbon status of soil due to addition of FYM either alone or in combination with fertilizers because of an increase in the addition of root biomass to the soil he also found a significant decrease in bulk density (1.27-1.18 g cm^{-3}) of soil after harvest of second crop in the soil amended with compost compared to the soil applied with inorganic fertilizers.

Sharma *et al.* (2000) reported a significant reduction in the bulk density improved water holding capacity and observed that the micronutrients like Zn, Fe, Mn and Cu content increased significantly due to crop residues and FYM incorporation compared to chemical fertilizer application. In vertisols, the bulk density was reduced from 1.32 to 1.28 g cm^{-3} in one season itself and application of composted coir pith and FYM reduced the bulk density appreciably over the control (Patil *et al.*, 2003).

Maximum water holding capacity of soil decreased with application of fly ash while it increased due to increasing FYM level (Patil *et al.*, 2003). Hangarge *et al.* (2004) reported higher organic carbon content, lower pH and EC with the combined application of vermicompost @ 5 t ha^{-1} and cow dung slurry @ 1 l/m^2 and organic booster @ 1 l/m^2. The microbial biomass C and mineralizable N was more with the addition of organic farming treatments. Organically-managed soils had higher organic matter content and provided a more stable soil structure than conventionally-managed soils (Papadopoulos *et al.*, 2006).

Gathala *et al.* (2007) observed that the addition of FYM increased the organic carbon content and lowered the bulk density. Use of organic sources of nutrients conserves the soil health by maintaining the equilibrium of organic matter and soil microflora (Walia and Kler, 2007). Shwetha and Babalad (1999) reported that the soil organic carbon content and available soil nutrients *viz.*, N, P_2O_5 and K_2O after harvest of soybean and wheat were significantly higher with the application of organic manures in combination with fermented organics over organics alone. The higher organic carbon, available N, P_2O_5 and K_2O values which ranged between 0.72 and 0.74 per cent, 263.40 and 269.60 kg ha^{-1}, 17.50 to 17.90 kg ha^{-1} and 383.00 and 391.00 kg ha^{-1}, respectively were recorded with combined application of organic matter and fermented organic manures Similarly, the uptake of N, P and K was also more with combined application of fermented organics and organics than RDF + FYM.

Ravishankar *et al.* (2008) reported that addition of FYM, vermicompost, neemcake and biofertilizers significantly contributed to the imporvement in soil organic carbon content. 50 per cent N as FYM also improved the soil organic carbon. He also found that application of organic sources of nutrients contributes to the improvement of organic carbon in the soil.

Gill and Prasad (2009) found that at Raipur the bulk density values remained lower (0.12 g/cc) in organic management compared to inorganic and integrated systems during all the years of study. P concentrations of the leaves and fruits were increased as the application rate of PM was increased. High levels of PM slightly increased the concentrations of leaf Mo and Br at the harvest stage Poultry manure applications had a positive effect on the concentrations of leaf Zn and Cu at both sampling stages (Azeez *et al.*, 2009).

Bandyopadhyay (2009) also reported an improvement in the physico-chemical properties of soil with the application of vermicompost along with chemical fertilizers in many crops. Addition of organic matter have been reported to increased the status of major and micronutrients along with enhancement of organic carbon and other physical properties of soils (Sur *et al.*, 2010). Jha *et al.* (2011) reported that under rice-potato-okra system, with different organic and inorganic nutrient management, the 100 per cent organic nutrient supply system exhibited a pronounced improvement in organic carbon content of soil.

1.3.2 Biological and microbial activity

Kumaran *et al.* (1998) reported that the improvement in quanity of fruit may be attributed to the improvement biological (bacteria fungi, actinomycetes and earth worm activity) properties in the soil. Delschen (1999) reported that organic farming practice and reduced-input strategies could rapidly improve soil microbial characteristics he also found that fields cultivated organically had higher biological activity and earthworms than conventionally cultivated fields

Highest population of bacteria and actinomycetes in the soil was observed in treatments with organic manures + bioinoculants. This was in agreement with the findings of earlier workers (Krishnakumar *et al.*, 2005; Hangarge *et al.*, 2004 and Ravishankar *et al.*, 2008) who recorded a significant positive association between organic matter status and microbial population (bacteria, fungi and actinomycetes) in the soil.

Rajeshwari (2005) reported significant increase in dehydrogenase activity with the application FYM. The significant increase in available P content could also be attributed to the organic manure mediated complex formuation of cations like Ca, Mg and Al responsible for fixation of P in soil (Sushma *et al.*, 2007). (Chandrakala, 2008) reported that dehydrogenase activity was significantly high for the treatment with Panchagavya in chilli (27.68 and 22.5 μg TPF/gm soil/day at 120 and 160 DAT respectively).

Shwetha and Babalad (2009) reported that the combined application of fermented organics *viz.*, Beejamrut, Jeevamrut, Panchagavya along with organics such as compost, vermicompost and green leaf manure recorded a higher soil biological activity. The dehydrogenase activity was higher with combined application of organics and fermented organics than their individual applications and RDF + FYM. The highest dehydrogenase activity of 34.84 g TPF g^{-1} soil day^{-1} was observed with compost + vermicompost + green leaf manure + Jeevamrut + Beejamrut and was on par with the treatment receiving vermicompost + green leaf manure + Jeevamrut + Beejamrut + Panchagavya. The lowest dehydrogenase activity of 24.27 g TPF g^{-1} soil day^{-1} was noticed with the application of RDF + FYM at 60 DAS of soybean.

Shashidhar *et al.* (2008) found more number of bacterial , fungal and actinomycetes colonies in plots mulched with *Cassia sericea* (32 cfu × 10^5/g), paddy straw (53 cfu × 10^4/g) and sunhemp (53 cfu× 10^3/g) respectively. Different organic manuring treatments gave significantly higher microbial population (fungi, bacteria and actinomycetes) and enzymatic activities in the soil and application of FYM (20 kg/plant) was best for improving soil quality (Ravishankar *et al.*, 2008).

Radhakrishnan (2009) reported that vermicompost contained appreciable count of beneficial microorganisms like *Pseudomonas, Azospirillum*, PSB, yeast, moulds and actinomycetes. Prasanthrajan *et al.* (2009) observed maximum microbial population and enzyme activity in soil applied with poultry manure @12 t ha^{-1}.

The addition of organic manures like FYM, vermicompost, neem cake significantly contributed to the improvement in soil microbial load in maize-rice-greengram cropping system at Tanjavur (Porpavol *et al.*, 2010). Kumar and Singaram (2011) reported increase in enzymes activity of the soil by increase in dehydrogenase, urease and catalase activity by the application of panchagavya 3 per cent as foliar spray.

1.4. EFFECT OF ORGANIC MANURES ON AVAILABILITY AND UPTAKE OF NUTRIENTS BY VEGETABLE CROPS

Studies on soil nutrients alone would not give any inference on the influence of various nutrients on plant growth and development. For that, the availability and uptake of nutrients by plant has to be studied. The availability and uptake of nutrients is influenced by several soil and plant factors. Organic manures greatly influence the availability and uptake of major and minor nutrients and are reviewed here under.

Babalad (1999) observed that application of crop residues recorded significantly higher available nitrogen (13 %) as compared to no residue in soybean safflower sequence. Mineralization and immobilization of phosphorus in soil with the addition of organics have been reported by a number of workers.

Channabasavanna and Biradar (2002) opined that as the nutrient present in poultry manure is easily available, its effect can be noticed directly on the crop and residual effect can also be seen. Due to high content of NPK, it has been proven that one tonne of poultry manure is equivalent to seven tones of farmyard manure and maintain adequate N status of soil. Patidar and Mali (2002) found that available N and P in soil increased after harvest of sorghum with farmyard manure 10 tonnes ha^{-1}.

Pannu *et al.* (2003) observed that all organic materials showed less K fixation as compared to inorganic N fertilizer. Nalatwadmath *et al.* (2003) reported a buildup of available K only in organic manure treatment which was maximum (33 %) as compared to control. Hangarge *et al.* (2004) reported that the application of liquid organic cowdung urine slurry @ 2 l m^{-2} along with vermicompost @ 5 t ha^{-1} in chilli resulted in higher available N (353.00 kg ha^{-1}), P_2O_5 (21.00 kg ha^{-1}) and K_2O (284.00 kg ha^{-1}) soil than those soil receiving RDF (319.00, 18.00, 280.00 kg N, P_2O_5 and K_2O respectively). Bonde *et al.* (2004) reported that incorporation of organic residues and FYM enhanced the soil available nutrient status. The highest available nitrogen (308.10 kg ha^{-1}), phosphorus (19.14 kg ha^{-1}) and potassium (290.40 kg ha^{-1}) were recorded with the application of FYM @ 5 t ha^{-1}compared to other organic residues application such as pressmud compost @ 10 t ha^{-1}, wheat straw @ 5 t ha^{-1}, sugarcane trash @ 5 t ha^{-1} and control under cotton-soybean intercropping in vertisol.

Dademal and Dongale (2004) conducted an experiment to know the effect of application of organic manures and fertilizers on concentration and uptake of nutrients by okra on lateritic soils of Konkan at College of Agriculture, Dapoli. The results revealed that the application of FYM @ 7.50 t ha^{-1} recorded higher total N (2.48 %), P (0.52 %) and K (3.10 %) over vermicompost applied @1.5 t ha^{-1} and no manure in fruits of okra besides recording higher uptake of N (437.80 mg $plant^{-1}$), P (72.40 mg $plant^{-1}$) and K (370.30 mg $plant^{-1}$) by okra.

Patil *et al.* (2005) had undertaken the studies on the effect of fly ash and FYM on nutrient uptake and yield of onion at Department of Horticulture, MAU, Parbhani during 1999. The results indicated that with increasing levels of FYM (0, 5, 15 and 30 t ha^{-1}), there was corresponding increased in uptake of N (ranged from 0.08 to 0.13 g $plant^{-1}$), P (ranged from 0.12 to 0.15 g $plant^{-1}$) and K (ranged from 0.61 to 0.92 g $plant^{-1}$) by onion bulb besides increasing onion yield. Santoshkumar and Shashidhara (2006) observed an increase in uptake of N, P, K, with application of FYM @ 10 t ha^{-1}. The increased nitrogen, phosphorus and potassium uptake was to the tune of 49.40, 9.00, 40.16 kg ha^{-1} respectively.

Yadav and Chhipa (2007) found that the application of FYM up to 20 t ha^{-1} increased the NPK contents significantly of the soil at Jaipur district, Rajasthan. The increase was to an extent of 19.58, 23.30 and 16.49 per cent N, P and S, respectively with the application of FYM up to 30 t ha^{-1} and 25.16 and 19.73 per cent P and K, respectively with the application of FYM up to 20 t ha^{-1} over control (no FYM). Similarly, the grain and straw yields of wheat increased significantly with the successive increase in the levels of FYM and consequently, the application of 30 t FYM ha^{-1} recorded the highest grain (2.79 t ha^{-1}) and straw (4.3 t ha^{-1}) yield over FYM @ 10 t ha^{-1} (2.29 and 3.50 t ha^{-1} grain and straw yield, respectively) and FYM @ 20 t ha^{-1} (2.60 and 4.00 t ha^{-1} grain and straw yield, respectively).

Shwetha and Babalad (2009) reported that the soil organic carbon content and available soil nutrients *viz.*, N, P_2O_5 and K_2O after harvest of soybean and wheat were significantly higher with the application of organic manures alone or in combination with fermented organics over organics alone. The higher organic carbon, available N, P_2O_5 and K_2O values which ranged between 0.72 and 0.74 per cent, 263.40 and 269.60 kg ha^{-1}, 17.50 to 17.90 kg ha^{-1} and 383.00 and 391.00 kg ha^{-1}, respectively were recorded with combined application of fermented organic manures *viz.*, Beejamrut, Jeevamrut and Panchagavya and organics *viz.*, compost, vermicompost and green leaf manure than the individual application of fermented organics and RDF + FYM after harvest of soybean under soybean-wheat cropping system. Similarly, the uptake of N, P and K was also more with combined application of fermented organics and organics over RDF + FYM and the individual applications of organics and fermented organics.

Bairwa *et al.* (2009) observed higher amount of available NPK in the experimental plot of okra where FYM, vermicompost and neem cake were applied. Kondapanaidu *et al.* (2009) reported that combined use of organics (FYM, vermicompost, biofertilizers and panchagavya) resulted in higher uptake of major nutrients in chilli. Chattoo *et al.* (2010) observed significant influence of organic sources on nutrient uptake and reported that application of poultry manure resulted in the highest uptake of all major nutrients in onion.

According to Geethakumari *et al.* (2010) maximum NPK uptake was observed in okra and cowpea when poultry manure, FYM and neem cake were used as nutrient sources, in comparison to all other sources. The application of liquid organics such as cow dung urine slurry, resulted in higher uptake of N, P and K by tomato plants (1.25 to 1.26 g $plant^{-1}$, 0.07 to 0.08 g $plant^{-1}$ and 0.84 to 0.86 g $plant^{-1}$, respectively) than those which received the recommended dose of fertilizers (1.05, 0.06 and 0.8 g $plant^{-1}$ N, P_2O_5 and K_2O, respectively) Magray *et al.* (2011).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench)" was carried out in the Department of Olericulture, College of Horticulture, KAU, Vellanikkara, Thrissur during 2010-11.

3.1 SITE, SOIL AND CLIMATE

The experiment was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara. The experimental site is located at 10° 32□ N latitude and 76° 13□ E longitude and at an altitude of 22.5 m above MSL .The experimental site has a sandy loam soil, which is acidic in reaction (pH 5.3). The area lies in tropical monsoon climatic region, with more than 80 per cent of the rainfall getting distributed through southwest and northeast monsoon showers. Data on temperature, rainfall, relative humidity, number of rainy days and sunshine hours during the entire cropping period were collected from meteorological observatory of College of Horticulture, Vellanikkara (Appendix I).

3.2 SEASON OF EXPERIMENT

The experiment was conducted during May - September 2010 and consisted of the following aspects:

- Testing and scientific validation of the farmer driven technologies in organic nutrient management in okra.

- Evaluation of organic management in terms of yield, shelf life and fruit quality of okra.

3.3 EXPERIMENTAL MATERIAL

3.3.1 Crop variety

The Okra variety Arka Anamika released from Indian Institute of Horticulture Research, Bangaluru was used for the study. The seeds of this high yielding and yellow vein mosaic resistant variety was obtained from vegetable seed production complex, Department of Olericulture, College of Horticulture, KAU, Vellanikkara, Thrissur.

3.4 EXPERIMENTAL METHOD

3.4.1 Design and layout

Design	-	Randomised Block Design
Replication	-	3
Plot size	-	3.6 x 3.6 m^2
Variety	-	Arka Anamika
Treatments	-	12

3.4.2 Treatments

T_1 - Manures and fertilizers as per POP recommendation

T_2 - Manures and fertilizers as per POP recommendation along with mulching

T_3 - FYM 17 t ha^{-1}

T_4 - Poultry Manure 12.5 t ha^{-1}

T_5 - Vermicompost 9 t ha^{-1}

T_6 - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost

T_7 - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost + Std. Panchagavya (P) at 10 days interval

T_8 - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval

T_9 - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost + Std. Amrutha Pani (AP) at 10 days interval

T_{10} - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval

T_{11} - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost + Fermented Plant Extract (FPE) at 10 days interval

T_{12} - 4 t ha^{-1} FYM + 3 t ha^{-1} Poultry Manure + 2.5 t ha^{-1} Vermicompost + P + FAA+ AP+ FOC+ FPE (2 times each)

In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided. Preparation of organic liquid manures (T_7 to T_{12}) is given in Appendix II.

3.4.3 Cultural operations

The experimental area was ploughed, harrowed and ridges were taken. Seeds were sown at the recommended spacing. Gap filling and thinning were done to secure a uniform stand of the crop. Weeding was done as and when required and nutrients were given as per the treatments.

3.4.4 Observations

Five plants per replication were selected from each treatment for taking observations. Following parameters were recorded and average was worked out for further analysis.

3.4.4.1 Growth parameters

3.4.4.1.1 Days taken for germination

The number of days taken for germination was noted and expressed in numbers.

3.4.4.1.2 Height of plant (m)

The height was taken from the base to the tip at the final harvest.

3.4.4.1.3 Number of branches

The number of branches was counted at the final harvest.

3.4.4.1.4 Nodes of first flower emergence

The position of the node on which the first flower emerged was counted from five plants and the mean was computed.

3.4.4.1.5 Days to first flower opening

The number of days was counted from the date of sowing to the opening of the first flower of five plants and the mean was computed.

3.4.4.1.6 Flower length (cm)

The length of five randomly selected flowers was measured from the base to the tip and the mean was computed.

3.4.4.1.7 Flower width (cm)

The diameter of five randomly selected flowers was measured and the mean was computed.

3.4.4.1.8 Leaf area index (LAI)

The leaf area index was worked out using the formula suggested by Watson (1962) at 50 DAS.

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

3.4.4.1.9 Total dry matter (TDM) (t ha^{-1})

The whole plant with leaves, stem and roots were oven dried at $50 \pm 5\ ^0$C to constant weight. The final dry weight was worked out.

3.4.4.1.10 Average fruit weight (g)

The weight of twenty pods was observed in an electronic balance and the average was worked out.

3.4.4.1.11 Fruit length (cm)

Length of twenty randomly selected fruits at vegetable maturity was measured and the average was worked out.

3.4.4.1.12 Fruit girth (cm)

The girth at the middle most portion of twenty randomly selected fruits at vegetable maturity was measured and the mean was worked out.

3.4.4.1.13 Number of seeds per fruit

The number of seeds in twenty fruits at fifth harvest was counted and recorded as average.

3.4.4.1.14 Days to first harvest

The number of days from sowing to the date of first harvest of the fruits was noted

3.4.4.1.15 Number of harvests

The total number of times the fruits were harvested was recorded.

3.4.4.1.16 Crop duration

The number of days from sowing to the date of final harvest of fruits at vegetable maturity was noted.

3.4.4.1.17 Fruits per plant

The total number of fruits produced per plant at the time of each harvest was recorded and the average was worked out.

3.4.4.1.18 Yield per plant (g)

Fruits were harvested separately from each plant periodically; weighed using a top loading balance and the total was worked out.

3.4.4.1.19 Yield per plot (kg)

Fruits were harvested separately from each plot periodically; weighed using a top loading balance and the total was worked out.

3.4.4.1.20 Yield per hectare (t ha^{-1})

Fruits were harvested separately from each plot periodically; weighed using a top loading balance and the total yield per hectare was worked out.

3.4.4.2 Incidence of pests and diseases

The incidence of pest and diseases were observed and recorded.

3.4.4.3 Fruit quality parameters

The quality of the fruits was judged by taking five fruits per treatment randomly. The following quality parameters were analyzed as detailed in Table 1.

3.4.4.4 Shelf Life

Five fruits from each treatment was harvested at five days maturity and kept in open room temperature (ambient conditions). Observations were taken, up to the day on which the fruits started expressing signs of shriveling and loss in physical appearance.

