QUALITY ASSESSMENT OF ORGANIC MANURES AND THEIR EFFECT ON OKRA

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(2016-11-095)

THESIS

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DECLARATION

I, K. Santhiya (2016-11-095) hereby declare that the thesis entitled **"Quality assessment of organic manures and their effect on okra"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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K. Santhiya

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%	-	per cent
@	-	at the rate of
ABA	-	Abscisic acid
As	-	Arsenic
B: C	-	Benefit Cost ratio
Cd	-	Cadmium
CEC	-	Cation Exchange Capacity
Cr	-	Chromium
Cfu	-	colony forming unit
CRD	-	Completely Randomised Design
DAS	-	Days after sowing
dS m^{-1}	-	Deci Siemens per meter
EC	-	Electrical conductivity
E. coli	-	*Escherichia coli*
et al	-	and others
etc	-	et cetera
FCO	-	Fertilizer Control Order
FYM	-	Farm yard manure
GA	-	Gibberellic acid

g cc^{-1}	-	Gram per cubic centimetre
IAA	-	Indole-3-acetic acid
i.e	-	that is
KAU	-	Kerala Agricultural University
Kg ha^{-1}	-	Kilo gram per hectare
μg g^{-1}	-	Micro gram per gram
mg kg^{-1}	-	Milli gram per kilo gram
Ni	-	Nickel
OC	-	Organic Carbon
Pb	-	Lead
ppm	-	Parts per million
POPR	-	Package of practices recommendation
PSB	-	Phosphate solubilising bacteria
Pnp	-	Para nitro phenol
RBD	-	Randomized Block Design
RFD	-	Recommended fertilizer dose
TPF g^{-1} soil day^{-1}	-	Triphenyl Formazan per gram soil per day
viz	-	Namely

Introduction

1. INTRODUCTION

The present day agriculture is facing new challenges like decline in productivity, soil and water degradation and environmental pollution. Continuous use of mineral fertilizers have resulted in the depletion of soil organic matter and thereby soil health. Organic farming is gaining momentum due to the beneficial effects like conservation of environment, sustainable crop production and safe to eat food.

Integration of crops with animal husbandry is the principal component of organic farming. It is better to rely on on-farm resources for the management of soil fertility rather than off-farm resources. Use of organic manures is inevitable and several researchers have reported that traditional organic manures can be potentially beneficial for improving the physical, chemical and biological properties which will enhance crop productivity and quality (Li and Zhang (2007), Ludwig *et al.* (2007) and Liu *et al.* (2008)). In addition to the supply of plant nutrients, the growth promoting hormones and enzymes present in the organic manures will increase the soil fertility and crop productivity. Bastia *et al.* (2013) observed that organic carbon content, total organic carbon stock and carbon sequestration rates were significantly influenced by the organic management. The cattle manure increased the pH and available P and K in acid soils (Whalen *et al.*, 2000).

According to Kumar *et al.* (2016), vermicompost increased the pore space, water holding capacity, CEC, organic carbon, nutrient content and microbial population in soil. Long term application of organic manures increased the activities of soil urease, invertase and neutral phosphatase enzymes which improved the content of organic matter, total nitrogen, phosphorus and available nitrogen and phosphorus (Jing *et al.*, 2014).

Low organic matter content is one of the reasons for low productivity in Kerala. Organic manures play an important role in increasing organic carbon content of the soil. Availability of quality organic manures is the major constraint especially in organic farming.

Commonly used organic manures include the excreta of animals and birds, green manures, compost *etc.* and application of these manures is a viable option for waste management also. Despite the misconceptions like bulkiness, high transportation and labour cost, organic fertilizers remain ecofriendly and leave residues in the soil which will improve the porosity, water holding capacity *etc.*

It is said that the animal/bird excreta from modern intensive farms contain harmful components like heavy metals, pathogenic microorganisms and veterinary drugs (Zhang *et al.*, 2005). This may cause detrimental impacts on soil quality in the long run and also hazards to human health.

There is lack of adequate research findings regarding the impact of different organic manures (animal/bird excreta) on soil quality and crop productivity. Hence, it is appropriate to study the physical, chemical and biological properties of commonly used animal manures such as cow dung, poultry manure and pig manure and okra (*Abelmoschus esculentus* (L.) Moench.) was selected as the crop for field study. The present research work on "Quality assessment of organic manures and their effect on okra" was undertaken with the following objectives.

1. To study the physical, chemical and biological properties of different organic manures
2. To study the effect of organic manures on soil quality, growth and yield of okra

Review of literature

2. REVIEW OF LITERATURE

The review of literature related to the study on "Quality assessment of organic manures and their effect on okra" is illustrated below.

2.1. CHARACTERISTICS OF ORGANIC MANURES

Manures are the important source of nutrients in organic production. They play a major role in sustainable agriculture by improving soil health and crop productivity. Farmyard manure, compost, sheep and goat manure, green and green leaf manure are bulky organic manures whereas groundnut cake, neem cake, bone meal *etc.* are concentrated organic manure. Organic manures improve the physical, chemical and biological properties of soil. Plant parasitic nematodes and fungi are also controlled to some extent by the application of organic manures.

2.1.1. Nutrient content in organic manures

Gaur and Adholeya (2002) reported that the FYM contains 1.6% N, 0.27% P and 0.4% K. Garg and Bahl (2008) also observed 1.23% N and 0.8% P in FYM.

According to Loh *et al.* (2005), goat manure was rich in P and K concentrations than cattle manure. Goat manure had a pH of 7.02 and organic carbon of 50.17%. The NPK contents were 1.03%, 0.56% and 0.52% respectively. Goat manure was rich in organic matter (69.2%), N (4.9%), P (4.1%), K (1.9%), Ca (1%) and Mg (0.9%) (Awodun *et al.*, 2007).

Cu *et al.* (2015) found that the dry matter content of chicken manure, goat manure, rabbit manure and piglet manure was 37.9%, 35.2%, 32.7% and 19.4% respectively. Garg and Bahl (2008) reported the total N content in poultry manure (1.87%) , green manure (0.71%) and crop residues (0.36%) and the total P content in poultry manure (1.27%), green manure (0.27%) and crop residues (0.15%). The chemical properties of the chicken manure was reported by Fawzy *et al.* (2016). It had a pH of 7.84, EC of 4.46 dS m^{-1}, N of 0.19%, P of 0.08%, K of 0.12%, Fe of 5198 ppm, Zn of 369 ppm, Mn of 768 ppm and Cu of 37 ppm and Pb of 112 ppm.

According to Lu *et al.* (2015), the soil amended with biochar poultry manure @ 12 t ha^{-1} showed greater soil microbial carbon (70-158%), soil nitrogen (65-88%) and the activity of urease and phosphatase. Ammonium retention also was higher which improved the productivity of maize in the saline soil.

The liquid bio fertilizer prepared from rabbit manure showed pH of 6.77, EC of 5.34 dS m^{-1}, nitrogen of 455 mg l^{-1}, carbon of 3924.40 mg l^{-1}, phosphorus of 544.30 mg l^{-1}, potassium of 322.69 mg l^{-1}, calcium of 217.33 mg l^{-1}, magnesium of 115.12 mg l^{-1}, manganese of 23.33 mg l^{-1}, iron of 9.56 mg l^{-1}, copper of 312.57 mg l^{-1}, zinc of 1.82 mg l^{-1}, sodium of 130.10 mg l^{-1}, humic acids of 537.88 mg l^{-1}, auxins of 44.75 mg l^{-1} and gibberellins of 828.86 mg l^{-1} (Valdez *et al.*, 2017).

Elephant dung had 25 to 60% of crude fibre, 2.1 to 2.7% of crude fat and 3 to 6% of crude protein (Anandhasubrahmanian, 1979). Mercy (2009) reported that elephant could only digest 44% of consumed feed. Nair (2011) found that composting of elephant dung with FYM in the ratio of 8:1 with *Aspergillus flavus* and *Bacillus subtilis* for 50 to 60 days increased the rate of microbial activity and nutrient content in the compost. The pH of elephant dung was 6.9, and the organic carbon content was 48.18%. It also had 0.86% N, 0.34% P, 0.37% K, 0.19% Ca, 0.05% Mg and 0.25% Na, 21.4% of crude fibre and 2.8% of crude fat.

Yang *et al.* (2015) estimated the nutrient content of horse manure with a total N of 12 g kg^{-1}, total P_2O_5 of 7 g kg^{-1}, and K_2O of 7.2 g kg^{-1}. The pH was 8.59 and the organic matter content was 407 g kg^{-1}. Horse manure contained greater quantity of woody debris and bedding straw so that it showed wider C: N ratio. But the nutrients were readily available to soil microorganisms compared to compost and this has led to increase in grain yield of the winter wheat (Jannoura *et al.*, 2014). Composting of horse manure with peat, wood shavings and pelted straw reduced the C: N ratio from 30:1 to 15:1 and it improved the water soluble N and P (Keskinen *et al.*, 2017).

Castaneda and Vaughn (2016) noticed that decomposition of horse manure with wood mulch material reduced the volume of manure than soil and sand. Ghiri *et al.* (2017) found that quail manure had a pH of 6.79 and EC of 17.6 dsm^{-1}. It also had 36% of carbon, 3.97% of N, 2.4% of P and 1.6 % of K.

Carmo *et al.* (2016) revealed that pig, quail and chicken manures had higher NPK and Ca than crop residues. The highest ash content was observed in chicken and quail manure but had lower carbon content.

Vermicompost had good structure, moisture holding capacity, available nutrients, microbial metabolites and they acted as plant growth regulators (Ahirwar and Hussain, 2015).

Olle (2016) reported that vermicompost produced by earthworms were rich in N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, B and growth promoting substances (auxins, gibberellins and cytokinins). Soil microorganisms like N fixers and P solubilizers were increased due to the application of vermicompost which resulted in increased plant height, stem diameter, number of leaves and number of flowers in tomato. The highest percentage of humic acids in vermicompost contributed to plant health by promoting the synthesis of phenolic compounds in plants (anthocyanins and flavonoids) which might have acted as a defense mechanism against pests and diseases (Theunissen *et al.*, 2010).

According to Ryan (2016), composting of crop residues and rabbit manure resulted in higher EC which caused phytotoxic problems. Therefore, vermicompost was the best one due to low electrical conductivity and C: N ratio.

2.1.2. Microbial content in organic manures

Sharma *et al.* (2005) reported that addition of organic manures increased the microbial activity of soil. The total bacteria ($30 x 10^2$ cfu g^{-1}), fungi ($22 x 10^4$ cfu g^{-1}) and actinomycetes ($23 x 10^2$ cfu g^{-1}) count was higher in FYM treated plots than that of crop residues and urea applied plots (Bhakare *et al*., 2008). The highest population of bacteria (28.60 to 27.12 x 10^5 cfu g^{-1}), fungi (23.96 to 22.17 x 10^2 cfu g^{-1}) and actinomycetes (14.16 to 12.92 x 10^2 cfu g^{-1}) was observed in FYM and vermicompost equivalent to 120 kg N ha^{-1} applied in soil (Meena *et al*., 2015).