3.4.4.4.1 Physiological loss in weight

Ten fruits from each treatment were harvested at five days maturity. Two sets of five fruits each were kept under ambient and refrigerated conditions for twelve days. The loss in weight was recorded and expressed in per cent.

Table 1. Methods followed for quality analysis of fruits

Sl. No.	Parameters	Method followed	Reference
1.	Moisture	Oven drying	Ranganna (1987)
2.	Crude fibre	Acid alkali digestion method	Sadasivam and Manickam (1996)
3.	ß-Carotene	A.O.A.C method	A.O.A.C (1980)
4.	Crude protein	N % x 6.25	Simpson *et al.* (1965)
5.	Vitamin C	Titration with 2, 6-dichlorophenol indophenol dye	Sadasivam and Manickam (1996)
6.	Calcium, Magnesium, Manganese, Copper, Zinc and Iron	Atomic Absorption Spectroscopy	Issac and Kerber (1971)
7.	Nitrogen	Modified Kjeldhal Digestion Method	Jackson (1973)
8.	Phosphorus	Spectrophotometry (Vanadomolybdo Phosphoric yellow colour method)	Issac and Kerber (1971)
9.	Potassium	Flame Photometry (Neutral Normal ammonium acetate extract)	Jackson (1973)

3.5 PLANT ANALYSIS

Five plant samples were collected from each treatment. The fruit, leaf, shoot and root samples were dried in a hot air oven at 50° C. Drying was continued till the samples attained constant weight. The following quality parameters were analyzed as detailed in Table 2.

3.5.1 Chlorophyll

The total amount of chlorophyll in leaves was measured using digital chlorophyll meter (Konica Minolta) on fifty DAS and expressed as SPAD (Soil Plant Analysis Development) units.

Table 2. Methods followed for plant analysis

Sl. No.	Parameters	Method followed	Reference
1.	Calcium, Magnesium, Manganese, Copper, Zinc and Iron	Atomic Absorption Spectroscopy	Issac and Kerber (1971)
2.	Nitrogen	Modified Kjeldhal Digestion Method	Jackson (1973)
3.	Phosphorus	Spectrophotometry (Vanadomolybdate yellow colour method)	Issac and Kerber (1971)
4.	Potassium	Flame Photometry (Neutral Normal ammonium acetate extract)	Jackson(1973)

3.5.2 Plant uptake of NPK

The per cent content of each nutrient was multiplied with the dry weight of root, stem, leaf and fruit separately for NPK and the total uptake was calculated in kg ha^{-1}.

3.6 SOIL ANALYSIS

Soil samples were collected separately from each experimental plot in the beginning and at the end of the experiment. The soil samples were air dried and analyzed for physical and chemical characteristics as detailed in Table 3.

3.6.1 Microbial population in soil

The microbial count of the soil samples was enumerated at the beginning, at 50 DAS and 100 DAS. The method used for the evaluation was Serial Dilution and Plate Count Technique as described by Agrawal and Hasija (1986).Ten grams of soil was added to 90 ml sterile water and agitated for 20 minutes. One ml of the solution was transferred to a test tube containing 9 ml sterile water to get 10^{-2} dilution and similarly 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} dilutions were also prepared.

Enumeration of total microbial count was carried out by using different media as detailed in Table 4. Suspension (15-20 ml) was poured on the corresponding medium. Plates were incubated at 28±2°C. Observations were taken as and when the colonies appeared (bacteria- 2-3 days, fungi- 5-7 days and actinomycetes- 3-14 days).

Table 3. Methods followed for soil analysis

Sl. No.	Physical / chemical characters	Method followed	Reference
1.	Organic Carbon (%)	Chromic acid wet digestion method	Walkely and Black (1934)
2.	Organic Matter (%)	Organic Carbon × 1.74	Jackson (1973)
3.	pH	1:25 soil water ratio	Jackson (1973)
4.	EC	Conductometric method	Jackson (1973)
5.	Available N (kg ha^{-1})	Modified Kjeldhal Digestion Method	Subbaiah and Asija (1982)
6.	Available P_2O_5 (kg ha^{-1})	Spectrophotometry (Bray-1 Extractant Ascorbic acid reductant)	Bray and Kurtz (1945)
7.	Available K_2O (kg ha^{-1})	Flame Photometry (Neutral Normal ammonium acetate extract)	Jackson (1973)
8.	Bulk density, Pore space and Water holding capacity	Keen Raczkowski Box method	Piper (1966)

3.7 B:C Ratio

Benefit cost ratio was worked out as per the formula given below

$$\textbf{BCR} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

Table 4. Media used for enumeration of soil micro organisms

Sl. No.	Microbes	Dilution for plating	Medium	Reference
1.	Bacteria	10^{-5}	Nutrient Agar	Rao (1986)
2.	Fungi	10^{-4}	Martin's Rose Bengal Agar	Martin (1950)
3.	Actinomycetes	10^{-6}	Kenknight & Munaier's Medium	Rao (1986)

3.8 Statistical analysis

Data pertaining to different characters were tabulated and subjected to statistical analysis using the MSTAT-C package (Federer, 1955). Treatments having same alphabets as superscript belong to homogenous group.

RESULTS

4. RESULTS

The studies on "Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench" were carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010-11 (Plates - 1 and 2). The results obtained from the experiment are presented under following heads.

4.1 GROWTH PARAMETERS

4.1.1 Days taken for germination

The number of days to germination did not differ among the treatments. In all the treatments germination was on the fourth day after sowing (DAS).

4.1.2 Height of plant

The data on plant height measured on the day of last harvest is presented in Table 5 and Fig 1. There were significant differences among the treatments for the height of the plants. The maximum height was recorded in treatment T_4 (3.61 m) on 120^{th} day and was on par with T_{11} (3.48 m), T_{10} (3.40 m) and T_9 (3.26 m). T_1 recorded 1.76 m on the final day of harvest.

4.1.3 Number of branches

The data on number of branches on the day of last harvest is presented in Table 5 and Fig 2. There were significant differences among the treatments for the number of branches of okra plants. The maximum number of branches was recorded in treatment T_4 and T_{11} (8) on 120^{th} day and it was on par with T_8, T_9, T_{10} and T_{12}. The plants under treatment T_1 had a duration of 97 days and it possessed only two branches during the final day of harvest.

Table 5. Height and number of branches at final harvest

TREATMENTS	Height (m)	Number of branches
T_1	1.76^{e}	2.00^{f}
T_2	2.16^{de}	3.33^{e}
T_3	2.46^{bcd}	4.66^{d}
T_4	3.61^{a}	8.00^{a}
T_5	2.30^{de}	4.00^{d}
T_6	2.35^{de}	6.00^{d}
T_7	2.59^{bc}	7.33^{c}
T_8	2.86^{b}	7.66^{ab}
T_9	3.26^{a}	7.66^{ab}
T_{10}	3.40^{a}	7.33^{c}
T_{11}	3.48^{a}	8.00^{a}
T_{12}	2.67^{bc}	7.33^{c}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, T_2 - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, T_4 - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Plate 1.General view of experimental plot

Fig. 1 Height of okra plants at final harvest

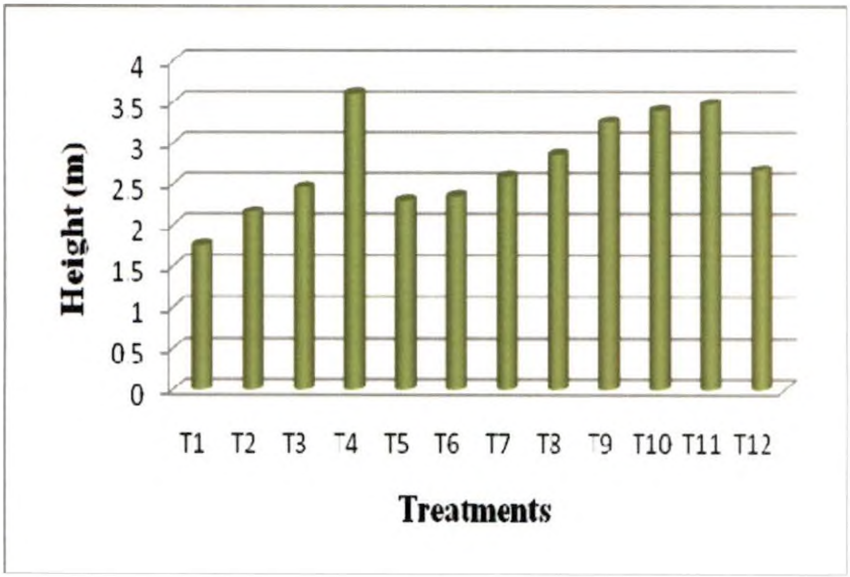
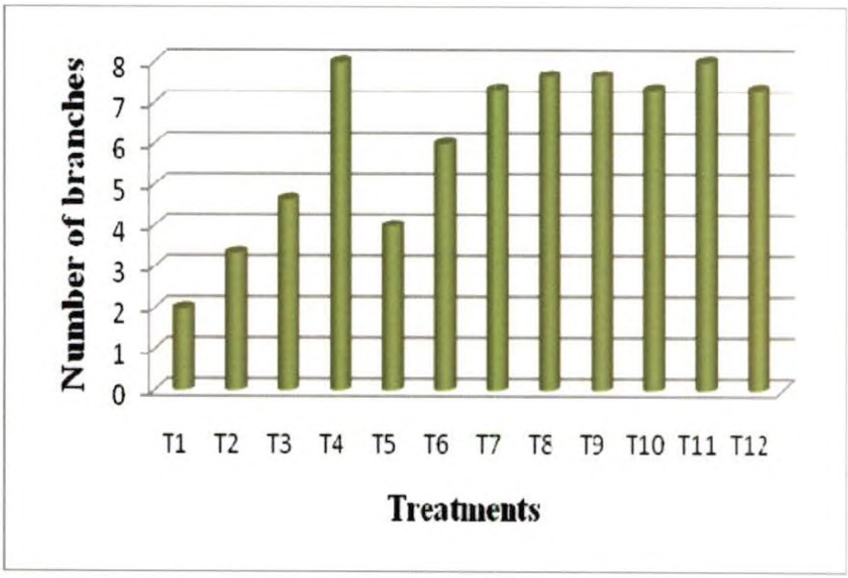


Fig. 2 Number of branches of okra plants at final harvest



4.1.4 Nodes of first flower emergence

The data on nodes of first flower emergence is presented in Table 6. It was observed that the nodes to first flowering emergence were not altered with different treatments and the first flower was on the 4^{th} node for all treatments.

4.1.5 Days to first flower opening

The data on days to first flower opening is presented in Table 6. The data showed significant differences among the treatments. The treatments T_4, T_8, T_{11} took the minimum number of days 35.67 to first flower opening. The treatment T_1 was late in flowering and it took 38.33 days.

4.1.6 Flower length

The data on flower length is presented in Table 6. The length of the flower was significantly different among the treatments. The maximum length was observed in the treatment T_{11} (9.60 cm) and T_4 (9.58 cm) and the minimum in T_1 (7.29 cm).

4.1.7 Flower diameter

The data on flower diameter is presented in Table 6. There was significant difference among the treatments. Maximum flower diameter was found in the treatment T_{11} (8.79 cm) and it was on par with T_4, T_5, T_6, T_7, T_8, T_9, T_{10} and T_{12}. The treatment T_1 had flowers with the minimum diameter (7.03 cm).

4.1.8 Leaf area index (LAI)

The data on leaf area index is presented in Table 7 and Fig. 3. The LAI showed significant difference between the treatments. The maximum LAI

Table 6. Nodes and days to first flower opening and flower characters of okra

TREATMENTS	Nodes to first flower emergence	Days to first flower opening	Flower length (cm)	Flower diameter (cm)
T_1	4	38.33^{a}	7.29^{e}	7.03^{b}
T_2	4	37.33^{bc}	7.43^{e}	7.33^{b}
T_3	4	38.00^{ab}	8.19^{d}	7.14^{b}
T_4	4	35.67^{e}	9.58^{a}	8.78^{a}
T_5	4	37.67^{ab}	9.26^{bc}	8.69^{a}
T_6	4	36.00^{ab}	9.243^{bc}	8.71^{a}
T_7	4	36.00^{de}	9.493^{ab}	8.26^{a}
T_8	4	35.67^{e}	9.33^{abc}	8.37^{a}
T_9	4	36.67^{cd}	9.33^{adc}	8.70^{a}
T_{10}	4	36.00^{de}	9.47^{ab}	8.53^{a}
T_{11}	4	35.67^{e}	9.60^{a}	8.79^{a}
T_{12}	4	36.67^{cd}	9.10^{c}	8.22^{a}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 7. Leaf area index (LAI) and Total dry matter (TDM)

TREATMENTS	LAI	TDM (t ha^{-1})
T_1	1.23^{c}	9.90^{h}
T_2	1.57^{bc}	10.31^{g}
T_3	1.50^{c}	12.36^{f}
T_4	1.90^{ab}	23.84^{a}
T_5	1.50^{c}	10.45^{g}
T_6	1.60^{bc}	10.99^{g}
T_7	1.60^{bc}	15.30^{e}
T_8	1.60^{bc}	16.20^{d}
T_9	1.60^{bc}	20.15^{b}
T_{10}	1.60^{bc}	16.49^{d}
T_{11}	2.17^{a}	19.38^{c}
T_{12}	1.60^{bc}	15.37^{e}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Fig. 3 Leaf Area Index of okra

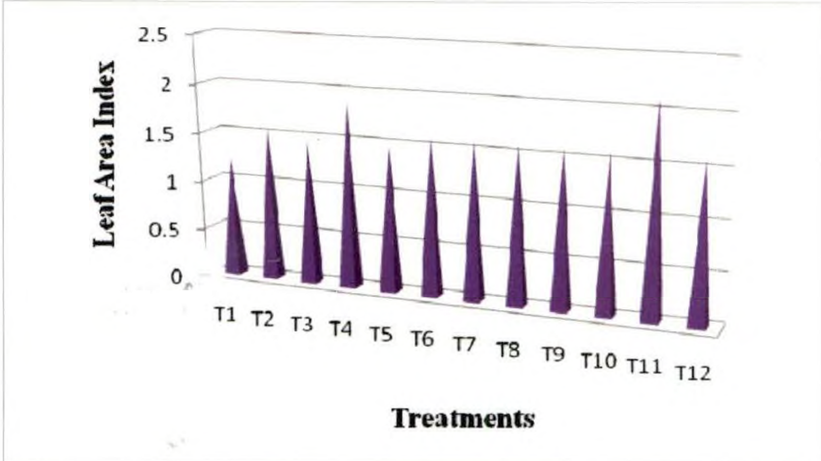


Fig. 4 Average weight of okra fruits

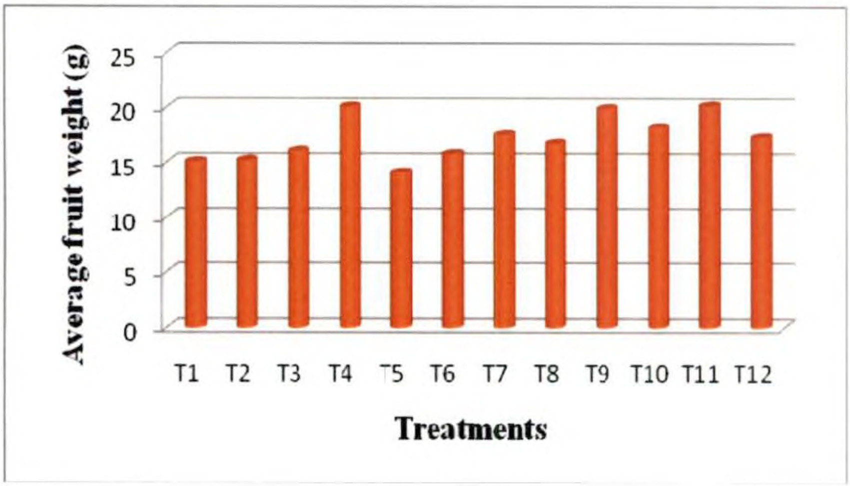
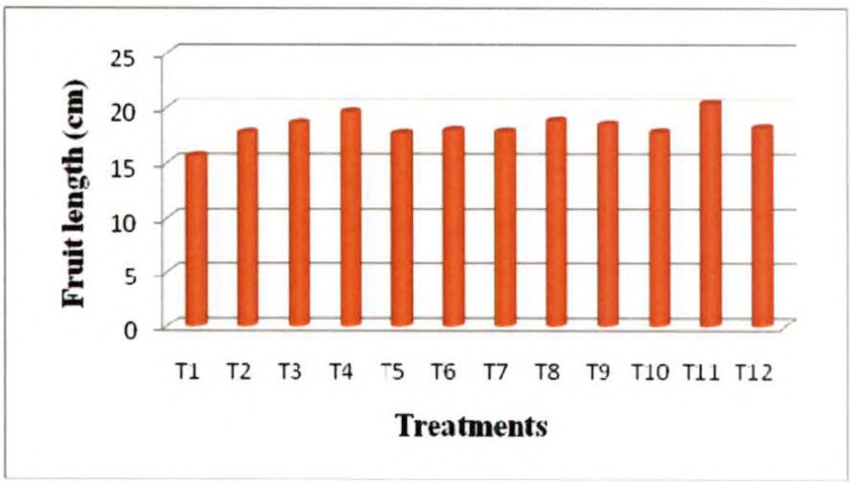


Fig. 5 Average length of okra fruits



2.17 was recorded in the treatment T_{11} followed by T_4 (1.90). The lowest LAI was recorded in the treatment T_1 (1.23).

4.1.9 Total dry matter (TDM)

The data on total dry matter production is presented in Table 7. The treatments differed significantly and the maximum amount of dry matter was recorded in the treatment T_4 (23.84 t ha^{-1}) followed by T_9 (20.15 t ha^{-1}).The minimum amount of dry matter was observed in the treatment T_1 (9.90 t ha^{-1}).

4.1.10 Average fruit weight

The data on average fruit weight is given in Table 8 and Fig. 4. The treatments differed significantly for fruit weight. Maximum average fruit weight was recorded by the treatment T_{11} (20.17 g) and was on par with T_4 (20.10 g) and T_9 (19.93 g).The minimum average fruit weight was observed in the treatment T_1 (15.10 g)

4.1.11 Fruit length

The data on fruit length is presented in Table 8 and Fig. 5. The treatments were significantly different (Plate - 3). The fruit length varied from 20.34 cm (T_{11}) to 15.59 cm (T_1). The treatments T_3, T_4, T_8, T_9 and T_{11} were on par in fruit length.

4.1.12 Fruit girth

The data on fruit girth is presented in Table 8 and Fig. 6. Significant difference was observed among the treatments for girth of fruits. The maximum fruit girth was recorded in the treatment T_4 and T_{11} (7.87 cm) followed by T_{12} (7.83 cm). The lower most fruit girth was observed in the treatment T_1 (6.03 cm).

Table 8. Fruit characters of okra

TREATMENTS	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Number of seeds
T_1	15.10^{ef}	15.59^{b}	6.03^{d}	75.00^{d}
T_2	15.23^{def}	17.79^{ab}	6.31^{cd}	77.33^{cd}
T_3	16.07^{cdef}	18.61^{a}	6.75^{bcd}	86.67^{ab}
T_4	20.10^{a}	19.60^{a}	7.87^{a}	90.67^{a}
T_5	14.10^{f}	17.71^{ab}	7.63^{ab}	78.67^{cd}
T_6	15.80^{cdef}	17.99^{ab}	7.29^{abc}	79.67^{c}
T_7	17.50^{bc}	17.85^{ab}	7.13^{abc}	78.33^{cd}
T_8	16.73^{bcde}	18.81^{a}	7.03^{abcd}	78.67^{b}
T_9	19.93^{a}	18.49^{a}	7.21^{abc}	84.67^{b}
T_{10}	18.20^{ab}	17.80^{ab}	7.21^{abc}	85.67^{b}
T_{11}	20.17^{a}	20.34^{a}	7.87^{a}	90.67^{a}
T_{12}	17.27^{bcd}	18.20^{ab}	7.83^{abcd}	85.67^{b}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Plate 2. Illustration of plant height

Plate 3. Fruits from different treatments

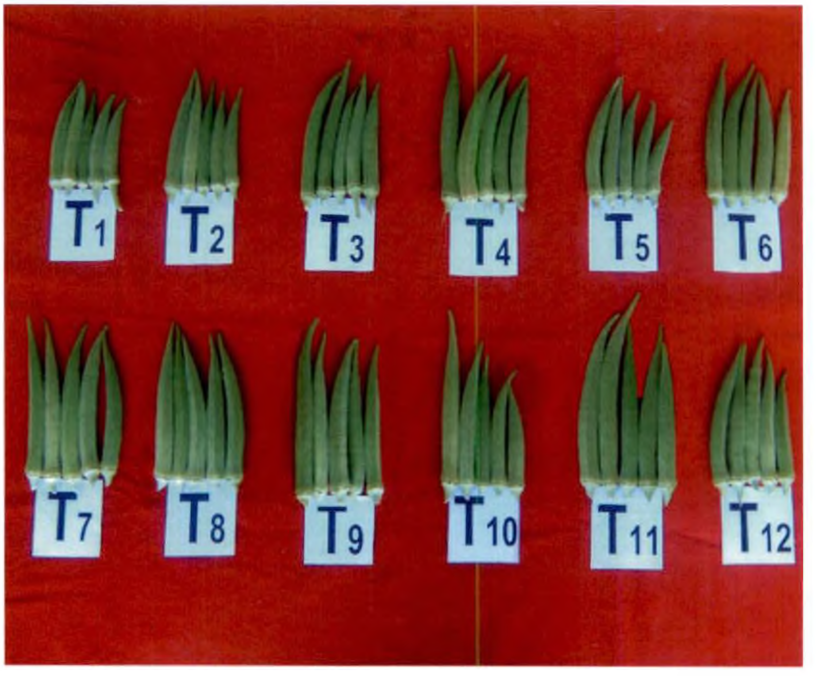


Fig.6 Average girth of okra fruits

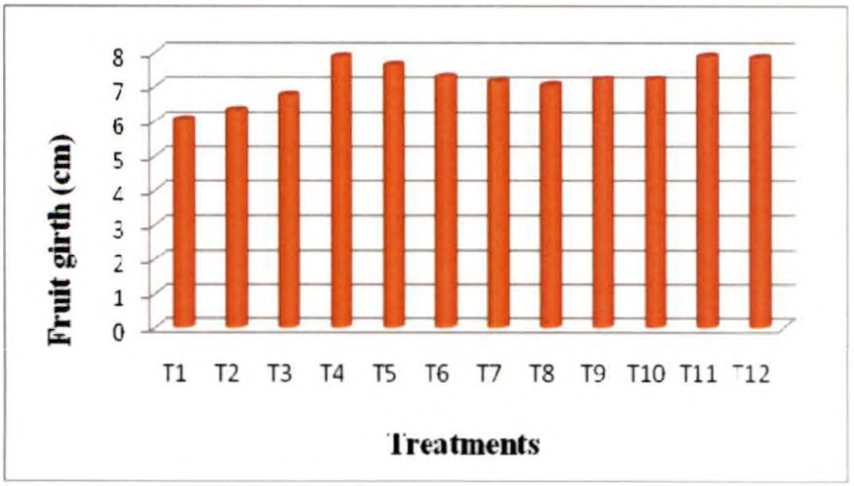


Fig. 7 Number of seeds in okra fruits

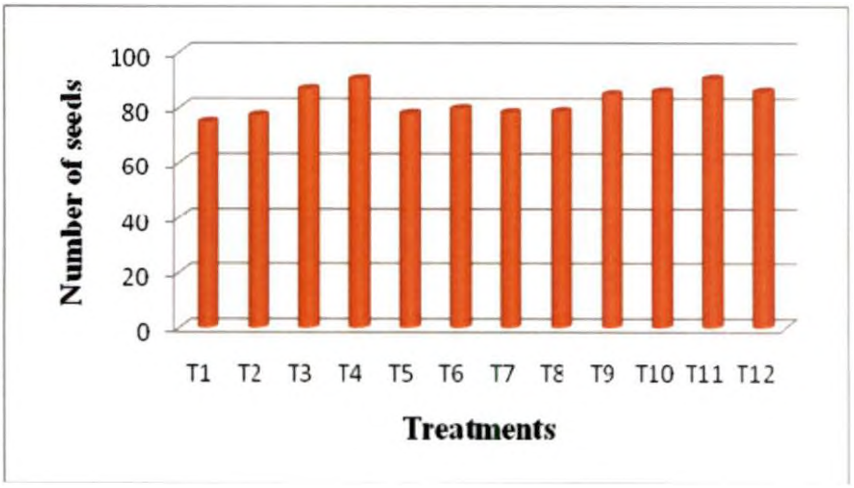
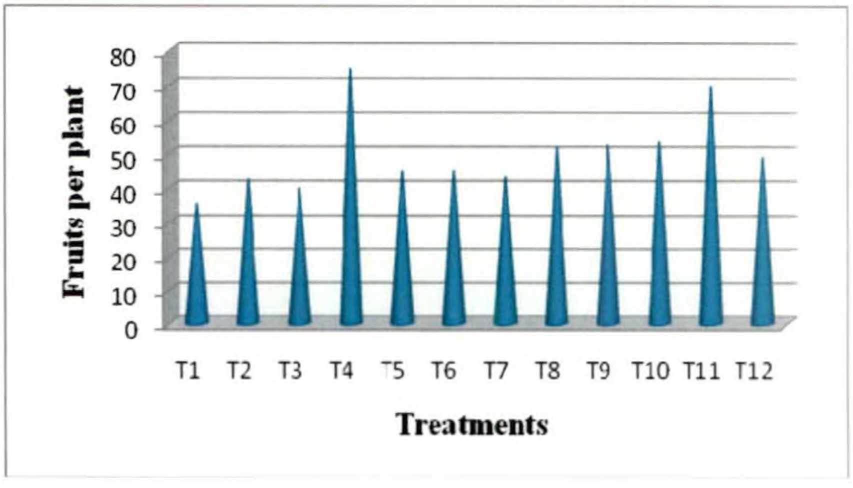


Fig. 8 Number of fruits per plant in okra



4.1.13 Number of seeds per fruit

The data on number of seeds per fruit is presented in Table 8 and Fig. 7. The treatments differed significantly for the number of seeds in a fruit. Maximum number of seeds was found in the treatments T_4 and T_{11} (90.67) and the minimum in treatment T_1 (75.00).

4.1.14 Days to first harvest

The data on days to first harvest is presented in Table 9. The result registered significant differences among the treatments. The treatments T_4, T_8 and T_{11} (40.67) were early and were on par. The maximum number of days to first harvest was recorded by T_1 (43.33).

4.1.15 Number of harvests

The data on number of harvests is shown in Table 9. Significant difference was observed among the treatments for the total number of times they were harvested. The maximum number of harvests were obtained from the treatments T_4, T_{10}, T_{11} and T_{12} (23.00) whereas the minimum harvests were made from the treatment T_1 (18.67).

4.1.16 Crop duration

The data on crop duration is presented in Table 9. The treatments differed significantly for the duration of the crop. The maximum duration of the crop was recorded by the treatment T_4 (126.33) whereas the lowest duration was recorded by T_1 (97.00).

4.1.17 Fruits per plant

The data on fruits per plant is presented in Table 10 and Fig. 8. Significant difference existed among the treatments. The maximum number of

Table 9. Number of days to first harvest, number of harvests and crop duration in okra

TREATMENTS	Days to first harvest	Number of harvests	Crop duration
T_1	43.33^{a}	18.67^{d}	97.00^{d}
T_2	42.33^{bc}	19.67^{d}	102.33^{cd}
T_3	43.00^{ab}	19.67^{d}	120.00^{ab}
T_4	40.67^{e}	23.00^{a}	126.33^{a}
T_5	42.67^{ab}	21.33^{bc}	110.67^{bcd}
T_6	41.00^{de}	21.00^{c}	109.00^{cd}
T_7	41.00^{de}	22.33^{ab}	116.00^{abc}
T_8	40.66^{e}	22.67^{a}	118.00^{abc}
T_9	41.67^{cd}	22.67^{a}	120.00^{ab}
T_{10}	41.00^{de}	23.00^{a}	120.00^{ab}
T_{11}	40.67^{e}	23.00^{a}	120.00^{ab}
T_{12}	41.67^{cd}	23.00^{a}	114.00^{abc}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

fruits per plant was recorded in the treatment T_4 (74.67) and it was on par with T_{11} (69.67). The lowest number of fruits per plant was obtained from the treatment T_1 (35.33).

4.1.18 Yield per plant

The data on yield per plant is presented in Table 10 and Fig. 9. The treatments differed significantly for yield per plant. The maximum yield per plant was recorded in the treatment T_4 (661.17 g) and it was on par with T_{11} (648.51 g) whereas the minimum was recorded in T_1 (324.01 g).

4.1.19 Yield per plot

The data on yield per plot is presented in Table 10. Significant difference was observed among the treatments for yield per plot. The maximum yield per plot was recorded in the treatment T_4 (31.75 kg) which was on par with T_{11} (30.19 kg), whereas the lowest yield was observed in treatment T_1 (15.55 kg).

4.1.20 Yield per hectare

The data on yield per hectare is presented in Table 10. Significant difference was observed among the treatments for yield. The maximum yield per hectare was recorded in the treatment T_4 (24.49 t ha^{-1}) and it was on par with T_{11} (24.02 t ha^{-1}), whereas the lowest yield was observed in treatment T_1 (12.00 t ha^{-1})

4.1.2.1 Incidence of pests and diseases

Irrespective of treatments, the field was totally free from pest and disease incidence.

Table 10. Yield of okra

TREATMENTS	Fruits/plant	Yield/plant (g)	Yield/plot (kg)	Yield/hectare (t)
T_1	35.33^{c}	324.01^{f}	15.55^{f}	12.00^{f}
T_2	42.33^{bc}	384.40^{ef}	18.45^{ef}	14.24^{ef}
T_3	39.67^{bc}	424.86^{def}	20.39^{def}	15.74^{def}
T_4	74.67^{a}	661.17^{a}	31.75^{a}	24.49^{a}
T_5	45.00^{bc}	434.48^{def}	20.86^{def}	16.09^{def}
T_6	45.00^{bc}	424.41^{def}	20.37^{def}	15.78^{def}
T_7	43.00^{bc}	553.99^{abc}	26.59^{abc}	20.59^{abc}
T_8	51.67^{bc}	481.07^{cde}	23.09^{cde}	17.82^{cde}
T_9	52.33^{b}	538.84^{bcd}	25.86^{bcd}	19.96^{bcd}
T_{10}	53.33^{b}	592.58^{abc}	29.44^{ab}	21.95^{ab}
T_{11}	69.67^{a}	648.51^{a}	30.19^{a}	24.02^{a}
T_{12}	49.00^{bc}	511.58^{cd}	24.56^{cd}	18.95^{cd}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Fig. 9 Per plant yield of okra

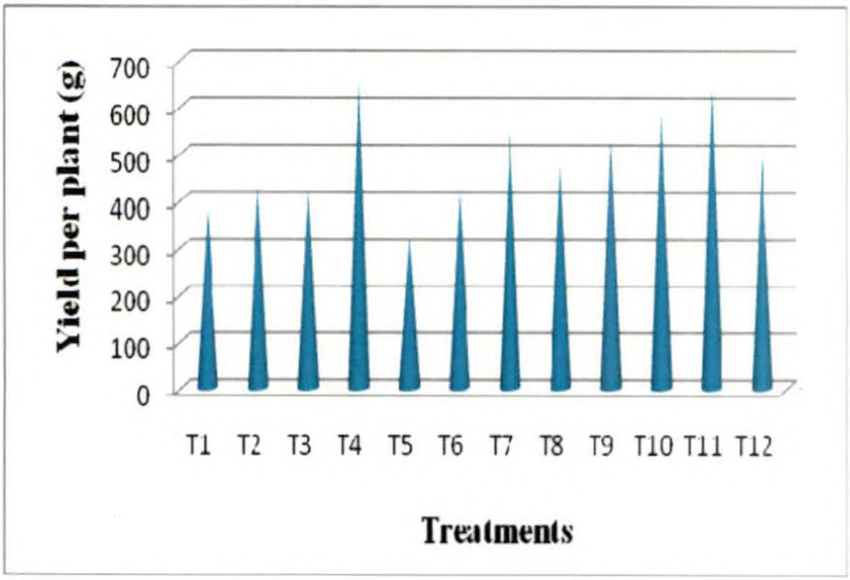
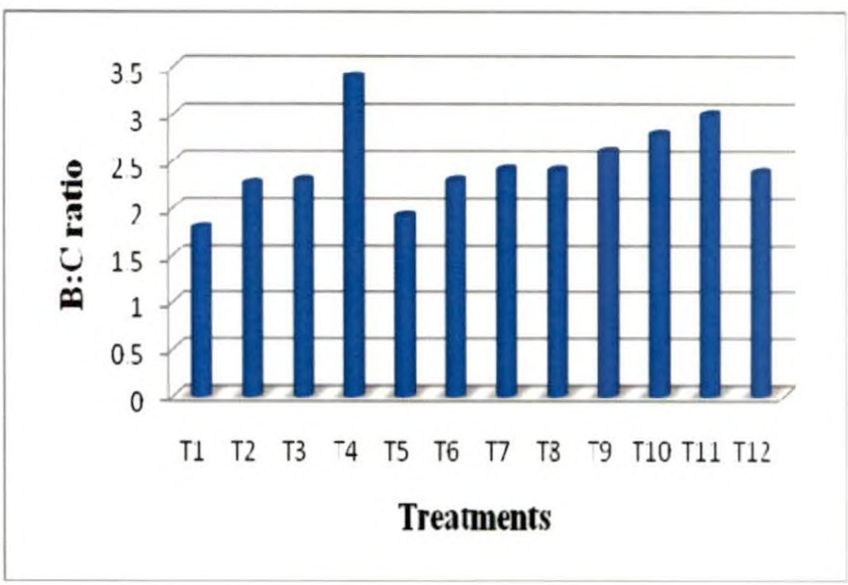


Fig. 10 B:C ratio under different treatments



4.2. FRUIT QUALITY

4.2.1 Moisture

The data on moisture content of fruits is presented in Table 11. The treatments did not differ significantly for the amount of moisture in the fruits. The fruits contained 90 % moisture.

4.2.2 Crude fibre

The data on crude fibre of fruits is presented in Table 11. Significant difference was observed among the treatments for the crude fibre of fruits. The minimum crude fibre was observed in the treatment T_4 and T_{11} (1.20 %). The fruits under treatment T_1 (1.50 %) recorded maximum crude fibre.

4.2.3 Vitamin C

The data on vitamin C of fresh fruits is presented in Table 11. Significant difference was observed among the treatments. Maximum ascorbic acid was present in fruits receiving treatment T_{11} (29.85 mg) followed by T_4 (29.11 mg) and minimum in T_1 (12.19 mg).

4.2.4 Crude Protein

The data on crude protein content of fruits is presented in Table 11. The treatments differed significantly and the maximum amount of crude protein was present in T_4 and T_{11} (20.64 %) and the minimum in T_1 (8.90 %).

4.2.5 Beta Carotene

The data on beta carotene content of fruits is presented in Table 11. There was significant difference among the treatments. Maximum beta carotene was present in T_{11} (122.50 μg/100 g) and was on par with T_4 (120.0 μg/100 g) and minimum in T_1 (63.0 μg/100 g).

Table 11. Effect of treatments on fruit quality in okra

TREATMENTS	Moisture (%)	Crude fibre (%)	Vitamin C (mg/100g)	Crude protein (%)	Carotene (µg/ 100g)
T_1	90.23^a	1.50^a	12.19^d	8.90^d	63.0^c
T_2	90.37^a	1.40^b	12.29^d	9.06^d	64.0^c
T_3	90.35^a	1.35^c	12.562^d	9.58^d	87.0^c
T_4	90.43^a	1.20^e	29.11^{ab}	20.64^a	120.0^a
T_5	90.62^a	1.30^d	25.05^b	9.91^d	72.0^c
T_6	90.25^a	1.35	25.34^b	10.39^d	67.5^c
T_7	90.36^a	1.33^b	26.07^{ab}	16.48^{bc}	115.0^{ab}
T_8	90.62^a	1.30^d	25.39^b	14.73^c	107.0^{ab}
T_9	90.48^a	1.30^d	28.45^{ab}	18.77^{ab}	111.0^{ab}
T_{10}	90.16^a	1.30^d	29.06^{ab}	19.20^{ab}	102.0^{bc}
T_{11}	90.42^a	1.20^e	29.85^a	20.64^a	122.5^a
T_{12}	90.63^a	1.35^c	20.71^c	16.40^{bc}	107.5^{ab}

Treatments having same alphabets as superscript form homogenous group.

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

4.2.6 Calcium

The data on calcium content of fruits is presented in Table 12. There was no significant difference among the treatments for calcium content in fruits.

4.2.7 Magnesium

The data on magnesium of fruits is presented in Table 12. Significant difference was observed among the treatments. Maximum magnesium was present in T_4 (0.193 %) and was on par with T_6, T_7, T_8 and T_9. The minimum magnesium content of fruits was present in T_1 and T_2 (0.092 %).

4.2.8 Manganese

The data on manganese content in fruits is presented in Table 12. There was significant difference among the treatments. Highest manganese content was present in T_{11} (0.246 %) and was on par with T_4 (0.233 %) and T_{10} (0.237 %). The lowest was in T_1 (0.072 %) and T_2 (0.079 %).

4.2.9 Zinc

The data on zinc content of fruits is presented in Table 12. Significant difference was observed among the treatments. Maximum zinc content was present in T_4 and T_{11} (0.062 %) and was on par with T_{10} (0.059 %). The minimum zinc content of fruits was in T_1 (0.040 %).