Dotaniya *et al.* (2013) noticed that roots of higher plants secrete various organic acids around the rhizosphere of soil, which are the source of easily available food for the microorganisms. The addition of nutrients in soil was proportional to the microbial biomass in soil and microbial activity (Masto *et al*., 2006). The organically managed field had a microbial biomass carbon value of 67.7 mg C g^{-1} (Bowles *et al*., 2014).

According to Kumar *et al.* (2016), vermicompost increased the microbial population in the soil. Mass multiplication of *Trichoderma viride* was found to be higher in neem cake (113.5×10^8 cfu g^{-1}) and among the organic manures, FYM contributed the maximum number of colonies (87×10^8 cfu g^{-1}) of *Trichoderma viride* followed by sheep and goat manure (Palanna *et al*., 2014).

Rajput *et al.* (2014) conducted a study on different organic substrates *viz*., rice grains, sorghum grains, wheat grains, millet grains, wheat straw, rice husk, cow dung, saw dust, and poultry manure for mass multiplication of *Trichoderma harzianum*. Sorghum grains were found to be the most suitable substrate (100.3×10^8 cfu g^{-1}) whereas cow dung had the lowest value of 2.07×10^8 cfu g^{-1}.

According to Tautges *et al.* (2016), organically managed soil had fungal and bacterial abundance in soil than the conventional system and the greater activity might be due to increased mycorrhizal symbiosis with plant roots. The arbuscular mycorrhizal fungal colonization was higher in organically managed soil compared to that amended with mineral fertilizers.

Integrated application *viz.*, FYM + vermicompost + green leaf manure (N equivalent basis), FYM + (*Azospirillum* + PSB microbial consortium) and biodigester to the soil @ 2500 l ha^{-1} recorded the maxiumum *Azospirillum* population (3.95 and 0.80 x 10^6 cfu g^{-1}), N fixers (42.7 and 39.8 x 10^3 cfu g^{-1}), PSB (44.2 and 41.8 x 10^4 cfu g^{-1}), dehydrogenase (15.7 and 14.3 g TPF g^{-1} soil day^{-1}) and phosphatase (29.9 and 28.7 g pNP g^{-1} soil h^{-1}) at the flowering and harvesting stages of aerobic rice (Basha *et al.*, 2017).

Ninh *et al.* (2015) observed higher microbial activity with the application of poultry manure @ 1.54 to 2 t ha^{-1}. Trawinska *et al.* (2015) noticed *Escherichia coli* (5.20×10^2 cfu g^{-1}) while *Salmonella* was absent in pig manure. The contamination is mainly associated with climatic conditions and the moisture content in pig manure.

Fresh elephant dung showed higher microbial activity, especially, bacteria which helped faster lignocellulose degradation and reduction in C: N ratio (Nair, 2011). Vermicompost showed the highest population of bacteria (132 x 10^5 cfu g^{-1}), fungi (28 x 10^5 cfu g^{-1}) and actinomycetes (Ravindran *et al.*, 2016). Escosteguy *et al.* (2015), detected pathogenic organisms such as *Escherichia coli* (5.5 x 10^3 cfu g^{-1})and *Clostridium perfringens* (5.9 x 10^5 cfu g^{-1}) in poultry manure while *Salmonella* was absent in it.

2.1.3. Growth hormones and enzyme activity in organic manures

Organic manures contained small quantity of plant nutrients compared to fertilizers. But the presence of growth promoting principles like enzymes and hormones helped to improve the soil fertility and crop productivity (Premsekhar and Rajashree, 2009).

Long-term application of organic manures increased the activity of soil urease, invertase and neutral phosphatase enzymes which improved the content of organic matter, total N, P and available N, P (Jing *et al.,* 2014).

Asghar *et al.* (2006) noticed that the external addition of L-Tryptophan to composted material increased the concentration of plant hormone (auxin) in the organic fertilizer and improved root growth and shoot growth of radish.

Vermicompost had growth hormones such as IAA (8.2 mg kg^{-1}) and kinetin (5.7 mg kg^{-1}) while the NADEP compost had IAA (21.4 mg kg^{-1}), kinetin (5.4 mg kg^{-1}) and panchakavya had IAA (10.4 mg kg^{-1} and kinetin (3.9 mg kg^{-1}). The ABA and GA_3 were absent in vermicompost, NADEP compost and panchakavya (Perumal *et al.*, 2012). Presence of gibberellic acid and auxins in panchakavya and jeevamurtham prepared from cow dung improved seed germination and rapid development of the shoot and flowers of tomato within two months (Ukale *et al.*, 2016).

Nagavallemma *et al.* (2004) noticed the presence of wide variety of microorganisms, hormones and enzymes in the intestine of earthworms which helped in rapid digestion and decomposition of waste material into vermicompost within 4-8 weeks. The study conducted by Ravindran *et al.* (2016) concluded that vermicompost contained IAA (7.37 mg kg^{-1}), Kinetin (2.8 mg kg^{-1}), GA_3 (5.7 mg kg^{-1}), whereas the ordinary compost had less quantity of these hormones.

Application of FYM significantly increased the dehydrogenase enzyme activity in soil (87 μg TPF g^{-1} soil day^{-1}) due to easy decomposition of FYM (Meena *et al.*, 2015). When soil was treated with organic manures, the total porosity was directly proportional to higher dehydrogenase activity (Marinari *et al.*, 2000).

2.1.4. Heavy metals in organic manures

Yanping *et al.* (2016) found heavy metals (Cr, Pb, Ni, Hg, Cd, As,) in pig and chicken feed. Pig manure had 6.91 mg kg^{-1} of Cr, 10 mg kg^{-1} of Ni, 0.4 mg kg^{-1} of Cd,

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3.8 mg kg^{-1} of Pb, 0.01 mg kg^{-1} of Hg, 28 mg kg^{-1} of As, whereas 4.86 mg kg^{-1} of Cr, 6.58 mg kg^{-1} of Ni, 0.27 mg kg^{-1} of Cd, 3.67 mg kg^{-1} of Pb, 0.03 mg kg^{-1} of Hg, 20.28 mg kg^{-1} of As was observed in poultry manure which might cause soil and health hazards.