4.2.10 Iron

The data on iron content of fruits is presented in Table 12. Significant difference was observed among the treatments. The highest iron content was present in T_{11} (0.190 %) and it was on par with T_4 and T_{10}. The lowest was in T_1 (0. 105 %).

Table 12. Effect of treatments on Ca, Mg, Mn, Zn, Fe and Cu content of okra fruits

TREATMENTS	Ca (%)	Mg (%)	Mn (%)	Zn (%)	Fe (%)	Cu (%)
T_1	0.084^a	0.092^d	0.072^e	0.040^b	0.105^d	0.013^a
T_2	0.088^a	0.092^d	0.079^e	0.048^{bc}	0.114^c	0.013^a
T_3	0.086^a	0.118^c	0.136^d	0.047^{bcd}	0.119^c	0.014^a
T_4	0.133^a	0.193^a	0.233^a	0.062^a	0.188^a	0.021^a
T_5	0.087^a	0.117^c	0.080^e	0.042^{de}	0.125^c	0.015^a
T_6	0.088^a	0.175^a	0.146^d	0.050^b	0.125^c	0.021^a
T_7	0.111^a	0.174^a	0.179^c	0.040^e	0.127^c	0.016^a
T_8	0.130^a	0.179^a	0.195^{bc}	0.047^{bcd}	0.174^b	0.018^a
T_9	0.123^a	0.187^a	0.210^b	0.052^b	0.175^b	0.020^a
T_{10}	0.131^a	0.128^{bc}	0.237^a	0.059^a	0.186^a	0.020^a
T_{11}	0.134^a	0.137^b	0.246^a	0.062^a	0.190^a	0.021^a
T_{12}	0.118^a	0.118^c	0.198^b	0.043^{cde}	0.170^b	0.019^a

Treatments having same alphabets as superscript form homogenous group.

T_1 - POP, **T_2** - POP with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - PM 12.5 t ha^{-1}, **T_5** -V 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t PM + 2.5 t V , **T_7** - 4 t FYM + 3 t PM + 2.5 t V + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t PM + 2.5 t V + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t PM + 2.5 t V + Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t PM + 2.5 t V + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t PM + 2.5 t V + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t PM + 2.5 t V + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

4.2.11 Copper

The data on copper content of fruits is presented in Table 12. There was no significant difference among the treatments. The values ranged from 0.013 % to 0.021 %.

4.2.12 Nitrogen

The data on nitrogen content of fruits is presented in Table 13. The treatments differed significantly. Maximum nitrogen content was present in T_{11} (3.303 %) and was on par with T_4 (3.166 %) and T_{10} (3.072 %). The minimum nitrogen content was in T_1 (1.425 %).

4.2.13 Phosphorus

The data on phosphorus content of fruits is presented in Table 13. There was no significant difference among the treatments.

4.2.14 Potassium

The data on potassium content of fruits is presented in Table 13. The treatments differed significantly and the maximum amount of potassium was present in T_4 and T_{11} (1.937 %). The minimum potassium content was in T_1 (0.910 %).

4.3 SHELF LIFE

The data on shelf life of fruits is presented in Table 14. The treatments differed significantly for shelf life. The fruits of treatment T_4 and T_{11} had maximum shelf life under both ambient (5.0 days) and refrigerated (9.0 days) conditions. The treatment T_1 had minimum shelf life under both open (3.0 days) and refrigerated (6.0 days) conditions.

Table 13. Effect of treatments on nitrogen, phoshphorus and potasium content of fruits in okra

TREATMENTS	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	1.425[d]	0.159[a]	0.910[e]
T_2	1.450[d]	0.168[a]	0.919[e]
T_3	1.532[d]	0.185[a]	0.976[d]
T_4	3.166[a]	0.324[a]	1.937[a]
T_5	1.585[d]	0.204[a]	0.972[d]
T_6	1.662[d]	0.231[a]	1.580[c]
T_7	2.637[bc]	0.231[a]	1.755[b]
T_8	2.357[c]	0.222[a]	1.729[b]
T_9	3.002[ab]	0.217[a]	1.755[b]
T_{10}	3.072[a]	0.302[a]	1.729[b]
T_{11}	3.303[a]	0.227[a]	1.937[a]
T_{12}	2.624[bc]	0.194[a]	1.675[bc]

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 14. Effect of treatments on shelf life (days) of okra fruits in ambient and refrigerated conditions

TREATMENTS	Shelf life (days)	
	Ambient condition	Refrigerated condition
T_1	3.0^{f}	6.0^{d}
T_2	4.0^{e}	7.0^{c}
T_3	4.0^{e}	8.0^{b}
T_4	5.0^{a}	9.0^{a}
T_5	4.0^{e}	7.0^{c}
T_6	4.0^{e}	7.0^{c}
T_7	4.6^{b}	7.0^{c}
T_8	4.3^{c}	8.0^{b}
T_9	4.6^{b}	8.0^{b}
T_{10}	4.6^{b}	8.0^{b}
T_{11}	5.0^{a}	9.0^{a}
T_{12}	4.3^{c}	8.0^{b}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

4.3.1 Physiological loss in weight

The data on physiological loss in weight is presented in Table 15. The data showed significant difference among the treatments. Minimum physiological loss in weight was recorded by treatments T_4 and T_{11} on first (5.33 %), fourth (10.67 %), eighth (20.33 %) and twelveth (25 %) days of storage. Maximum loss in weight was recorded by T_1 and T_2 on first (20 %), fourth (31.33 %), eighth (45.33%) and twelveth (45.33 %) days of storage.

4.4 PLANT ANALYSIS

4.4.1. Calcium

The data on calcium content in leaf, stem and root is presented in Table 16. The data showed significant difference among the treatments. Maximum calcium content was present in the leaves, stem and roots of treatment T_{11} (0.271, 0.127 and 0.087 %), it was on par with T_4. The minimum calcium content was in T_1 (0.079, 0.071 and 0.018 %).

4.4.2. Magnesium

The data on magnesium content in leaf, stem and root is presented in Table 17. Significant difference was observed among the treatments. Maximum magnesium content was present in the leaves, stem and roots of treatment T_{11} (0.313, 0.188 and 0.093 %) and it was minimum in T_1 (0.096, 0.120 and 0.057 %).

4.4.3. Manganese

The data on manganese content in leaf, stem and root is presented in Table 18. Significant difference was observed among the treatments. Maximum manganese content was present in the leaves, stem and roots of

Table 15. Effect of treatments on physiological loss in weight of okra fruits

TREATMENTS	Loss in weight (%)			
	1st day	4th day	8th day	12th day
T_1	20.00^{a}	31.33^{a}	45.33^{a}	45.33^{a}
T_2	20.00^{a}	31.33^{a}	45.33^{a}	45.33^{a}
T_3	17.00^{b}	26.00^{b}	30.33^{c}	39.67^{b}
T_4	5.33^{e}	10.67^{f}	20.33^{e}	25.00^{d}
T_5	15.00^{bc}	26.00^{b}	36.00^{b}	39.67^{b}
T_6	14.00^{c}	26.00^{b}	37.00^{b}	42.67^{a}
T_7	13.67^{c}	20.33^{e}	30.67^{c}	38.00^{b}
T_8	13.67^{c}	24.00^{bc}	29.67^{c}	38.33^{b}
T_9	11.00^{d}	21.33^{de}	26.00^{d}	31.33^{c}
T_{10}	11.00^{d}	21.00^{e}	31.67^{c}	33.00^{c}
T_{11}	5.33^{e}	10.67^{f}	20.33^{e}	25.00^{d}
T_{12}	13.00^{cd}	23.33^{cd}	31.67^{c}	38.33^{b}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, T_2 - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, T_4 - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 16. Effect of treatments on calcium content in leaf, stem and root of okra

TREATMENTS	Calcium (%)		
	Leaf	Stem	Root
T_1	0.079^{d}	0.071^{c}	0.018^{a}
T_2	0.109^{cd}	0.071^{c}	0.026^{a}
T_3	0.175^{b}	0.072^{c}	0.027^{a}
T_4	0.275^{a}	0.126^{a}	0.086^{a}
T_5	0.139^{bc}	0.080^{c}	0.028^{a}
T_6	0.189^{b}	0.087^{c}	0.072^{a}
T_7	0.196^{b}	0.105^{b}	0.079^{a}
T_8	0.190^{b}	0.113^{ab}	0.321^{a}
T_9	0.158^{bc}	0.118^{ab}	0.082^{a}
T_{10}	0.187^{b}	0.124^{a}	0.086^{a}
T_{11}	0.271^{a}	0.127^{a}	0.087^{a}
T_{12}	0.144^{bc}	0.105^{b}	0.073^{a}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 17. Effect of treatments on magnesium content in leaf, stem and root

TREATMENTS	Magnesium (%)		
	Leaf	Stem	Root
T_1	0.096^{e}	0.120^{d}	0.057^{c}
T_2	0.112^{e}	0.122^{d}	0.058^{c}
T_3	0.133^{de}	0.125^{d}	0.067^{bc}
T_4	0.296^{ab}	0.184^{a}	0.094^{a}
T_5	0.173^{d}	0.122^{d}	0.067^{bc}
T_6	0.247^{bc}	0.130^{cd}	0.082^{ab}
T_7	0.239^{c}	0.165^{b}	0.082^{ab}
T_8	0.285^{abc}	0.175^{ab}	0.083^{ab}
T_9	0.287^{abc}	0.171^{ab}	0.087^{a}
T_{10}	0.298^{ab}	0.180^{ab}	0.094^{a}
T_{11}	0.313^{a}	0.188^{a}	0.093^{a}
T_{12}	0.284^{abc}	0.143^{c}	0.076^{ab}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 18. Effect of treatments on manganese content in leaf, stem and root

TREATMENTS	Manganese (%)		
	Leaf	Stem	Root
T_1	0.133^{d}	0.126^{ab}	0.030^{d}
T_2	0.142^{cd}	0.126^{ab}	0.030^{d}
T_3	0.158^{cd}	0.134^{ab}	0.038^{cd}
T_4	0.203^{bcd}	0.183^{a}	0.075^{ab}
T_5	0.314^{ab}	0.150^{ab}	0.042^{cd} ·
T_6	0.217^{bcd}	0.146^{ab}	0.062^{ab}
T_7	0.258^{bc}	0.102^{b}	0.056^{bc}
T_8	0.213^{bcd}	0.178^{a}	0.074^{b}
T_9	0.291^{ab}	0.179^{a}	0.077^{a}
T_{10}	0.382^{a}	0.180^{a}	0.078^{a}
T_{11}	0.389^{a}	0.185^{a}	0.079^{a}
T_{12}	0.247^{bcd}	0.173^{a}	0.070^{ab}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, T_2 - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, T_4 - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

treatment T_{11} (0.389, 0.185 and 0.079 %) and was on par with T_{10}. Manganese content was minimum in T_1 (0.133, 0.126 and 0.030 %).

4.4.4. Zinc

The data on zinc content in leaf, stem and root is presented in Table 19. There was significant difference among the treatments. Maximum zinc content was present in the leaves, stem and roots of treatment T_{11} (0.078, 0.049 and 0.059 %) and minimum in T_1 (0.054, 0.025 and 0.031 %).The zinc content in stem and root of T_4 was on par with T_{11}.

4.4.5. Iron

The data on iron content in leaf, stem and root is presented in Table 20. Significant difference was observed among the treatments. Maximum iron content was present in the leaves, stem and roots of treatment T_{11} (0.258, 0.195 and 0.094) and minimum in T_1 (0.124, 0.125 and 0.057 %). The iron content in stem and root of T_4 was on par with T_{11}.

4.4.6. Copper

The data on copper content in leaf, stem and root is presented in Table 21. The data showed significant difference among the treatments. Maximum copper content was present in the leaves and roots of treatment T_{11} (0.028 and 0.032 %) and stem of T_4 (0.028 %). The minimum copper content was in treatment T_1 (0.005, 0.010 and 0.001 %).

4.4.7. Nitrogen

The data on nitrogen content of leaf, stem and root is presented in Table 22. Significant difference was observed among the treatments. Maximum nitrogen content was present in the leaves, stem and roots of treatment T_{11} (3.936, 2.628 and 1.417%) and minimum in T_1 (1.458, 0.924 and

Table 19. Effect of treatments on zinc content in leaf, stem and root

TREATMENTS	Zinc (%)		
	Leaf	Stem	Root
T_1	0.054^{b}	0.025^{c}	0.031^{a}
T_2	0.054^{b}	0.026^{bc}	0.350^{a}
T_3	0.073^{ab}	0.032^{abc}	0.041^{a}
T_4	0.057^{b}	0.040^{a}	0.058^{a}
T_5	0.065^{ab}	0.031^{abc}	0.040^{a}
T_6	0.065^{ab}	0.033^{abc}	0.047^{a}
T_7	0.062^{ab}	0.030^{abc}	0.045^{a}
T_8	0.065^{ab}	0.041^{abc}	0.045^{a}
T_9	0.067^{ab}	0.042^{abc}	0.040^{a}
T_{10}	0.072^{ab}	0.045^{ab}	0.053^{a}
T_{11}	0.078^{a}	0.049^{a}	0.059^{a}
T_{12}	0.068^{ab}	0.037^{abc}	0.047^{a}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, T_2 - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, T_4 - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 20. Effect of treatments on iron content in leaf, stem and root

TREATMENTS	Iron (%)		
	Leaf	Stem	Root
T_1	0.124^{d}	0.125^{d}	0.057^{d}
T_2	0.139^{cd}	0.130^{d}	0.058^{d}
T_3	0.101^{d}	0.132^{d}	0.067^{cd}
T_4	0.233^{ab}	0.194^{a}	0.094^{a}
T_5	0.187^{bc}	0.165^{c}	0.067^{cd}
T_6	0.136^{cd}	0.165^{c}	0.082^{abc}
T_7	0.113^{b}	0.132^{d}	0.082^{abc}
T_8	0.125^{d}	0.180^{abc}	0.083^{abc}
T_9	0.139^{cd}	0.173^{bc}	0.087^{ab}
T_{10}	0.101^{d}	0.165^{c}	0.094^{a}
T_{11}	0.258^{a}	0.195^{a}	0.094^{a}
T_{12}	0.135^{cd}	0.187^{ab}	0.076^{bc}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, T_2 - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, T_4 - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 21. Effect of treatments on copper content in leaf, stem and root

TREATMENTS	Copper (%)		
	Leaf	**Stem**	**Root**
T_1	0.005^{d}	0.010^{e}	0.001^{c}
T_2	0.005^{d}	0.010^{e}	0.001^{c}
T_3	0.005^{d}	0.015^{e}	0.012^{bc}
T_4	0.022^{ab}	0.028^{a}	0.026^{b}
T_5	0.005^{d}	0.020^{d}	0.012^{bc}
T_6	0.005^{d}	0.022^{c}	0.024^{ab}
T_7	0.011^{c}	0.020^{d}	0.026^{ab}
T_8	0.017^{bc}	0.026^{b}	0.026^{ab}
T_9	0.018^{bc}	0.026^{b}	0.026^{ab}
T_{10}	0.019^{bc}	0.020^{d}	0.027^{ab}
T_{11}	0.028^{a}	0.026^{b}	0.032^{a}
T_{12}	0.019^{ab}	0.026^{b}	0.025^{ab}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 22. Effect of treatments on on nitrogen, phoshphorus and potassium content of leaves, stem and roots of okra

TREATMENTS	Leaves			Stem			Root		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
T_1	1.458^{d}	0.004^{e}	0.458^{a}	0.914^{g}	0.008^{b}	0.675^{cd}	0.556^{c}	0.004^{e}	0.135^{a}
T_2	1.483^{d}	0.007^{e}	0.483^{a}	0.924^{g}	0.008^{b}	0.872^{bcd}	0.573^{dc}	0.005^{d}	0.136^{a}
T_3	1.532^{d}	0.015^{d}	0.532^{a}	1.032^{g}	0.011^{ab}	0.874^{bcd}	0.877^{cde}	0.007^{b}	0.275^{a}
T_4	3.653^{a}	0.016^{a}	0.653^{a}	2.329^{a}	0.011^{ab}	0.927^{a}	1.328^{a}	0.007^{b}	0.317^{a}
T_5	1.585^{d}	0.012^{d}	0.585^{a}	1.142^{fg}	0.009^{ab}	0.972^{a}	1.172^{abc}	0.007^{b}	0.276^{a}
T_6	2.66^{bc}	0.005^{c}	0.662^{a}	1.359^{f}	0.009^{ab}	0.580^{d}	0.923^{bcd}	0.005^{d}	0.242^{a}
T_7	2.637^{bc}	0.005^{b}	0.637^{a}	1.641^{de}	0.009^{ab}	0.755^{b}	1.212^{abc}	0.006^{c}	0.212^{a}
T_8	2.357^{c}	0.013^{b}	0.624^{a}	1.830^{cd}	0.009^{ab}	0.729^{bc}	1.142^{abc}	0.005^{d}	0.242^{a}
T_9	3.002^{b}	0.014^{b}	0.869^{a}	1.866^{cd}	0.010^{ab}	0.755^{b}	1.175^{abc}	0.006^{c}	0.175^{a}
T_{10}	3.072^{b}	0.013^{bc}	0.872^{a}	1.976^{c}	0.010^{ab}	0.729^{bc}	1.269^{ab}	0.005^{d}	0.269^{a}
T_{11}	3.936^{a}	0.017^{a}	0.936^{a}	2.628^{a}	0.016^{a}	0.937^{a}	1.417^{a}	0.008^{a}	0.382^{a}
T_{12}	2.624^{bc}	0.013^{bc}	0.558^{a}	1.496^{e}	0.011^{ab}	0.699^{cd}	1.324^{a}	0.005^{d}	0.306^{a}

Treatments having same alphabets as superscript form homogenous group.

T_1 - POP , **T_2** - POP along with mulching, **T_3** - FYM [1], **T_4** - PM, **T_5** - V, **T_6** - FYM + PM + V ,**T_7** - FYM + PM + V + P, **T_8** - FYM + PM + V FAA, **T_9** - FYM + PM + V AP, **T_{10}** - FYM + PM + V 4 FOC, **T_{11}** - FYM + PM + V FPE, **T_{12}** - FYM + PM + V + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

0.556 %).Treatment T_4 was on par with T_{11} for nitrogen content in leaves and roots.

4.4.8. Phosphorus

The data on phosphorus content of leaf, stem and root is presented in Table 22. Significant difference was observed among the treatments. Maximum phosphorus content was present in the leaves, stem and roots of treatment T_{11} (0.017, 0.016 and 0.008 %) and minimum in T_1 (0.004, 0.008 and 0.004 %).

4.4.9. Potassium

The data on potassium content of leaf, stem and root is presented in Table 22. Significant difference was observed among the treatments. Maximum potassium content was present in the leaves, stem and roots of treatment T_{11} (0.936, 0.937 and 0.382 %) and it was on par with T_4 and minimum in T_1 (0.458, 0.675 and 0.135 %). There was no significant difference among treatments in the potassium content of leaves.