Kandil *et al.* (2012) conducted a study on application of sewage sludge, cotton compost and banana compost in the soil @ 11, 22 and 44 t ha^{-1} to corn plants. The total and available heavy metals (Pb, Cd, and Ni) were found to be higher in sewage sludge followed by banana compost and cotton compost treated soil. Kuziemska *et al.* (2015) reported the highest heavy metal content in chicken (broiler) manure *viz.*, Zn (328 ppm), Fe (3547 ppm), Cr (12.51 ppm). The lowest Zn was found in bovine manure (118.1ppm) and the lowest Fe and Cr were found in chicken (layer) manure (682.6 ppm and 4.371 ppm respectively).

Gondek (2010) found that application of mineral fertilizer to soil caused mobilization of Zn and Cd into the maize plant than FYM and sewage sludge. The best remediation for polluted soil was addition of composted sheep manure as it reduced the mobility of salt and uptake of heavy metals by plants (Budai *et al.*, 2009).

Vallejera *et al.* (2014) observed the highest content of heavy metals (lead, strontium, nickel, copper, and zinc) in swine manure. The content of heavy metals was noticed by Wang *et al.* (2016) in the following order pig manure > buffalo manure > chicken manure > cowdung.

Cadmium was added to pots containing 4 kg of polluted soil @ four rates (0, 25, 50 and 100 mg kg^{-1}) to triticale plant and various sources of organic manures including cow dung, poultry manure, wheat residues and vermicompost were applied @ 5%. The mobility of Cd to triticale stem and leaf was improved due to organic matter decomposition and it's availability in the soil increased by the addition of organic matter. So the triticale plant might be used for phytoremediation (Karimkhani *et al.*, 2012).The concentration of Cd in wheat increased when pig manure was used as a source of nutrient (Narwal and Singh, 1998). The mobility of metals was increased in the soil by the application of compost and vermicompost since they formed soluble metal organic complexes after decomposition (Yang *et al.*, 2005).

The heavy metals (Cd, Ni, Cr, Pb) in harvested plants were in a detectable range with the application of 40 t ha^{-1} of sewage sludge to soil (Morariu *et al.*, 2014). FYM (0, 10, 20 t ha^{-1}) and Pb (0, 10, 20 mg kg^{-1}) were applied to the soil for the production of coriander. Lead accumulation in soil was decreased by the application of FYM due to the immobilization of Pb by FYM and the highest biomass yield (28.46%) of coriander was obtained (Mani *et al.*, 2015).

2.2. EFFECT OF ORGANIC MANURES ON CROP NUTRITION, GROWTH AND YIELD

According to Premsekhar *et al.* (2009), organic manures gave better quality fruits with less moisture content of 87.4% by the application of FYM @ 20 t ha^{-1} to okra and the organic matter from FYM accumulated more dry matter in fruits. Ezeocha *et al.* (2014) reported that application of poultry manure increased the dry matter, starch, fibre, protein and decreased the fat content of *Dioscorea bulbifera*. Basal application of FYM @ 10 t ha^{-1} increased the plant height, leaf-area index and chlorophyll content during flowering, dry matter accumulation, grain yield and protein content in sorghum grains (Patidar and Mali, 2004).

Premsekhar (2009) found that application of FYM @ 20 t ha^{-1} improved the parameters like plant height (57.6 cm), number of fruits per plant (19.3) and yield (10.39 t ha^{-1}), crude fibre (10.31 %) and also recorded higher B: C ratio of 3.56 in okra. Growth parameters like plant height (58.62 cm), number of pods /plant (22.428), number of grains /pod (8.688), 100 grain weight (52.630 g) of pea plant were significantly increased with increase in the dose of FYM up to 80 t ha^{-1} and the highest green pod yield of 62445.8 kg ha^{-1} was obtained (Khan *et al.*, 2015).

The quality parameters of radish viz., TSS (6.15 °Brix) and vitamin C (18.13 mg/ 100g) were higher with combined application of FYM 50% + poultry manure 50%. It was also beneficial for improving the growth, yield and quality parameters of radish (Singh *et al*., 2016).

Olowookere *et al*. (2015) reported that application of cow dung @ 0, 5, 10,15 and 20 t ha^{-1} to okra did not influence the vegetative growth stage whereas at harvesting time cow dung (20 t ha^{-1}) recorded the highest number of fruits/ plant (25.37).

Kumar and Dhiman (2007) observed the highest root length (14.94 cm) of *Vigna radiata* with the application of horse manure whereas the shoot length (49.23 cm) and number of pods (2.67) were more with cow dung. Buffalo dung application resulted in more number of nodules (38) in roots of *Vigna radiata* and thereby increased the nitrogenase enzyme activity as compared to horse manure and cow dung.

Application of goat manure to soil improved the growth and yield characters of pepper *viz.,* plant height, number of leaves and branches, stem girth, number and weight of fruits (Awodun *et al*., 2007). Zaller (2007) and Lazcano *et al*. (2010) observed that seed germination of *Rumex obtusifolius* (bitter dock) and *Pinus pinaster* (cluster pine) were increased by 48% and 16% due to the application of vermicompost prepared from cattle manure and rabbit manure.