4.4.2.1Chlorophyll

The data on chlorophyll content of leaves is presented in Table 23. There was significant difference among the treatments. Highest chlorophyll content was present in T_{11} (56.63) followed by T_{10} (55.43) and T_4 (54.77).The lowest content was in the treatment T_1 (43.73).

4.5. UPTAKE OF NUTRIENTS

4.5.1 Nitrogen

The data on nitrogen uptake by plants is presented in Table 24. There was significant difference among the treatments for the uptake of nitrogen.

Table 23. Effect of treatments on chlorophyll content of leaves of okra

TREATMENTS	CHLOROPHYLL (SPAD units)
T_1	43.73[e]
T_2	44.80[de]
T_3	47.03[cde]
T_4	54.77[abc]
T_5	47.70[bcde]
T_6	48.73[abcde]
T_7	51.30[abcde]
T_8	52.10[abcd]
T_9	52.00[abcd]
T_{10}	55.43[ab]
T_{11}	56.63[a]
T_{12}	51.53[abcd]

Treatments having same alphabets as superscript form homogenous group.

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry 'Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

Table 24. Effect of treatments on uptake of on nitrogen, phoshphorus and potassium by okra plants

TREATMENTS	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1	81.11^{h}	11.01^{g}	33.64^{j}
T_2	92.37^{g}	12.12^{g}	39.63^{i}
T_3	120.70^{f}	16.04^{e}	66.34^{h}
T_4	494.00^{a}	44.39^{c}	243.99^{a}
T_5	108.37^{g}	14.97^{f}	55.86^{i}
T_6	122.93^{f}	17.78^{e}	95.50^{g}
T_7	280.07^{e}	23.80^{d}	147.68^{f}
T_8	321.83^{d}	24.60^{d}	154.30^{de}
T_9	432.33^{b}	42.70^{b}	194.49^{c}
T_{10}	402.54^{c}	35.14^{c}	166.81^{d}
T_{11}	402.11^{c}	37.96^{a}	206.46^{b}
T_{12}	337.85^{d}	20.89^{d}	141.59^{f}

Treatments having same alphabets as superscript form homogenous group

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

The highest nitrogen uptake was by the plants receiving treatment T_4 (494.00 kg ha^{-1}). Lowest uptake of nitrogen was by the plants receiving treatment T_1 (81.11 kg ha^{-1}).

4.5.2 Phosphorus

The data on phosphorus uptake by plants is presented in Table 24. There was significant difference among the treatments for the uptake of phosphorus. The highest phosphorus uptake was by the plants receiving treatment T_4 (44.39 kg ha^{-1}). Lowest uptake of phosphorus was by the plants receiving treatment T_1 (11.01 kg ha^{-1}).

4.5.3 Potassium

The data on potassium uptake by plants is presented in Table 24. There was significant difference among the treatments for the uptake of potassium. The highest potassium uptake was by the plants receiving treatment T_4 (243.99 kg ha^{-1}). Lowest uptake of potassium was by the plants receiving treatment T_1 (33.64 kg ha^{-1}).

4.6 SOIL ANALYSIS

4.6.1 Organic carbon

The data on organic carbon content of the soil is presented in Table 25. The initial carbon content was 0.32 %. The final organic carbon content ranged from 0.37 % (T_1) to 0.56 % (T_{11}). Soil under T_{11} (71.88 %) showed highest increment (71.88 %) in organic carbon content. The treatment T_1 showed the lowest increment (15.63 %) in organic carbon content.

Table 25. Effect of treatments on organic carbon, organic matter, pH and EC of soil of experimental plots

TREATMENTS	Organic carbon (%)	Organic matter (%)	pH	EC ($d\ sm^{-1}$)
	Final	**Final**	**Final**	
T_1	0.37^{c} (15.63%)	0.64^{f} (14.29%)	5.2^{d} (01.96%)	0.1
T_2	0.38^{c} (18.75%)	0.66^{f} (17.86%)	5.3^{d} (03.92%)	0.1
T_3	0.38^{c} (18.75%)	0.66^{f} (17.86%)	5.4^{d} (05.88%)	0.1
T_4	0.55^{a} (68.75%)	0.94^{ab} (67.86%)	6.5^{a} (27.45%)	0.1
T_5	0.45^{b} (31.25%)	0.78^{e} (39.26%)	5.8^{c} (13.73%)	0.1
T_6	0.49^{ab} (53.13%)	0.85^{d} (10.71%)	6.1^{ab} (19.61%)	0.1
T_7	0.50^{a} (56.25%)	0.87^{c} (55.36%)	6.1^{a} (19.61%)	0.1
T_8	0.53^{a} (59.38%)	0.89^{c} (58.93%)	6.2^{ab} (21.26%)	0.1
T_9	0.54^{a} (65.63%)	0.92^{b} (64.29%)	6.3^{ab} (24.22%)	0.1
T_{10}	0.55^{a} (68.75%)	0.94^{ab} (67.86%)	6.2^{a} (21.26%)	0.1
T_{11}	0.56^{a} (71.88%)	0.96^{a} (71.43%)	6.5^{a} (27.45%)	0.1
T_{12}	0.55^{a} (68.75%)	0.94^{ab} (67.86%)	6.2^{bc} (21.26%)	0.1
Initial	0.32	0.56	5.1	0.1

Treatments having same alphabets as superscript form homogenous group. Values in parenthesis indicate per cent increase over the initial observation.

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

4.6.2 Organic matter

The data on organic matter content of the soil is presented in Table 25. The initial organic matter content was 0.56 %.The final organic matter content ranged from 0.64 % (T_1) to 0.96 % (T_{11}). Soil under T_{11} registered the highest increment (71.43 %) in organic matter content and that under treatment T_1 the lowest (14.29 %).

4.6.3 pH of soil

The data on pH of the soil is presented in Table 25. The initial pH was 5.1 and the final pH ranged from 5.2 (T_1) to 6.5 (T_4 and T_{11}). Significant variation existed among the treatments in final pH levels of the soil. Soil under T_4 and T_{11} showed the highest increment (27.45 %) in pH and treatment T_1 showed the lowest (1.96 %).

4.6.4 EC of soil

The data on EC of the soil is presented in Table 25. The data showed no difference among the treatments. It was 0.1 d Sm^{-1} for all the treatments.

4.6.5 Available N

The data on available nitrogen content of the soil is presented in Table 26. The data showed significant difference among the treatments. The initial available nitrogen was 374 kg ha^{-1} in soil. The available nitrogen during final harvest ranged from 378 (T_1 and T_2) to 412 kg ha^{-1} (T_{11}).

Soil under treatment T_{11} had maximum increment (10.16 %) over the initial of available nitrogen content whereas T_1 and T_2 had the minimum (1.07 %) increment.

Table 26. Effect of treatments on soil nitrogen, phoshphorus and potassium content

TREATMENTS	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
	Final	Final	Final
T_1	378^e(01.07%)	35^c (02.94%)	>400
T_2	378^e (01.07%)	35^c (02.94%)	>400
T_3	380^f (01.60%)	40^b (17.65%)	>400
T_4	411^b (09.89%)	42^a (31.25%)	>400
T_5	386^e (03.21%)	42^a (31.25%)	>400
T_6	390^d (04.28%)	42^a (31.25%)	>400
T_7	411^b (09.89%)	42^a (31.25%)	>400
T_8	410^b (06.95%)	42^a (31.25%)	>400
T_9	410^c (09.63%)	42^a (31.25%)	>400
T_{10}	411^b (09.89%)	42^a (31.25%)	>400
T_{11}	412^a (10.16%)	42^a (31.25%)	>400
T_{12}	410^c (09.63%)	42^a (31.25%)	>400
Initial	374 kg ha^{-1}	34 kg ha^{-1}	374 kg ha^{-1}

Treatments having same alphabets as superscript form homogenous group. Values in parenthesis indicate per cent increase over the initial observation.

T_1 - POP recommendation, **T_2** - POP recommendation (with mulching), **T_3** - FYM 17 t ha^{-1}, **T_4** – PM 12.5 t ha^{-1}, **T_5** – V 9 t ha^{-1}, T_6 - 4 t FYM + 3 t PM + 2.5 t V, **T_7** - 4 t FYM + 3 t PM + 2.5 t V + P at 10 days interval, **T_8** - 4 t FYM + 3 t PM + 2.5 t V + FAA at 10 days interval, **T_9** - 4 t FYM + 3 t PM + 2.5 t V t+ AP at 10 days interval, **T_{10}** - 4 t FYM + 3 t PM + 2.5 t V + FOC at10 days interval, **T_{11}** - 4 t FYM + 3 t PM + 2.5 t V + FPE at 10 days interval, **T_{12}** - 4 t FYM + 3 t PM + 2.5 t V + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching 25 t green leaves ha^{-1} was provided.

4.6.6 Available P_2O_5

The data on available phosphorous content of the soil is presented in Table 26. The data during final stage showed significant difference among the treatments. The initial available soil phosphorous was 34 kg ha^{-1} and during final stage it ranged from 35 (T_1 and T_2) to 42 kg ha^{-1} (T_4 to T_{12}).

Soil under T_1 and T_2 showed the minimum increment (2.94 %) of available phosphorous followed by T_3 (17.65 %); rest of the treatments registered an increment of (31.25 %).

4.6.7 Available K_2O

The data on available potassium content of soil is presented in Table 26. The initial available potassium was 374 kg ha^{-1} in soil. The available potassium rose above 400 kg ha^{-1} later for all the treatments.

4.6.8 Bulk density

The data on bulk density of the soil is presented in Table 27. The data showed significant difference among the treatments. The initial bulk density was 1.50 g cm^{-3}. Finally the bulk density came down for all the treatments and it ranged from 1.06 g cm^{-3} (T_{11}) to 1.49 (T_1) g cm^{-3} Soil under T_{11} showed maximum (29.43 %) reduction in bulk density, whereas the treatment T_1 showed only (0.60 %) reduction.

4.6.9 Pore space

The data on pore space of the soil is presented in Table 27. The data showed significant difference among the treatments. The initial pore space was 51.501 % and the finally it ranged from 52.60% (T_1) to 54.83 (T_{11}) %. Soil under the treatment T_{11} showed the highest increment (6.44 %) in pore space, the minimum was observed in T_1 (2.14 %).

Table 27. Effect of treatments on bulk density, pore space and water holding capacity (WHC) of the soil

TREATMENTS	Bulk Density (g cm^{-3})	Pore space (%)	WHC (%)
	Final	Final	Final
T_1	1.49^{a} (00.60%)	52.60^{d} (2.14%)	29.33^{e} (01.07%)
T_2	1.43^{ab} (04.59%)	52.63^{d} (2.19%)	34.26^{de} (18.06%)
T_3	1.40^{ab} (06.99%)	53.30^{c} (3.63%)	32.47^{de} (11.90%)
T_4	1.10^{de} (26.96%)	54.47^{ab} (5.76%)	51.51^{a} (77.51%)
T_5	1.26^{c} (16.11%)	53.82^{bc} (4.52%)	37.07^{cd} (27.57%)
T_6	1.39^{ab} (08.47%)	53.91^{bc} (4.68%)	47.85^{ab} (64.91%)
T_7	1.31^{bc} (13.78%)	53.91^{bc} (4.68%)	37.02^{cd} (27.57%)
T_8	1.21^{cd} (19.64%)	53.79^{bc} (4.43%)	37.61^{cd} (29.61%)
T_9	1.24^{c} (17.24%)	53.89^{bc} (4.65%)	36.82^{cd} (26.90%)
T_{10}	1.21^{cd} (19.44%)	53.89^{bc} (2.02%)	41.88^{b} (44.32%)
T_{11}	1.06^{e} (29.43%)	54.83^{a} (6.44%)	50.73^{a} (74.84%)
T_{12}	1.32^{bc} (12.12%)	53.97^{bc} (4.61%)	36.21^{cd} (24.79%)
Initial	1.50 g cm^{-3}	51.50 %	29.02 %

Treatments having same alphabets as superscript form homogenous group. Values in parenthesis indicate per cent increase over the initial observation.

T_1 - Manures and fertilizers as per POP recommendation, T_2 - Manures and fertilizers as per POP recommendation along with mulching, T_3 - FYM 17 t ha^{-1}, T_4 - Poultry Manure 12.5 t ha^{-1}, T_5 - Vermicompost 9 t ha^{-1}, T_6 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , T_7 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, T_8 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Amrutha Pani (AP) at 10 days interval, T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, T_{11} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, T_{12} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

4.6.10 Water holding capacity

The data on water holding capacity of the soil is presented in Table 27. The data on water holding capacity showed significant difference among the treatments. The initial water holding capacity of the soil was 29.02 %. The water holding capacity ranged from 29.33 % (T_1) to 51.51 (T_4) % finally. Soil under T_4 showed highest (77.51 %) increment in water holding capacity and was on par with T_{11}. The minimum increase (1.07 %) in water holding capacity was observed in T_1.

4.6.11 Microbial population in soil

The data on fungal population in the experimental soil is presented in Table 28 and Plate - 4.

4.6.11.1 Fungus

The initial population was 20 × 10^4 cfu/g. On 50^{th} day the fungal population was (52.75 × 10^4 cfu/g) in the treatment T_{11} and with the highest increment of 163.8 % over other treatments. The treatment T_1 showed the lowest (20.75× 10^4 cfu/g) fungal population and increment of 3.8 % on 50^{th} day.

The highest fungal population (61.50 × 10^4 cfu/g) was observed in T_{11} on the 100^{th} day and with the highest increment of 207.5 % over other treatments. The treatment T_1 recorded the lowest fungal population (21.0 × 10^4 cfu/g) and increment of 5.0 %.

4.6.11.2 Bacteria

The initial bacterial population was 15 × 10^6 cfu/g. On 50^{th} day the bacterial population was 45.25 × 10^6 cfu/g in T_{11} with an increment of 201.7 %. The increment was the highest in the treatment T_{11}. The treatment T_1

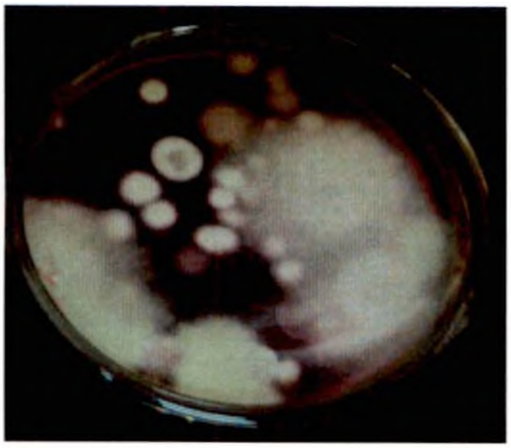
Table 28. Effect of treatments on total microbial population in soil

TREATMENTS	Fungal count (x 10^4 cfu/g)		Bacterial count (x 10^6 cfu/g)		Actinomycetes count (x 10^5 cfu/g)	
	50th day	100th day	50th day	100th day	50th day	100th day
T_1	20.75^{d} (003.8%)	21.00^{d} (05.0%)	26.25^{d} (075.0%)	28.75^{e} (91.7%)	11.00^{d} (010.0%)	12.00^{d} (20.0%)
T_2	30.00^{cd} (050.0%)	31.00^{c} (55.0%)	30.75^{cd} (105.0%)	35.25^{d} (135.0%)	17.75^{c} (077.5%)	20.50^{c} (105.0%)
T_3	30.00^{cd} (050.0%)	38.50^{b} (92.5%)	30.75^{cd} (105.0%)	38.00^{d} (153.3%)	19.00^{c} (090.0%)	26.50^{b} (165.0%)
T_4	34.75^{bc} (073.8%)	41.25^{b} (106.3%)	37.00^{bc} (146.7%)	43.75^{c} (191.7%)	20.50^{cb} (105.0%)	27.00^{b} (170.0%)
T_5	43.50^{ab} (117.5%)	55.75^{a} (178.8%)	41.00^{ab} (173.3%)	45.00^{bc} (200.0%)	20.50^{cb} (105.0%)	27.25^{b} (172.5%)
T_6	46.50^{ab} (132.5%)	58.50^{a} (192.5%)	41.00^{ab} (173.3%)	49.50^{a} (230.0%)	21.00^{cb} (110.0%)	27.25^{b} (172.5%)
T_7	47.00^{a} (135.0%)	59.25^{a} (196.3%)	42.50^{ab} (183.3%)	50.25^{a} (235.0%)	21.00^{cb} (110.0%)	28.25^{b} (182.5%)
T_8	48.25^{a} (141.3%)	59.25^{a} (196.3%)	42.75^{ab} (185.0%)	51.50^{a} (243.3%)	21.50^{c} (115.0%)	28.50^{b} (185.0%)
T_9	49.50^{a} (147.5%)	59.50^{a} (197.5%)	43.00^{ab} (186.7%)	52.00^{a} (466.7%)	24.00^{ab} (140.0%)	29.00^{b} (190.0%)
T_{10}	50.75^{a} (153.8%)	59.75^{a} (198.8%)	44.00^{ab} (193.3%)	53.00^{a} (253.3%)	24.50^{ab} (145.0%)	32.50^{a} (225.0%)
T_{11}	52.75^{a} (163.8%)	61.50^{a} (207.5%)	45.25^{a} (201.7%)	55.00^{a} (266.7%)	26.00^{a} (160.0%)	34.50^{a} (245.0%)
T_{12}	51.00^{a} (155.0%)	60.50^{a} (202.5%)	45.00^{a} (200.0%)	54.00^{a} (260.0%)	25.00^{a} (150.0%)	34.25^{a} (242.5%)
Initial	20 x 10^4 cfu/g		15 x 10^6 cfu/g		10 x 10^5 cfu/g	

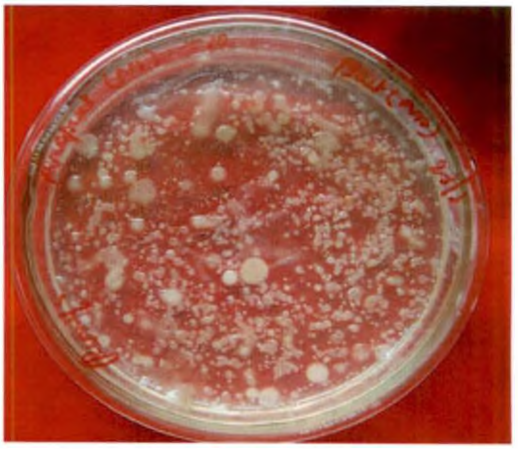
Treatments having same alphabets as superscript form homogenous group. Values in parenthesis indicate per cent increase over the initial observation.

T_1 - POP , T_2 - POP along with mulching, T_3 - FYM [1], T_4 - PM, T_5 - V, T_6 - FYM + PM + V ,T_7 - FYM + PM + V + P, T_8 - FYM + PM + V FAA, T_9 - FYM + PM + V AP, T_{10} - FYM + PM + V 4 FOC, T_{11} - FYM + PM + V FPE, T_{12} - FYM + PM + V + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1 mulching (25 t green leaves ha^{-1} was provided).

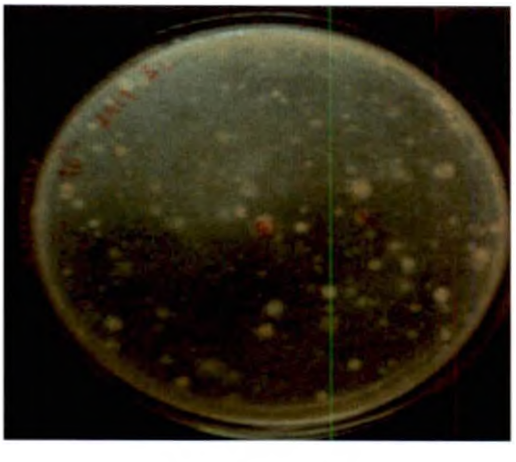
Plate 4. Petri plates of fungi, bacteria and actinomycetes



a. Fungus



b. Bacteria



c. Actinomycetes

showed the lowest bacterial population of 26.25 × 10^6 cfu/g with an increment of 75.0 % on 50^{th} day.

The highest bacterial population (55 × 10^6 cfu/g) was observed in T_{11} on 100^{th} day with the highest increment of 266.7 %. The treatment T_1 recorded the lowest bacterial population of 28.75 × 10^6 cfu/g. The increment of the population was only 91.7 %.

4.6.11.3 Actinomycetes

The initial actinomycetes population was 10 × 10^5 cfu/g. On 50^{th} day the actinomycetes population multiplied to 26.00 × 10^5 cfu/g and the increment was the highest (160.00 %) in treatment T_{11}. The treatment T_1 showed the lowest (11.00 × 10^5 cfu/g) actinomycetes population and increment (10.0 %) on 50^{th} day.

The highest actinomycetes population (34.50 × 10^5 cfu/g) and the highest increment (245.0 %) were observed in T_{11} on the 100^{th} day. The treatment T_1 recorded lowest actinomycetes population (12.00 × 10^5 cfu/g) and the increment was only 20.0 %.

4.7 B:C RATIO

The effect of treatments on benefit: cost ratio is given in Table 29 and Fig. 10. There was significant difference among the treatments. The highest (3.40) benefit:cost ratio was recorded in the treatment T_4. This was closely followed by T_{11} (3.00). The lowest benefit: cost ratio was recorded in T_1 (1.80) and T_5 (1.92).

Table 29. Effect of treatments on benefit:cost ratio

TREATMENTS	B:C RATIO
T_1	1.80[f]
T_2	2.27[de]
T_3	2.30[de]
T_4	3.40[a]
T_5	1.92[f]
T_6	2.30[de]
T_7	2.41[d]
T_8	2.40[d]
T_9	2.60[c]
T_{10}	2.79[c]
T_{11}	3.00[b]
T_{12}	2.38[c]

Treatments having same alphabets as superscript form homogenous group.

T_1 - Manures and fertilizers as per POP recommendation, **T_2** - Manures and fertilizers as per POP recommendation along with mulching, **T_3** - FYM 17 t ha^{-1}, **T_4** - Poultry Manure 12.5 t ha^{-1}, **T_5** - Vermicompost 9 t ha^{-1}, **T_6** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost , **T_7** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Panchagavya (P) at 10 days interval, **T_8** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Fish Amino Acid (FAA) at 10 days interval, **T_9** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost+ Std. Amrutha Pani (AP) at 10 days interval, **T_{10}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at10 days interval, **T_{11}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Plant Extract (FPE) at 10 days interval, **T_{12}** - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompt + P + FAA + AP + FOC + FPE (2 times each). In all treatments except T_1, mulching (25 t green leaves ha^{-1}) was provided.

DISCUSSION

5. DISCUSSION

Organic agriculture is a production system that sustains the health of soils, ecosystems and the people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promotes fair relationships and quality of life for all involved (IFOAM, 2011). The presence of growth promoting factors like enzymes and hormones, besides small quantities of all the plant nutrients make organic manures essential for improvement of soil fertility and productivity (Bhuma, 2001). Decomposition of organic manures in soil results in the release of CO_2, which gets converted into carbonic acid by dissolution in soil water, and enhances weathering of minerals and release of plant nutrients. Further, the sustainability in agriculture production refers to the capacity to remain productive continuously while maintaining the soil fertility and increasing biodiversity. Biologically active preparations of animal and plant origin were most commonly used by ancient farmers who unknowingly materialized sustainable production.

The results, obtained in the study on "Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench)" carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010-11 in the variety Arka Anamika, are discussed in this chapter. The study was conducted to test and scientifically validate the farmer driven technologies for organic management and to evaluate the management in terms of yield, shelf life and fruit quality in okra.

5.1 GROWTH AND YIELD PARAMETERS

The crop responded well to the application of various treatments. Application of organic manures registered significantly higher plant growth and was superior to the treatments with inorganic fertilizers (T_1 and T_2). There were significant differences among the treatments for the vegetative characteristics of the plants. Maximum height.(3.61 m) was recorded in treatment T_4 (Poultry Manure 12.5 t ha^{-1}). It was on par with T_{11} with basal dose of manures and Fermented Plant Extract (FPE) as top dressing at 10 days interval (3.48 m), T_{10} - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Fermented Oil Cake Solution (FOC) at 10 days interval (3.40 m) and T_9 - 4 t FYM + 3 t Poultry Manure + 2.5 t Vermicompost + Std. Amrutha Pani (AP) at 10 days interval (3.26 m) whereas T_1- (POP recommendation) recorded the lowest (1.76 m). The number of branches was more in the organic treatments than in the inorganic ones.

Significant influence on growth characters due to the enhancement of uptake of nutrients favoured by the addition of organic manures was reported by Cosenova *et al.* (1990). The increase in plant growth might be because of the suitable soil rhizosphere and nutrient status, which facilitated earlier and better growth. The addition of organic mulches and organic manures imparted beneficial effects on plant growth through the supply of nutrients, by improving soil physical conditions and by stimulating the microorganisms (Ribeiro and Linderman, 1991). Espitiru *et al.* (1995) attributed the presence of both readily available and slow release nitrogen due to addition of poultry manure, as the reason for yield improvement. The improved growth was attributed to better soil properties and greater nutrient availability to plants (Zone, 1996). The enhanced cellulase production by microbes induced growth stimulation as reported by Brion *et al.*, 1998. Improvement in soil physical conditions and the soil available N, P and K enhanced the root growth and plant height in onion (Sankar *et al.*, 2009).

Krochmal and Samuels (1970) found that increased number of leaves produced more photosynthates and yield in cabbage. Anitha (1997) and Dileep (2005) obtained significant increase in plant height in chilli by the application of different organic manures. Anitha (1997) reported that application of poultry manure in chilli resulted in production of more photosynthates and improved yield. The beneficial effect of poultry manure in improving vegetative growth might be due to higher availability of essential plant nutrients, rapid mineralization and favourable C:N ratio (Mali *et al.*, 2005 ; Shelke *et al.*, 2005 and Prabhakaran, 2008). Faster decomposition of organic matter in tropical climate increased the availability of nutrients especially nitrogen which helped in protein synthesis and ultimately in higher growth rate (Gennaro and Quaglia, 2003).

The vegetative characters like height and number of branches were always superior in T_4 (full poultry manure) as compared to T_3 (FYM +V+PM) and T_5 (full vermicompost) indicating that there was no need of combining vermicompost and FYM along with poultry manure or substituting for poultry manure. The beneficial effect of poultry manure was clear from the result in terms of improved vegetative characters throughout the crop growth. For supplying the recommended dose of nitrogen, the basal dose of manures [12 t ha^{-1} of FYM (taking the nitrogen equivalent)] were split into 3 t ha^{-1} of poultry manure, 4 t ha^{-1} of FYM and 2.5 t ha^{-1} vermicompost. Considering these three treatments alone, poultry manure application was the best when compared to the other two. This leads to the conclusion that for obtaining optimum growth, there is no need of applying FYM or vermicompost as basal manures if poultry manure is available. Considering the treatment from T_6 onwards along with the basal application of FYM, poultry manure and vermicompost, there were supplements with various organics at 10 days interval. Among these six treatments T_{11} (FPE) was the best with optimum plant height and number of branches. The growth increment in terms of height and branches was also better in T_4 and T_{11} showing that right from the beginning, the supply and uptake of nutrients from the soil was more advantageous for putting forth better crop growth. Raj (1999) also obtained better response in okra due to the application of organic manures (oil cake, green leaf, poultry manure, FYM and enriched compost) than through the application of POP recommendation.

Highest LAI was recorded in the treatment T_{11} (2.17) followed by T_4 (1.90) and the lowest LAI was in treatment T_1 (1.23). The higher leaf area index in plants may be due to increased uptake of N which might have caused faster cell elongation and multiplication (Tinker, 1975). Studies done by Pimentala *et al.* (1984), comparing organic and inorganic grain production system in several vegetable crops had proved that organic farming was more energy efficient. Significant increase in leaf area index and leaf emergence rate by application of poultry manure was reported by Ndabuaku and Kassim (2003) in cocoa. Babu, (2004) reported that the prominent form of N in poultry manure is uric acid that readily transforms to ammoniacal form which is easily available for plants and resulted in increased leaf area index because of effective utilization of sunlight and nutrients. Singh, (2009) also reported that application of organic manures like FYM, compost and panchagavya significantly increased the plant LAI over control in soyabean during the kharif, rabi and zaid seasons.

Significant differences were noticed among the treatments with regard to the total dry matter production. Maximum amount of dry matter was recorded in the treatment T_4 (23.84 t ha^{-1}) followed by T_9 (20.15 t ha^{-1}). The treatment T_1 (9.90 t ha^{-1}) recorded the minimum. The increased dry matter production was the result of better plant growth as reflected by increased plant height, more branching and higher number of leaves. Production of photosynthates and effective utilization might have been another reason for increased biomass. Paramashivan *et al.* (2005) obtained a total dry matter production of 11.38 t ha^{-1} in okra variety Arka Anamika under integrated nutrient management. Babalad (2005) and Dhananjaya (2007) reported increased total dry matter production by application poultry manure and other green manures in chilli and radish respectively. Sankar *et al.* (2009) also reported that the increase in the dry matter production might be due to the enhancement of nutrient uptake favoured by improvement in soil physical conditions. Significant influence on growth and thereby dry matter production might be due to the enhanced uptake of nutrients favoured by the addition of organic manures as reported by Shijini (2010).

The number of nodes to first flower emergence did not show any significant difference among the treatments and flowering was observed in the fourth node for all the treatments. The plants should be either early in flowering or should be under prolonged reproductive phase to get more number of harvests. The plants receiving the treatments T_4 (PM), T_8 (FAA) and T_{11} (FPE) took the minimum number of days (35.67) to first flower opening and first harvest (40.67 days), but the treatment T_1 (POP) was late in flowering by three days and it took 38.33 days. Earliness in flowering by five days due to application of combinations of FYM and panchagavya was reported by Kumaran *et al.* (1998) in tomato. Similarly Rekha (1999) and Krishna (2005) found early flowering by the application of poultry manure in brinjal and cowpea respectively. Shijini (2010) reported that early flowering in papaya could be attributed to higher availability and uptake of nutrients from poultry manure.

The treatments differed significantly for weight of fruits. Maximum average fruit weight was recorded by the treatment T_{11} (20.17 g) and was on par with T_4 (20.10 g) and T_9 (19.93 g). Minimum average fruit weight was in the treatment T_1 (15.10 g). The fruit length varied from 20.34 cm (T_{11}) to 15.59 cm (T_1). The treatments T_3, T_4, T_8, T_9 and T_{11} were on par in fruit length. The maximum fruit girth was recorded in the treatment T_4 and T_{11} (7.87 cm) followed by T_{12} (7.83 cm). The lower most fruit girth was observed in the treatment T_1 (6.03 cm).

The number of seeds per fruit was found to be affected by various treatments. The highest number of seeds per fruit was recorded in the treatments T_4 and T_{11} (90.67) and the minimum in treatment T_1 (75.0). Early harvesting of fruits could be done from the treatments T_4, T_8 and T_{11} (40.67) and the treatment T_1 (43.33) was late. Maximum number of harvests could be done from the treatments T_4 (PM), T_{10} (FOC),

T_{11} (FPE) and T_{12} (P+FAA+AP+FOC+FPE) (23.0) whereas the lowest was in treatment T_1 (18.67). The maximum duration of the crop was recorded by the treatment T_4 (126.33 days) whereas the lowest was recorded by T_1 (97.0 days).

An additional benefit of 23 yielding days with 5.29 kg of fruits was available for T_4 and 5.03 kg for T_{11} (Fig. 11) *Prolonged yield in okra, due to long period of* active growth of plant by the application of locally available organic manures in alluvial regions of West Bengal was reported by Rakshit (2009).

Chattoo *et al.* (2009) suggested that improvement in seed yield and related attributes due to integration among organic sources could be attributed to balanced C:N ratio, organic matter build up, better root proliferation, sustainable nutrient availability, accelerated transport and higher concentration of plant nutrients. These might have lead to better photosynthesis and efficient translocation of photosynthates from the source to sink, resulting in an improvement in fruit yield and related attributes. They also opined that superiority of poultry manure over rest of the organic sources in improving yield and related attributes could be due to its nutritional richness and stimulatory role.

Yield of economic part is the most important parameter which decides the profitability of a crop. The maximum number of fruits per plant (74.67), yield per plant (661.17 g) and yield per plot (31.75 kg) was recorded in the treatment T_4 (PM) and it was on par with T_{11} (FPE). The maximum yield per hectare was recorded in the treatment T_4 (24.49 t ha^{-1}) and it was on par with T_{11} (24.02 t ha^{-1}) whereas the lowest yield was observed in treatment T_1 (12.00 t ha^{-1}). Acharya (2004) reported a yield of 29.95 t ha^{-1} in Arka Anamika due to application of triacontanol. The lowest number of fruits per plant (35.33), yield per plant (324.01 g) and yield per plot (15.55 kg) was recorded in the treatment T_1 (POP).

Sivakumar *et al.* (2005) reported 22.24 t ha^{-1} of yield in okra variety Arka Anamika under integrated nutrient management system where 12.5 t ha^{-1} of poultry manure was used, whereas only 20.05 t ha^{-1} could be realized when 12.5 t ha^{-1} FYM was applied as basal dose. Further there was an increase of 40 per cent yield over package of practices recommendation, due to poultry manure application. Increment in yield due to application of poultry manure (T_4) and plant extracts (T_{11}) may be due to the complementary effect of plant growth promoting ability of the microbes by its mass multiplication rate, regulated by the organic amendments and thereby the increased soil fertility as reported by Christapher (1991). High yield in treatments with poultry manure might be due to increased availability of nitrogen from this organic source. A balanced supply of N promotes translocation of phytohormones to shoot which probably induced early flower formation (Marschner, 1983; Banker and Mukthopadhyay, 1990). Nandini (1998) realized higher yield in okra, from plots receiving different doses of poultry manure and maximum from plots in which poultry manure equivalent to 100 kg N ha^{-1} was applied. The positive influence of poultry manure on yield attributes is well documented by many researchers. The beneficial effect on improving yield might be due to better plant growth by the sustained and increased availability of nutrients throughout the growth phase and enhanced photosynthesis and accelerated mobility of photosynthates from the source to the sink as influenced by the growth hormones released or synthesized from these manures (Natarajan, 2003 and Sivakumar *et al.*, 2005).

Mikhailovskaya and Batchilo (2007) reported increased activity of enzymes like dehydrogenase, invertase, urease, peroxidase and polyphenol oxidase in soil due to poultry manure application. Beaulah (2001) reported that in inorganic treatments the plants might have suffered from lower fertility levels compared to the organic treatments. With regard to yield parameters all the organic treatments exhibited positive influence over control indicating that okra responds well to organic manures. All vegetative and reproductive parameters were positively influenced by organic manure application and the treatments T_4 and T_{11} were the most superior ones in realizing actual yield. Mulched crops, irrespective of irrigation levels and methods of irrigation, recorded significantly higher levels of fruit yield in okra (Kumar, 1998). Rakshit (2009) also obtained increased fruit yield in okra with poultry manure and attributed it to the higher retentivity of water and nutrients, and higher uptake of major and minor nutrients from poultry manure. Shijini (2010) reported higher fruit size, fruit weight and fruit girth in papaya from treatments receiving poultry manure.

In okra, yield attributes mainly include earliness in flowering and harvest, prolonged crop duration and improved yield per plant. Positive influences of the organic treatments were also reflected in improved vegetative growth which significantly influenced the yield potential of okra.

5.2 FRUIT QUALITY PARAMETERS

Significant differences were noticed with regard to quality traits like moisture content, crude fibre, crude protein, beta carotene, vitamin C, micronutrients and NPK content of the okra fruits among the treatments. Organic treatments recorded significantly higher values for quality parameters. The maximum amounts of ascorbic acid (29.85 mg/100 g) and beta carotene (122.50 µg/100 g) were observed in the treatment T_{11}. The lowest amounts of ascorbic acid (12.19 mg/100 g), beta carotene (63.00 µg/100 g) and micronutrients were observed in T_1. The minimum crude fibre (1.20 %) was observed in the treatments T_4 and T_{11} whereas maximum amount of crude fibre was observed in T_1 (1.50 %). Maximum crude protein (20.64 %) was observed in the treatments T_{11} and T_4 and minimum crude protein in the treatment T_1 (8.90 %). Omori and Ogura (1972) obtained improved fruit quality in terms of crude protein, crude fibre, and vitamin C by the application of FYM, compost, oil cakes, green leaf and poultry manure in vegetable crops like tomato, onion, gourds, egg plant, chinese cabbage and chilli. Several workers (Raj, 1999; Anand *et al.*, 2005;

Patel *et al.*, 2009; Tripathy *et al.*, 2009 and Karthikeyan, 2010) reported huge variation in crude protein (19.56 - 31.73 %) and ascorbic acid (21.92 - 24.82 mg/100g) contents in okra due to various treatments. Chattoo *et al.* (2009) reported 20.98 per cent protein in seeds of okra.

Joseph (1998 a) obtained better yield of snake gourd, with lower fibre and higher protein, in poultry manure applied plants. Similar results were obtained by Kumar (2007) in Knol-khol and Singh (2007) in tomato. Mikhailovskaya and Batchilo (2007) reported increase in gluten content of wheat from 30.4 per cent to 32.7 per cent on application of poultry manure. They have reported that application of poultry manure provided balanced plant nutrition, significant improvement of crop productivity and product quality.

The improvement in quality could be explained with the differences in soil nutrition, which affects mineral absorption from soil and the plant metabolism as reported by Gennaro and Quaglia, 2003. In snake gourd, maximum fibre content (19.14 %) was present in fruits obtained from plants under chemical management and the least from plants provided with poultry manure (15.31 %) (Joseph, 1998 b). Improvement in quality attributes of lettuce due to application of solely organic manures could be attributed to better and balanced nutrition and production of growth-promoting substances by organics (Mujahid and Gupta, 2010).