Goat manure applied before four weeks of planting of sweet corn resulted in an increase in growth parameters such as plant height (193.44 cm), number of leaves (9.99), diameter of stem (1.98 cm) and also resulted in increased cob weight at six weeks after planting (Saputra *et al*., 2017). The highest transpiration rate (2.37 mmol m^{-2} s^{-1}) and total soluble solids (3.00 ºBrix) content in okra was recorded with the application of goat manure (Khandaker *et al*., 2017).

Poultry manure was applied @ 4, 6, 8, 10 and 12 t ha^{-1} to maize. The highest plant height, number of rows per cob, number of grains per row, 1000 grain weight, grain yield, biological yield and harvest index were recorded with the application of 12 t ha^{-1} of poultry manure (Farhad *et al.*, 2009). Application of poultry droppings (2.5 kg per 10 kg of soil) was found to be the best followed by cow dung (Uka *et al.*, 2013).

According to Boateng *et al.* (2006), application of poultry manure @ 4 t $month^{-1}$ ha^{-1} produced 2.07 t ha^{-1} of maize grain and it also increased the CEC of the soil. According to Adeniyan *et al.* (2011), the marginal and unproductive soils can be reclaimed by the application of cassava peelings and poultry manure.

Rathiya *et al.* (2007) found that application of poultry manure @ 2.5 t ha^{-1} along with 100% of recommended dose of fertilizer increased sunflower seed and stalk yield compared to cow dung due to the solubilisation of fixed forms of nutrients in soil.

Pso and Nweke (2015) reported that the yield characters of cucumber *viz.*, length of fruits (171.25 cm), number of fruits (10.75) and weight of fruits (2.38 kg ha^{-1}) were found to be higher from poultry manure applied plots than the mineral fertilizer applied plots.

Muoneke *et al.* (2014) reported that dry matter production and total tuber yield of sweet potato was optimum with the application of poultry manure @ 20 t ha^{-1}. Application of poultry manure and refuse dump compost showed the highest plant height, number of leaves, leaf area, fresh and dry weight of leaves, stems, roots and seeds of *Amaranthus hybridus*. But, the accumulation of heavy metals like Cd and Pb was found to be higher in refuse dump compost which might cause health hazards (Chikodili, 2015).

Growing pots containing 1/3 volume of soil and 2/3 volume of goat manure showed optimal plant growth in terms of plant height, number of leaves, leaf area and no symptoms of chlorosis was observed in the maize plant (Hariadi *et al.*, 2016).

The ash and total carbohydrate content of amaranthus was found to be higher with the application of poultry manure applied soil while the protein and crude fibre content was the highest in NPK fertilizer applied plot (Oyedeji *et al.*, 2014). Different organic manures *viz*., chicken manure, pig and cow manure @ 2.5, 5, 7.5, 10, 12.5 t /ha was applied to *Andrographis paniculata* Nees. The highest plant height (30.48 cm), stem dry weight (11.06 g plant^{-1}), leaf dry weight per plant (10.95 g) and pod dry weight per plant (2.61 g) were recorded with chicken manure (Detpiratmongkol *et al*., 2014).

Combined application of organic manures *viz*, farmyard manure + poultry manure, farmyard manure + bagasse ash, farmyard manure + rice husk ash, poultry manure + bagasse ash, poultry manure + rice husk ash, and bagasse ash + rice husk ash revealed that the combination with poultry manure produced the highest plant height, number of effective tillers per sq. meter, spike length and yield of wheat (Kaur and Verma, 2016).

Singh *et al*. (2016) conducted a study in radish and observed the highest plant height (36.13 cm), number of leaves (16.88) at 60 days, leaf length (17.17 cm), and root length (20.04 cm) with the combined application of vermicompost 50% + poultry manure 50%. The fresh weight of leaves (134.77 g), root weight (197.07 g), root diameter (5.74 cm) and yield ha^{-1} (36.42 t ha^{-1}) were significantly higher with the combined use of FYM + Vermicompost + Poultry manure. According to Dauda *et al*. (2009), application of poultry manure @ 9.9 t ha^{-1} improved the parameters like plant height, number of fruits and yield of water melon.

The corn- soybean rotation system was maintained by the application of swine manure in liquid, solid and liquid manure compost form. The highest corn yield was observed from liquid swine manure treatment followed by solid swine manure while the soybean yield did not differ among the three forms of swine manure (Hao *et al*., 2015). Pig manure (0, 10, 20 t ha^{-1}) and water (3, 4, 5 days interval) supplied to moringa resulted in the highest plant height, stem girth and number of leaves (Baiyeri*et al*., 2015).

Iren *et al*. (2016) noticed that balanced and combined use of both organic (45 kg N/ha of the pig manure- ½ dose manure) and inorganic (30 kg N/ha of urea -½ dose urea) nutrients increased the stem girth (17.42 cm), number of leaves per plant (44.76), fresh yield (41.51 t ha^{-1}) and dry matter yield (3.49 t ha^{-1}) of *Amaranthus* than individual application. Seedlings of *Polygonum hydropiper* grown with swine manure (0–200 g swine manure kg^{-1} soil) had the highest P content than other treatments.

Azarmi *et al.* (2008) found that the leaf area and shoot dry weight of tomato was increased by the application of 15 t ha^{-1} sheep manure vermicompost. Atiyeh *et al.* (2001) also observed the highest shoot height in tomato by amending the soil with 5 % pig manure vermicompost.

Long term practice of integrated nutrient management and in-situ green manuring with daincha improved the grain and straw yield of rice and it was identified as a low cost farmer friendly technology (Thulasi *et al.*, 2016).

Swetha (2015) found that use of vermicompost as a component in integrated nutrient management improved not only the yield but also the quality of okra. Fagwalawa and Yahaya (2016) recommended poultry manure or sheep + poultry + cow dung manure for the production of okra which improved the income of farmers. Nweke (2013) observed more number of flowers for okra in poultry manure treated soil compared to goat and pig manure treated plot.

Humic acid extracted from vermicompost increased the plant growth when sprayed @ 50–500 mg kg^{-1} whereas the growth has significantly decreased when the concentration was more than 500- 1000 mg kg^{-1} (Atiyeh *et al.*, 2002). The growth of tomato seedlings in pot was decreased in 100% pig manure vermicompost applied soil due to high concentration of soluble salts (Atiyeh *et al.*, 2001).

Plant growth and development was enhanced due to the presence of cytokinins in vermicompost prepared from tea waste (Zhang *et al.*, 2018). Application of FYM @ 5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} recorded the highest plant height, number of capsules per plant, number of seeds per capsule, seed yield and stalk yield of sesame.

The organic manures could provide all the essential nutrients to plant and soil and especially reduced the deficiency of micro nutrients Choudhary *et al.* (2017).

Tank *et al.* (2017) observed that organic manure treated coriander had the highest chlorophyll content and better aesthetic value. Application of vermicompost improved the quality (vitamin A, Vitamin C and Capsaicin content) of chilli (Kumar *et al.*, 2016). Integrated application of enriched compost (1/3) + vermicompost (1/3) + Green leaf manure (1/3) + FYM + Jeevamurtham 500 l ha^{-1} at 30 and 60 DAS + Panchagavya 5% each at panicle initiation and flowering stages recorded higher growth parameters and higher grain (3837 kg ha^{-1}) and straw yield (5855 kg ha^{-1}) in aerobic rice (Sahare and Mahapatra, 2015).

Conversion of algal biomass into fertilizer was done by co-composting with sawdust and quail manure and this compost improved the content of micro and macro nutrients in the plants, especially boron, calcium, iron and silicon (Michalak *et al.*, 2017).

Sahoo *et al.* (2015) observed that the height of chilli seedling was enhanced by 38.9% in vermicompost applied plot and also gave four times more number of fruits than control plot.

According to Prajapati *et al.* (2018), application of NPK @ 100% + Vermicompost @ 100% to maize had resulted in the highest plant height (158.22 cm), number of leaves per plant (11), cob length (17.50 cm), leaf length per plant (48.50 cm), and plant dry weight (163.46 g) and also it recorded the highest cost benefit ratio of 2.55. The growth characters of radish (*Raphanus sativus*) including plant height (50 cm), weight of fruits (152.30 g) and number of fruits (44.38), stem diameter (1.40 cm), dry matter yield (41.36 gm) were the highest in vermicompost applied pot (Kumar, 2016). Combined application of vermicompost (2 t ha^{-1}) and inorganic P fertilizer (75 kg P_2O_5 ha^{-1}) to mung bean improved the nutrient uptake, nutrient content and yield (Arsalan *et al.*, 2016).

Kumar *et al.* (2015) found that the highest yield of potato was obtained with mulching followed by integrated application of vermicompost (6 t ha^{-1}) and biofertilizers (Azotobacter + phosphate solubilizing bacteria) @ 312 q ha^{-1}. Application of vermicompost to pepper reduced the premature dropping of fruits, induced early flowering, reduced the abscission of fruit and leaf, increased the chlorophyll content in leaf and reduced the pest and disease incidence (Ganeshnauth *et al.*, 2018).

Cannabis sativa plant was supplied with FYM and vermicompost (Cow dung + Vegetable wastes + *Eisenia foetida*). The total protein (71.47 mg $plant^{-1}$), alkaloid (1.135 mg $plant^{-1}$) and reducing sugar (11.46 mg $plant^{-1}$) was found to be higher in vermicompost applied plot than FYM (Kumari, 2014).

According to Rahman *et al.* (2012), kitchen waste compost produced by bacteria had the highest nutrient content and it could be used as an organic fertilizer. The microorganisms present in the compost increased the root surface area, water-use efficiency and photosynthetic activity of chilli. Application of poultry manure and vermicompost improved the tomato yield and shelf life than cow dung (Solaiman *et al.*, 2015). Application of FYM @ 20 t ha^{-1} and vermicompost @ 5 t ha^{-1} recorded 10.31% and 13.4% crude fibre respectively whereas synthetic fertilizer applied plot produced fruits with higher crude fibre content of 15.34% (Premsekhar *et al.*, 2009).

2. 3. EFFECT OF ORGANIC MANURES ON SOIL QUALITY

Increased soil organic matter content, water holding capacity, porosity, infiltration capacity, hydraulic conductivity, water stable aggregation and decreased bulk density and surface crusting were observed due to the application of organic manures (Haynes and Naidu, 1998). Vajantha *et al.* (2013) revealed that the total NPK uptake of ashwangandha was improved by spraying panchagavya 5% made from cow dung and buffalo dung.

The organically managed field for 7 years improved the soil physical, chemical (total nitrogen, nitrate and available phosphorous) and biological properties (microbial biomass content, acid phosphatase, protease, dehydrogenase activity) than inorganically managed field (Marinari *et al.*, 2006).

Kumar *et al.* (2016) reported that application of FYM @ 10 t ha^{-1} decreased the bulk density and hydraulic conductivity of soil whereas the soil organic carbon, available NPKS was increased with vermicompost @ 5 t ha^{-1}. Whalen *et al.* (2000) found that cattle manure increased the pH and available P and K in acid soils. Nweke *et al.* (2013) revealed that integrated use of organic manures and mineral fertilizers had more benefits than that of organic manure or mineral fertilizer alone in intensive agricultural system and poultry manure act as a best source of soil nutrients and improved the soil properties and thereby the growth and yield of cucumber was increased.