The treatments differed with respect to micronutrient content of fruits, highest being recorded in T_4 and T_{11}. According to Sharma *et al.* (2000) the better efficiency of organic manures might be due to the fact that they provide the micronutrients such as Zn, Cu, Fe, Mn and Mg at optimum levels. Although, the organic manures contain plant nutrients in small quantities as compared to the fertilizers, they also contain growth promoting substances like enzymes and hormones which make them essential for improvement of soil fertility and productivity (Bhuma, 2001). Magnesium and iron are involved in the pathway for chlorophyll synthesis which in turn increases the rate of photosynthesis. Application of organic manures thus would have accelarated the plant metabolic activites (Anburani and Manivannan, 2002). Zinc, is involved in the biochemical synthesis of the most important phytohormone - Indole Acetic Acid through the pathway of conversion of tryptophan to IAA (Azeez *et al.*, 2009).

The maximum amount of nitrogen (3.303 %) and potassium (1.937 %) in fruits was observed in the treatment T_{11} and it was on par with T_4. The lowest amount of nitrogen (1.425 %) and potassium (0.910 %). was observed in T_1. Subbiah (1991) reported 4.78, 0.74 and 5.3 per cent of NPK contents in okra fruits. There was only a marginal difference in phosphorus. Being a part of protoplasm, N plays a key role in the buildup of new cells and chlorophyll synthesis. Beneficial effect of poultry manure might be due to continuous release of nutrients which resulted in increased plant growth, more production and translocation of photosynthates, resulting in better nutrient content of fruits (Zhou-Dongmei *et al.*, 2005). Meerabai and Raj (2001) reported that poultry manure with its low C:N ratio and good nutrient value suits well for all crops especially vegetables and its higher efficiency was due to large quantities of easily mineralisable N. Nitrogen from organic manures is released slowly as compared to chemical fertilizers which ensures a steady and continuous supply of the available nitrogen (Erenstein, 2007). Recovery of P from organic manures is slightly better than that from fertilizers, as CO_2 released by decomposition improves the availability of P from soil (Rakshit, 2009).

Balanced nutrient supply is necessary not only for obtaining higher and regular yields of better quality fruits but also for increasing the shelf life of fruits. Increase in shelf life and minimum post harvest loss will go a long way in increased fruit avaliability. The fruits of treatment T_4 and T_{11} had maximum shelf life under both ambient (5.0 days) and refrigerated (9.0 days) conditions. The treatment T_1 had minimum shelf life under both open (3.0 days) and refrigerated (6.0 days) conditions.

Minimum physiological loss in weight was recorded by treatments T_4 & T_{11} on first (5.33 %), fourth (10.67 %), eighth (20.33 %) and twelveth (25 %) days of storage. Maximum loss in weight was recorded by T_1 and T_2 on first (20 %), fourth (31.33 %), eighth (45.33%) and twelveth (45.33 %) days of storage. Lindner (1985) found that respiration rate and enzyme activity were lower in organically produced vegetables, leading to reduced storage losses. High shelf life in organic papaya fruits was also reported by Shijini (2010) and she attributed it to higher calcium content in fruits. The shelf life of snake gourd was also better in treatments provided with poultry manure (Joseph, 1998 a).

When poultry manure is applied long term increase in soil nutrients levels of B, Ca, Mg, Cu and Zn can be expected (Bitzer and Sims, 1988). Importance of minerals like boron in keeping quality of fruits and tubers was indicated by Tisdale (1995) and he found that the application of poultry manure favourably influenced the shelf life of fruits. Fritz and Habbene (1972) reported that K avaliability increased the durability of fruits by lowering the activity of enzymes which breakdown the carbohydrates.

5.2.1 Plant analysis

In plants the micronutrients like calcium, magnesium, manganese, zinc, iron and copper were higher in leaves than in root and stem samples. Irrespective of the treatments, in general, the micronutrients were higher in the plants receiving organic treatments. Swarup (1984) reported that application of farmyard manure increased the availability of both native and applied micronutrient cations. These ions formed stable complexes with organic ligands which decreased their susceptibility to adsorption and fixation. According to Qingren *et al.* (2009), the complexing property of organic matter influenced the availability and mobility of micronutrients. Microbial decomposition of organic manures with simultaneous release of organic acids might have favoured the availability of micronutrients in soil and their uptake by okra as reported by Chattoo *et al.* (2009). Amitava and Debashish (2008) reported significantly higher uptake of micronutrients in okra plants manured with oil cakes.

Significant difference was seen among the treatments for chlorophyll content and the highest amount was present in T_{11} (56.63). This was followed by T_{10} (55.43). The lowest content was in plant receiving the treatment T_1 (43.73). Sanwal *et al.* (2007) obtained an increase in chlorophyll content in the leaves with the application of organic source of nutrients. According to Nehra *et al.* (2001) the increased application of fresh cow dung, which contains appreciable quantities of magnesium, might have helped in chlorophyll synthesis which in turn increased the rate of photosynthesis. Application of organic inputs showed accumulation of nutrients in leaf tissue, which in turn ensured the photosynthetic efficiency, causing greater synthesis, translocation and accumulation of carbohydrates and chlorophyll (Gathala *et al.*, 2007). Significant difference was observed among the treatments for nitrogen, phosphorus and potassium in leaves, root and stem samples. Maximum amount was found in treatment T_{11}which was on par with T_4 and was minimum in T_1. Akande *et al.* (2010) reported that nitrogen content (during last harvest) of okra leaves increased from 4.09 per cent in control (no fertilizer) to 5.61 per cent on application of *Gliricidia* mulch. The increasing availability of nutrients especially N which is an important constituent of chlorophyll and amino acids might have helped in accumulation of chlorophyll.

Estimation of NPK during the last stage of crop growth clearly indicated that application of poultry manure resulted in increased nitrogen content. Plants receiving treatment T_4 had highest nitrogen (494.00 kg ha^{-1}), phosphorus (44.39 kg ha^{-1}) and potassium uptake (243.99 kg ha^{-1}). Lowest uptake of nitrogen (81.11 kg ha^{-1}), phosphorus (11.01 kg ha^{-1}) and potassium (33.64 kg ha^{-1}) was by the plants receiving treatment T_1 (POP). In a study on functional efficiency of organic meal in groundnut production Senthil (2000) obtained a total biomass production of 18.37 t ha^{-1} with a total nutrient uptake of 442.16 kg ha^{-1} N, 42.01 kg ha^{-1} P and 217.69 kg ha^{-1} K on application of organic meal @ 100 kg ha^{-1} + 10 kg ha^{-1} N+ 75 kg ha^{-1} K_2O. He has also found that the uptake varied according to treatments.

Application of poultry manure augmented plant nutrient uptake and reduced the loss of nitrates through leaching from the soil, provided a significant amount of plant micronutrients and created a balancing effect on the supply of nitrogen, phosphorus and potassium (Mallanagouda *et al.*, 1995). The highest N content of leaves in treatments containing poultry manure might be due to release of N from poultry manure as uric acid, which is readily available to plants, having 60 % N in the ammoniacal form helps in the efficient utilization by the plants (Mali *et al.*, 2005 and Shelke *et al.*, 2005). More N content in leaves under treatment with poultry manure in the present study can also be counted as a reason for the positive influence of this organic source on the yield attributes of okra.

Poultry manure is having low C:P ratio which helps in easy extractability of available P to plants which ultimately resulted in higher P content of leaves, stem and roots in crop plants (Kaistha *et al.*, 1997). Tisdale (1995) found that the organic manure in the nutrient supply systems enhanced the moisture retention capacity of soil and there by accelerated the K diffusion to roots which have resulted in better K uptake. Hangarge *et al.* (2002) reported that increased uptake of K in the chilli crop was the result of increased availability of K in the soil due to the application of organics. Application of liquid manures recorded higher uptake of N, P and K in chilli plants due to increased availability of nutrients as a result of rapid buildup of soil microflora resulting in increased enzymatic activity (Vijayashankar *et al.*, 2007). Varying influence of organic manures on soil properties also caused differences in the performance of nutrient sources (Rakshit, 2009).

5.3 SOIL ANALYSIS

Use of organic amendments improves physical properties of the soil and balances the nutrient availability to plants and boosts up production and quality of the crop. The living microbes mobilize nutritionally important elements to available form through biological processes (Burton, 1967).

In the present study, a positive influence on soil properties like pH, organic carbon content, available N, available P and available K was noted in treatment T_{11}. The initial organic carbon and organic matter content of soil of experimental plots were 0.32 % and 0.56 % respectively. At the final stages of the experiment the increment ranged from 15.63 % (T_1) to 71.88 % (T_{11}) in the case of organic carbon and 14.29 % (T_1) to 71.43 % (T_{11}) in organic matter content. The increase in organic carbon content of soils under organic farming was quite obvious since the carbonaceous materials contribute to soil organic carbon after their decomposition. The increase in organic carbon content might be ascribed to direct incorporation of FYM or organic matter to the soil (Hangarge *et al.*, 2004).

The initial pH of the experimental plot was 5.1. The final pH ranged from 5.2 to 6.5. The soil pH of T_{11} and T_4 (6.5) was statistically superior indicating that significant variation existed among the treatments. The treatment T_1 (5.2) showed the minimum soil pH. Singh and Singh (1976) observed that by the application of organic manures pH can be brought to neutral. Mikhailovskaya and Batchilo (2007) reported that poultry manure highly influenced the soil fertility status and resulted in optimization of pH value from 5.2 to 5.6. Shankar (2008) also found that soil properties like pH was improved by the application of poultry manure. Okra is a crop which requires a soil pH of 6.0 - 6.8 for its successful cultivation (Chadha, 2004). An increase in soil pH as a result of poultry manure application might have increased the availability of nutrients and resulted in better growth and yield. The data on EC showed no significant difference among the treatments. It was the same (0.1 d Sm^{-1}) for all treatments. Similar results were obtained by Mallanagouda *et al.*, 1995. Incorporation of organic substances increased the micronutrient status in soil depending upon the supply of reducing and chelating substances. In this regard, Singh and Singh (1976) observed higher concentrations of micronutrients in the soil treated with poultry manure and *Sesbania aculeata.*

The initial contents of available nitrogen, phosphorous and potassium in soil were 374, 34 and 374 kg ha^{-1} respectively. The available nitrogen after the crop period ranged from 378 to 412 kg ha^{-1}. Soil under T_{11} had maximum increment (10.16 %) of available nitrogen whereas T_1 and T_2 had the minimum (1.07 %). The accelerated uptake of nitrogen, chief constituent of protein, essential for the formation of protoplasm, led to cell development, enlargement and plant growth. Moreover N is an important component of amino acids and co-enzymes which are of considerable biological importance in the physiological growth of crop plants (Bakly, 1974). Role of N in favouring the growth of crop plants especially through organic sources has been well documented by Tomar *et al.* (1998). Mikhailovskaya and Batchilo (2007) stated that 40 per cent of total nitrogen and 60-65 per cent of total phosphorus in poultry manure are in available forms for plant nutrition. Poultry manure provided increase in total and available nutrient status. Kara *et al.* (2007) observed stimulation of soil biological characteristics such as CO_2 production, dehydrogenase activity and mineralization of organic nitrogen into NH_4^+ N and NO_3^- N when poultry manure was used.

Though not significant, the available nitrogen content was slightly higher in treatments T_3 to T_{12} than in T_1 and T_2 where the inorganic fertilizers were used. Production of appreciable quantities of carbonic acid during decomposition of organic matter mineralizes the complex organic substances, which in turn would contribute to N pool. An increase in available N by application of vermicompost and FYM was reported by Pawar (1996). Improvement of soil structure and biological activity of the soil would have reduced the loss of nitrogen through increased cation and anion exchange capacities of the soil (Mizuni, 1996). The increase in available nitrogen due to organic matter application is also attributable to the greater multiplication of soil microbes caused by the addition of organic materials, which mineralize organically bound N to available form (Bellakki and Badanur, 1994).

The available phosphorous in soil ranged from 35 to 42 kg ha^{-1}. Soil under T_1 and T_2 showed the minimum increment (2.94 %) of available phosphorous followed by T_3 which registered 17.65 %. Rest of the treatments had an increment of 31.25 % available phosphorous in soil. The available phosphorus content was slightly higher in treatments T_3 to T_{12} compared to T_1 and T_2 where the inorganic fertilizers were used. Tandon (1987) attributed the increase in available phosphorus with poultry manure application, to the contribution of P by the organics to the soil available pool and the coating of organic material on sesquioxides which reduces the phosphate fixing capacity of the soil. Similar observations were also reported by Bharadwaj and Omanwar (1994). Increase in total and available P_2O_5 content in soil due to vermicompost application was reported by Radhakrishnan (2009). This was due to greater mineralization of organic matter with the aid of micro flora associated earthworms. Increased P_2O_5 content was due to high phosphatase activity. Damke *et al.* (1988) showed that phosphate dissolution rates can be greatly accelerated in soil in presence of organic acids such as malate, citrate and oxalate leading to 10-1000 fold higher P concentration in soil solution depending on soil type and concentration of organic acids. According to Baiju *et al.* (2010), the major effect of vermicompost application in soil was a reduction in P fixation and thus increasing the P availability in acid soils. The available potassium irrespective to all treatments, later became more than 400 kg ha^{-1}.

The data on bulk density, particle density, water holding capacity and pore space showed significant difference among the treatments. Minimum bulk density (1.06 g cm^{-3}) was found in the treatment T_{11} whereas T_1 had the maximum bulk density (1.49 g cm^{-3}). Maximum pore space (54.83 %) was found in the treatment T_{11} and the highest water holding capacity (51.51 %) was found in T_4. T_1 had minimum pore space (52.60 %) and water holding capacity (29.33 %). Acharya *et al.* (1988) observed improvement in water holding capacity of soil due to addition of organic manures compared to addition of inorganic fertilizers alone. Jadhav *et al.* (1993) and Sharma *et al.* (2000) reported increased water holding capacity, build up of soil organic matter and improvement in soil structure by application of FYM and vermicompost respectively. Improvement of water holding capacity and air permeability by improving the soil structure was also reported by Mizuni (1996).

The study conducted by Ofosu-Anim *et al.* (2007) in okra revealed that the application of garden compost, poultry manure and cow dung improved the soil physical condition, particularly, structure and drainage and enhanced the yield components of okra plants. Inorganic fertilizers improved only the chemical properties, but the soil physical properties such as structure were not improved. The present study clearly indicated the superiority of poultry manure over cow dung and compost as a source of manure for okra production. Decrease in bulk density and increase in porosity and water holding capacity of the soil due to organic manures might have contributed to increased root volume and absorption of nutrients by the plants (Giraddi, 1993). The increase in bulb diameter and length of onion was attributed to solubilization of plant nutrients by addition of vermicompost, poultry manure and FYM leading to an increased uptake of NPK (Subbaiah and Asija, 1982). Similar results were obtained by Renuka and Ravishankar (2001) in tomato.

Soil physical properties showed a slight improvement in four months. If we continue the addition of organics for a longer period it would definitely improve the soil properties in due course. Bellakki and Badanur (1994), favouring organic farming, proclaimed that by the application of 5 t of FYM, subabul and sorghum stubbles as mulch for three years significantly improved the soil properties. Bulk density decreased from 1.56 to 1.07 g cm^{-3} and soil organic carbon increased from 0.32 to 0.69 % in three years.

5.3.2 Microbial population in soil

The initial fungal population was 20×10^4 cfu/g, bacterial population was 15×10^6 cfu/g and actinomycetes population was 10×10^5 cfu/g later increased to 61.50×10^4 cfu/g, 55.00×10^6 cfu/g and 34.50×10^5 cfu/g respectively for fungi, bacteria and actinomycetes by adding organic manures (T_3 - T_{12}). The total microbial population (Fig. 12) was high in the case of all organic treatments. This could be attributed to favourable effects of manures in proliferating microbial population by providing carbon as a source of energy for microflora and also protection to the enzyme fraction due to increase in the humus content (Martens *et al.*, 1992). Mikhailovskaya and Batchilo (2007) observed that poultry manure application was accompanied by significant increase of dehydrogenase activity (ten times) which is a reliable indicator of soil microflora status. Before the organic nitrogen is used by the crops, it is converted through bacterial action into readily usable ammoniacal nitrogen and nitrate nitrogen. These organic manures are, therefore, relatively slow acting, but they supply available nitrogen for a longer period (Reddy and Reddy, 2005).

Since in a soil plant system, the soil's energy powerhouse is the rhizosphere, any alteration to the fertility management (eg. balanced or imbalanced fertilization, use of organics) will have a strong impact or feed back at the soil-plant interface, subsequently on the agricultural productivity and sustainability of the ecosystem. Since microbial processes are dynamic, patterns of temporal fluctuation during crop

Fig. 11 Additional yield and number of yielding days of okra plants in comparison to POP

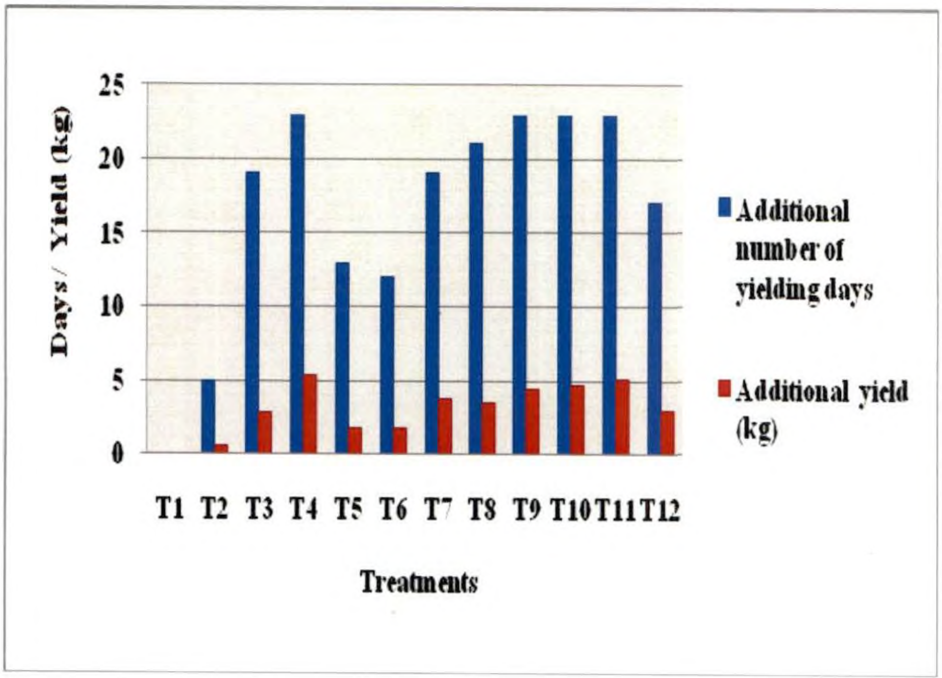
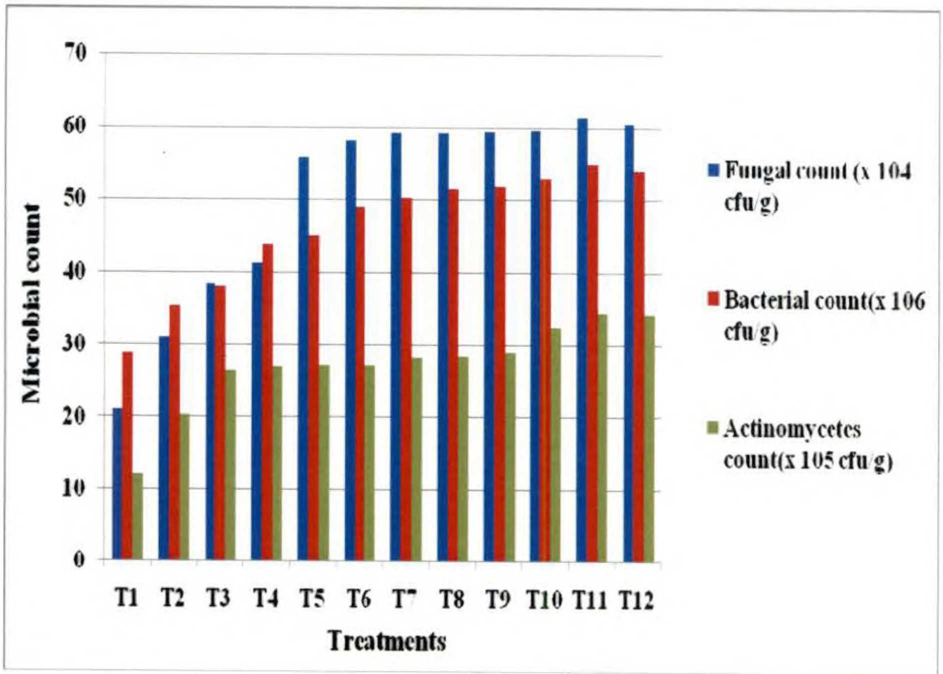


Fig. 12 Total microbial population in soil at final harvest



growth are of great importance in relation to the nutrient supplying capacity through organic matter recycling of the ecosystem and the crop demand (Asit *et al.,* 2007).

The treatment T_2 (POP with mulching) with mulching showed better results in yield and microbial count than T_1 (POP). Straw mulching enhanced microbial biomass, activity, and potential N availability by 42, 64 and 30 %, respectively, relative to non-mulched soils, likely via improving C and water availability for soil microbes (Tu *et al.,* 2006). Application of organic manures at 10 days interval has enhanced the microbial activity in soil. The bulk density was low in soils under organic farming system than the soils under the conventional farming system. Consequently the organic soils possessed good aeration and there by good biological activity (Arun, 2004). The findings that microbial properties and N availability for plants differed under different organic input regimes suggest the need for effective residue management in organic farming systems (Tu *et al.*, 2006). Palekar (2006) reported that jeevamrut contains enormous amount of microbial load which when applied to soil multiplied in the soil and plants under such management put forth better growth and yield.

Organic mulching had beneficial effects on soil microbes likely through buffering the extreme fluctuations in soil moisture and temperature (Erenstein, 2007). In addition, mulching provided other benefits through reducing soil erosion and nutrient losses and suppressing weeds, as weed control generally poses a major challenge in organic farming. Mulching was effective in sustaining soil microbial biomass and activity in our soils. These results indicated that the amount and quality of organic C inputs could profoundly impact the microbial properties and N availability for plants, highlighting the need for effective residue management in organic farming systems (Erenstein, 2007). Different organic manuring treatments gave significantly higher microbial population (fungi, bacteria and actinomycetes) and enzymatic activities in the soil and application of poultry manure, vermicompost and FYM in combination was good for improving soil quality (Ravishankar *et al.*, 2008).

Soil-bound organisms often benefit and increase due to natural manures, while experiencing reduced intake of herbicides and pesticides. Increased biodiversity, especially from beneficial soil microbes and mycorrhizae have been proposed as an explanation for the high yields experienced by organic plots. Microbes break down the plant matter and animal wastes into productive soil nutrients. In turn the soil becomes healthier and more productive. Fields with less or no manure, display significantly lower yields, due to decreased soil microbe community (Bengtsston *et al.*, 2005)

5.4 B:C RATIO

There was significant difference among the treatments. The highest (3.40) benefit: cost ratio was recorded in the treatment T_4. This was closely followed by T_{11} (3.00). The lowest benefit: cost ratio was recorded in T_1 (1.80) and T_5 (1.92). The cost of vermicompost was high compared to FYM and poultry manure but has only a marginal increase in nitrogen content.

Highest B:C ratio was observed in the treatment under poultry manure alone which might be due to the availability of poultry manure at a cheap rate and the highest yield obtained by way of its application. Treatments with other organic manures resulted in better gross income; however the poor BC ratio indicated their less cost effectiveness. High B:C ratio by the application of poultry manure was reported in brinjal by Prasanna (1998) and Nandini (1998) in okra. Magray *et al.* (2011) reported the highest cost benefit ratio of 5.28 and highest gross return of Rs.3.88 lakh in tomato, by the application of 7 t ha^{-1} of poultry manure alone as compared to different combinations of chemical and organic manures.

The economics of organic farming cannot be worked out merely based on yield *per se*. It encompasses the entire process and effects of organic farming in terms of benefits to human society, including social costs, opportunity costs, unintended consequences, information asymmetries, and economies of scale. Although the scope of economics is broad, agricultural economics tends to focus on maximizing yield and efficiency at the farm level (Nwaiwu *et al.*, 2010).

5.5 CONCLUSION

The above findings revealed that organic manures would be able to sustain the soil fertility and maintain crop productivity. The vegetative growth and yield parameters of okra were significantly influenced by organic treatments when compared to the inorganic ones. Even among the inorganic treatments, mulching alone could increase the yield by 2.90 kg plot^{-1} (T_2). Comparing the source efficiency of three common organics *viz*., FYM, vermicompost and poultry manure it was found that poultry manure was the best in terms of yield, the most important economic component. So whenever possible, it is most ideal to recommend poultry manure as basal dose @ 12.5 t ha^{-1}.

Taking into consideration of all treatments where liquid organic manures (farmer's innovations) were used, the treatment T_{11} (FPE) performed the best in terms of yield, quality and shelf life. The differences in yield when compared to T_{11} was 0.656 kg plot^{-1} in T_{10} (Fermented Oil Cake), 3.797 kg plot^{-1} in T_7 (Panchagavya), 4.274 kg plot^{-1} in T_9 (Amruta Pani) and 7.077 kg plot^{-1} in T_8 (Fish Amino Acid). Probably such a reduction in yield (compared to T_{11}) might have resulted from insufficient quantity of liquid manures used for the experimental purpose. But all these treatments were superior to POP. Further the inputs like fish waste, oil cakes, cow dung and cow urine (Amrutha pani) can be chosen by farmers according to household/local/regional availability and convenience and can be made more cost effective.

Future line of work

Research can be conducted using higher doses of liquid organic manures with full basal dose of poultry manure in many other vegetables. Numerous cost effective, locally available organic byproducts can be included for further studies. Several other innovations by farmers are still to be tested.

SUMMARY

6. SUMMARY

The studies on "Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench" were carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010-11 in the variety Arka Anamika. The study was conducted to test and scientifically validate the farmer driven technologies in organic nutrient management in vegetables with special reference to okra, to work out the practical feasibility and financial viability of vegetable cultivation with organic sources of nutrients and to assess the crop response to organic management in terms of yield, shelf life and fruit quality and to initiate a standardization of package on nutrient management through organic means. During the course of the experiment, plant growth, yield and quality of the produce under different treatments were critically observed. The salient findings of the study are summarized below.

Remarkable variation in terms of vegetative growth was observed among the treatments. Application of organic manures registered significantly higher plant growth and was superior to the inorganics (T_1 and T_2). There were significant differences among the treatments for the height of the plants. Maximum height was recorded in the treatment T_4 receiving - Poultry Manure 12.5 t ha^{-1}. The height of the plants under the use of Fermented plant extract (T_{11}) was on par with that of Fermented oil cake (T_{10}) and Amrutha pani (T_9) whereas T_1 receiving - POP recommendation recorded the lowest (1.76 m) height. The highest numbers of branches (8) was produced in the treatment with poultry manure (T_4) and were on par with FPE (T_{11}), but T_1 recorded the lowest. T_1 had duration of 97 days and it produced two branches till the final day of harvest.

Plants under the treatments T_4, T_8 and T_{11} were early to flower (35.67 days) and to harvest (40.67 days) but the treatment T_1 was late in flowering and harvesting.

Maximum average fruit weight was recorded by the treatment T_{11} (20.17 g) and was on par with T_4 (20.10 g) and T_9 (19.93 g). Minimum average fruit weight was in the treatment T_1

(15.10 g). The fruit length varied from 15.59 cm (T_1) to 20.34 cm (T_{11}). The treatments T_3, T_4, T_8, T_9 and T_{11} were on par in fruit length. The maximum fruit girth was recorded in the treatment T_4 and T_{11} (7.87 cm) followed by T_{12} (7.83 cm). The lower most fruit girth was observed in the treatment T_1 (6.03 cm). The number of seeds per fruit was found to be affected by various treatments. Maximum number of seeds was found in the treatments T_4 and T_{11} (90.67). The lower most fruit girth was observed in the treatment T_1 (75.0).

The maximum number of harvests was obtained from the treatments T_4, T_{10}, T_{11} and T_{12} (23.00) whereas, the lowest number of harvests was made in treatment T_1 (18.67). The maximum duration of the crop was recorded by the treatment T_4 (126.33 days). An additional benefit of 23 yielding days with 5.29 kg of fruits per plot was available for T_4 and 5.03 kg for T_{11}. A significant improvement in fruits per plant, yield per plant and yield per plot was observed in treatments with poultry manure and fermented plant extract. The maximum number of fruits per plant (74.67), yield per plant (661.17 g) and yield per plot (31.75 kg) were obtained from T_4.

Qualitative characters like crude fibre, crude protein, beta-carotene and vitamin C content of the okra fruits significantly differed among the treatments and quality was found to be influenced by various treatments. The treatments differed significantly for shelf life. The fruits of treatment T_4 and T_{11} had maximum shelf life under both ambient (5.0 days) and refrigerated (9.0 days) conditions.

Significant difference in LAI was observed among the treatments, highest LAI was recorded in the treatment T_{11} (2.17) followed by T_4 (1.90). Maximum amount of total dry matter was recorded in the treatment T_4 (23.84 t ha^{-1}) followed by T_9 (20.15 t ha^{-1}). The minimum total dry matter was recorded in T_1 (9.90 t ha^{-1}).

The highest chlorophyll content was present in T_{11} (56.63) followed by T_{10} (55.43) and T_4 (54.77). The lowest content was in the treatment T_1 (43.73). Application of poultry manure also resulted in higher uptake of nutrients from soil and the lowest was by the plants receiving the treatment T_1 (POP).

The initial carbon content was 0.32 %. The final organic carbon content ranged from 0.37 % to 0.56 % (T_{11}). The initial pH was 5.1 and the final pH ranged from 5.2 (T_1) to 6.5 (T_4 and T_{11}). The initial available nitrogen, phosphorous and potassium was 374, 34 and 374 kg ha^{-1} in soil. The available nitrogen during final harvest ranged from 378 (T_1 and T_2) to 412 (T_{11}) kg ha^{-1} .The available soil phosphorous ranged from 35 (T_1 and T_2) to 42 kg ha^{-1} (T_4 to T_{12}). The available potassium rose above 400 kg ha^{-1} later for all treatments.

The data on bulk density, water holding capacity and pore space showed significant difference among the treatments. Minimum bulk density (1.06 g cm^{-3}) was found in the treatment T_{11} whereas, T_1 had maximum bulk density (1.49 g cm^{-3}). Maximum pore space (54.83 %) was found in the treatment T_{11} and water holding capacity (51.51 %) was found in T_4.

The initial fungal population was 20×10^4 cfu/g, bacterial population was 15×10^6 cfu/g and actinomycetes population was 10×10^5 cfu/g which later increased to 61.50×10^4 cfu/g, 55.00×10^6 cfu/g and 34.50×10^5 cfu/g respectively by way of adding organic manures. The microbial population was high in of all organic treated plots.

The highest (3.40) benefit: cost ratio was recorded in the treatment T_4, This was closely followed by T_{11} (3.00). As far as the overall performance is concerned the treatments T_4 and T_{11} resulted in increased vegetative growth with significant positive influence on yield and quality attributes.

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APPENDICES

Appendix I. Mean monthly meteorological data

Source: Department of Agricultural Meteorology, KAU, Vellanikkara

Months	Max.Temp. (°C)	Min.Temp. (°C)	Rainfall (mm)	RH (%)	No. of rainy days	Sunshine hours	Wind Speed (Km hr^{-1})
May	33.1	25.6	128.8	79	07	166.5	3.0
June	30.4	23.8	700.4	87	24	89.7	2.8
July	29.2	22.9	552.0	88	25	56.8	2.0
August	29.3	23.2	224.1	87	16	78.6	3.0
September	30.5	23.1	326.7	83	17	125.6	2.6

Appendix II. Preparation of organic liquid manures

1. Panchagavya (P)

Constituents	Quantity
Fresh Cow dung	4.8 kg
Fresh Cow urine	4.0 litres
Milk	500 ml
Curd	500 ml
Ghee	200 g
Jaggery	50 g
Yeast & Salt	1 pinch
Tender coconut water	1 litre
Banana	10 nos.

Preparation

- It can be prepared in mud / concrete / plastic tank.
- Knead cow dung and ghee thoroughly for 15-20 minutes.
- Add cow urine, curd, milk, tender coconut water, jaggery, salt, yeast and ripened banana.
- Mix well, cover and keep under shade.
- Stir for 10 minutes twice a day, both during morning and evening hours for 15 days.
- Mix 1 litre in 10 litre of water and pour in the basins.

2. Fish Amino Acid (FAA)

Constituents	Quantity
Fish	1 kg
Jaggery	1 kg

Préparation

- Chop 1 kg fish/fish waste into very small pieces.
- Add 1 kg of jaggery and mix well.
- Keep it in air tight container for 10 days.
- Final product will be a viscous fluid.
- Mix 1ml in 1 litre of water and pour in the basins.

3. Amrutha Pani (AP)

Constituents	Quantity
Cow dung	1 kg
Cow urine	1 litre
Water	10 litres
Jaggery	250 g

Preparation

- Take1Kg fresh cow dung, mix it in 10 litres of water.
- Add 1 litre of cow urine and 250 g of jaggery.
- Mix well and keep it for 1 day.
- Mix 1ml in 10 litres of water and pour in the basins.

4. Fermented Oil Cake Solution (FOC)

Constituents	Quantity
Groundnut cake	250 g
Sesamum cake	250 g
Coconut cake	250 g
Neem cake	50 g
Cow dung	1 kg
Water	20 litres

Preparation

- Take 250 g of groundnut, sesamum and coconut oil cakes and 50 g of neem cake.
- Add 1Kg fresh cow dung and 20 litres of water.
- Keep it for 3 days. Stir for 3 minutes during morning and evening hours.
- Mix 1 litre solution in 2 litres of water and pour in the basins.

5. Fermented Plant Extract (FPE)

Constituents	Quantity
Clerodendron infortunatum	2 kg
Vitex negundo	2 kg
Pongamia glabra	2 kg
Chromelina odorata	2 kg
Azadirachta indica	2 kg
Cow dung	5 kg
Jaggery	100 g
Yeast	10 g
Water	100 litres

Preparation

- Take 2 Kg leaves each of *Clerodendron infortunatum, Vitex negundo, Pongamia glabra, Chromelina odorata* and *Azadirachta indica*
- Cut leaves into small pieces and put in a jute sac.
- Dip the sac in a tank containing 5 kg fresh cow dung, 100 g jaggery, 10 g yeast and 100 litres of water.
- Shake the jute sac for 10 minutes during morning and evening hours for 20 days.
- Remove the jute sac and collect the extract.
- Pour the extract in basins.

ABSTRACT

VALIDATION OF FARMERS' PRACTICE OF ORGANIC MANURING IN OKRA
(*Abelmoschus esculentus* (L.) Moench)

By

ANKITA SINGH
(2009 - 12 - 117)

ABSTRACT OF THE THESIS

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9. ABSTRACT

The studies on "Validation of farmers' practice of organic manuring in okra (*Abelmoschus esculentus* (L.) Moench" were carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2010-11. The experiment was laid out in Randomized Block Design with three replications. The variety Arka Anamika was used for the study. The organic manures used were FYM, poultry manure, vermicompost, panchagavya, fish amino acid, amrutha pani, fermented oil cake solution and fermented plant extract. In all treatments except T_1, mulching was provided. The study revealed that okra cultivated under organic treatments gave good results.

Application of organic manures registered significantly higher plant growth and was superior to the inorganic ones (T_1 and T_2). Maximum height (3.61 m) was recorded in the treatment T_4 and it was on par with T_{11}. The maximum numbers of branches were also recorded in the treatment with poultry manure (T_4). It was on par with the treatment with fermented plant extract (T_{11}), but T_1 recorded the lowest.

Among the yield attributes, maximum average fruit weight was recorded by the treatment T_{11} (20.17 g) and was on par with T_4 (20.10 g) and T_9 (19.93 g). Minimum average fruit weight was in the treatment T_1 (15.10 g). The fruit length varied from 15.59 cm (T_1) to 20.34 cm (T_{11}). The treatments T_3, T_4, T_8, T_9 and T_{11} were on par in fruit length. The maximum fruit girth was recorded in the treatments T_4 and T_{11} (7.87 cm).

Number of fruits per plant (74.67) and yield per plant (661.17 g) registered significant improvement in treatments with poultry manure alone. It was on par with T_{11} (Fermented Plant Extract). Towards the end of the experiment there was a significant increase in the soil organic carbon and organic matter by the application of organic manures. The available N and P contents were slightly higher in treatments T_3 to T_{12} than in T_1 and T_2 where the inorganic fertilizers were used. The K content of the soil improved uniformly in all treatments irrespective of whether it was organic or inorganic.

There was an improvement of bulk density, water holding capacity and pore space due to the application of various organic treatments, which showed significant difference among the treatments. Minimum bulk density (1.06 g cm^{-3}) was found in the treatment T_{11} whereas T_1 registered maximum bulk density (1.49 g cm^{-3}). Maximum pore space (54.83 %) was found in T_{11} and water holding capacity (51.51 %) in the treatment T_4 whereas T_1 had the minimum pore space (52.60 %) and water holding capacity (29.33 %). The microbial population (fungi, bacteria and actinomycetes) of the soils under organic treatments was on a higher side when compared to the inorganics.

The highest benefit: cost ratio (3.40) was recorded in the treatment T_4. This was closely followed by T_{11} (3.00). The lowest benefit: cost ratio (1.80) was recorded in T_1. Considering the overall performance, application of organic manures was highly beneficial for the growth and yield of okra. Addition of organics alone could supply nutrients, at the optimum level, to support a steady growth rate which finally resulted in higher yield and quality of the produce. The upgradation of physical and biological properties of the soil was also experienced in the experimental plots. Similarly mulching also proved to be highly influential in boosting production of okra.