According to Subramanian *et al.* (2016), inorganic fertilizer treated soils had the lowest organic carbon content (4.5 g kg^{-1}) compared to that of organic manure (12.2 g kg^{-1}) treated soils. The soil phosphatase, glycosidase and dehydrogenase activities were found to be higher (26%, 28% and 21%) in organic fertilizer treated soils.

Jatropha press cake (3.89 t ha^{-1}) and FYM (18.7 t ha^{-1}) were applied to waste land and the enzyme activities and lignin content was higher in FYM treated land whereas the soil physical, chemical and microbial properties were improved by the application of jatropha press cake. The ratio of microbial biomass carbon to soil organic carbon was also found to be higher in jatropha press cake treated soil (Anand *et al.*, 2015).

Sradnick *et al.* (2018) found that long term application of cattle manure increased the total N (0.79 mg g^{-1} soil) in the top soil at a depth of 0–25 cm than the mineral fertilizer (0.65 mg g^{-1} soil) applied soil. Vermicompost produced from cattle manure improved the soil structure and increased the beneficial microorganisms in the soil. The hormones and humates produced by those beneficial microorganisms during vermicomposting resulted in the highest germination, growth and flowering of petunia (Aracon *et al.*, 2005).

Summer (2011) found that application of cow dung or NPK fertilizer resulted in the highest average number of leaves, stem diameter, shoot and root dry weight in maize. So, cow dung could be used as a source of nutrient in the absence of NPK fertilizer because of its easy availability, cost effectiveness and the farmers will get good yield without deteriorating the soil fertility (Wisdom *et al.*, 2012).

Cow dung @ 10 t ha^{-1} was applied to acidic and non-calcareous soil by Zaman *et al.* (2017). Increase of all plant nutrients (available N, P, K, Ca, Mg, S, Zn and B), organic matter and decrease in pH of soil could be achieved by this. Application of 20 t ha^{-1} FYM in combination with 100 % RFD resulted in the highest plant height (83.29 cm), number of branches (12.42), leaf are index (2.29) and root spread in chilli. This might be due to narrow C: N ratio in organic manures which might have increased the production of humic acid and humic substances and thereby produced chelated phosphorous which is soluble in water and could be made available to the crop (Akshay *et al.*, 2018).

Application of FYM along with green manuring to rice field created a good soil condition by increasing soil organic matter and water holding capacity (Tadesse *et al.*, 2013). A study conducted by Meng *et al.* (2005) revealed that long term application of organic manures reduced the nitrogen loss as N_2O emission from soil when compared to that of mineral fertilizer.

Long term application of swine manure and no-tillage system increased the microbial biomass carbon and soil organic matter (Morales *et al.*, 2016). Ganeshnauth *et al.* (2018) found that combined use of vermi wash and vermicompost improved the physical and chemical properties of soil.

Okonkwo *et al.* (2012) observed improvement in the soil physical properties by the application of poultry droppings, sewage sludge, cow dung and goat droppings @ 5 t ha^{-1}. Application of organic manures stimulated the activity and growth of microorganisms in soil which has led to an increase in total microbial population

(Upadhyay *et al.*, 2011). Garg and Bahl (2008) reported that the plot receiving poultry manure showed greater P availability, phosphatase enzyme activity, and total P uptake in maize plant followed by FYM, green manure and crop residues received plots. Nweke (2013) observed the highest nutrient release from poultry manure treated soil compared to goat and pig manure treated plot of okra.

Mupondi *et al.* (2006) found that compost produced from pine bark and goat manure had high CEC, low C: N ratio, neutral pH and higher inorganic N and bases (K, Ca, and Mg). The tannin content of the pine bark-goat manure compost was less than 20 g/kg and did not cause any toxicity and was found to be safe to use as a growing medium for plants. Nutrient content in the rabbit manure varied quantitatively and qualitatively corresponding to the feed diet (Adande *et al.*, 2017).

The soil supplied with poultry litter and livestock manure showed better soil macro pore and meso pore volumes, soil aggregate wet stability index, microbial biomass C (89%), N content (74%), soil basal respiration rate (49%) and soil microbial quotient (Li*et al.*, 2011). The soil contaminated with chromated-copper-arsenate was amended with poultry manure, cow dung and natural rubber processing sludge by Okieimen *et al.* (2011). The total metal (Cr, Cu, As,) uptake by maize decreased mainly due to the phosphorus and organic matter content of these organic amendments which lead to in-situ immobilization of heavy metals.

Agbede *et al.* (2008) reported that application of poultry manure @ 7.5 t ha^{-1} decreased the soil bulk density, temperature and increased porosity, moisture content and soil organic matter. The soil and leaf N, P, K, Ca, Mg concentrations and plant height, leaf area, stem girth and weight of roots, shoot and grain yield of sorghum were increased by the application of poultry manure.

In contrast to broadcasting of poultry manure, incorporation to soil was found to be the best method of application as the former method caused leaching of nutrients and volatilization of N. Incorporation reduced the volatilization loss by 50 to 90% and increased the soil organic matter, N, P, K, Ca and Mg (Adekiya *et al.*, 2017).

Instead of ploughing the soil, manual cleaning and application of poultry manure @ 7.5 t ha^{-1} improved the soil nutrient and fertility status and thereby increased the sustainability and productivity of cocoyam (Adekiya and Agbede, 2016).

Addition of 10% of Ca-bentonite prior to composting of pig manure improved the organic carbon content, total nitrogen, total phosphorus and immobilization of Zn and Cu in soil thereby reduced the uptake by plants and improved the yield of Chinese cabbage (Wang *et al.*, 2016).

Ndukwe *et al.* (2011) reported that the valuable source of crop nutrients and organic matter were derived from animal manure which improved the soil biophysical conditions and had made the soil more productive and sustainable for plant growth. Both acid phosphatase and phytase activities in roots increased with increase in the concentrations of swine manure and the highest activity of acid phosphatase was noticed @ 100 g of swine manure kg^{-1} soil (Ye *et al.*, 2014).

Venkatesan *et al.* (2013) observed that organic manures improved plant growth and yield of elephant foot yam due to slow release of all nutrients. Quail litter biochar was applied @ 0, 24.6, 49.2, 73.8, 98.4 and 123 g per pot to soybean for improving the soil fertility and the highest yield was obtained when it was applied @ 98.4 g per plot (Suppadit *et al.*, 2012). Compost prepared from the flowers with sawdust and manures (broiler chicken manure, hen manure or quail manure) was applied to rose and it was noticed that the composting pile with quail manure registered the maximum organic matter degradation (Novillo *et al.*, 2018).

Application of FYM (12.5 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) resulted in an increase in pore space, water holding capacity, cation exchange capacity, organic carbon, macro and micro nutrients and microbial population in the soil (Kumar *et al.*, 2016).Earth worms produced cytokinins and auxins from organic wastes and released the metabolites such as vitamin B and vitamin D to the soil (Joshi *et al.*, 2015).

Kumar *et al.* (2012) reported that the combination of manures and biofertilizers increased the bacterial population in the soil. Intensive crop production and little K application were the reasons for low availability of K in calcareous soils and it was overcame by treating the soil with organic materials including residues (from alfalfa, broad bean, barley, pea), manure (from camel, cow, pigeon, poultry, quail, and sheep) and household vermicompost. All organic amendments (except camel and sheep manure) showed an increase in K release from soil (Ghiri *et al.*, 2017).

Three organic manures *viz.*, cattle manure, poultry manure and vermicompost were applied to the soil @ 0, 1 and 2 per cent and three levels of soluble Cd 0, 5 and 10 mg l^{-1} were also provided. More than 90% of added Cd remained in the soil. At a depth of 0-3 and 3-6 cm, the concentration of Cd was found to be higher in vermicompost treatment whereas the value was higher in poultry manure treated soil at a depth of 6-9 cm (Mahdavi *et al.*, 2013).

Waghmode *et al.* (2015) found that combined application of green leaf extract, enriched compost and vermicompost improved the organic carbon, copper, manganese, zinc and iron content in the soil.

2.4. EFFECT OF ORGANIC MANURES ON THE INCIDENCE OF PESTS AND DISEASES

Humic acid derived from vermicompost act as a plant growth stimulant, soil conditioner and enhanced the plant resistance against different pests (Scheuerell and Mahaffee, 2006). According to Nath and singh (2015), foliar spray of vermiwash produced by composting of buffalo manure, gram bran and water hyacinth suppressed the infestation of pests in maize.

Abolusoro and Abolusoro (2012) noticed that the soil amended with poultry manure, cow dung, compost and domestic waste @ 5 t ha^{-1} reduced the population of root-knot nematode (*Meloidogyne incognita*) by activating the beneficial microorganisms. The infestation of striga was reduced by the application of vermicompost @ 1.0 t ha^{-1} for sorghum (Biri *et al.*, 2016).

Nchore *et al.* (2011) reported that application of cattle manure reduced the root knot nematode population density and galling index and it might be due to low potassium, narrow C: N ratio and high nitrogen content in the manure. Application of vermicompost imparted resistance to pests due to all essential nutrient elements present in vermicompost compared to inorganic fertilizers (Aracon *et al.*, 2008).

Presence of soluble nutrients, free enzymes, soluble phenolic compounds and a wide range of microorganisms in vermicompost which pass into the tissues of plants resulted in the suppression of pests (Edwards *et al.*, 2010). Arthropod pests were effectively controlled by the application of vermicompost which is rich in chitinase enzyme (Hahn, 2001 and Edwards *et al.*, 2010).

Materials & Methods

3. MATERIALS AND METHODS

The present study entitled "Quality assessment of organic manures and their effect on okra" was carried out at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2017-2018. The details of materials used and the methodologies adopted during the course of study are presented in this chapter.

3.1. Experiment I

Evaluation of physical, chemical and biological properties of organic manure

3.1.1. Experimental site

The experiment was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara.

3.1.2. Time of experiment

The experiment was conducted from May to August, 2017.

3.1.3. Methods

Fresh organic manures were collected from the College of Veterinary and Animal Sciences, Mannuthy. The elephant dung was collected from temple. Vermicompost was collected from Coconut Development Farm (CDF) and shade dried for 10 days and afterwards it was used for further quality analysis.

Technical programme

Design : CRD

Treatments : 11

Replication : 3

Plate 1. Different sources of organic manures

Treatments

T_1 - Cow dung (Desi)

T_2 - Cow dung (Cross breed)

T_3 - Buffalo manure

T_4 - Goat manure

T_5 - Chicken manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermi compost

3.1.4. Observations

3.1.4.1. Particle size

The particle size of different organic manures was estimated by using a 4 mm, 2 mm and 0.5 mm sieve.

3.1.4.2. Moisture content

A known weight of the sample collected in a moisture can was dried in an oven at 105°C till constant weight was obtained. The quantity of moisture lost was determined gravimetrically and expressed as oven dry basis.

3.1.4.3. Colour

Visual observation of colour during collection time was noted.

3.1.4.4. Odour

Sensory evaluation of manures during collection time was conducted.

3.1.4.5. Nutrient content

All the manures were analysed to determine the content of nutrients using the standard methods as given in Table 1.

3.1.4.6. pH

The pH of organic manures was estimated using pH meter with glass and reference elctrode method (Jackson, 1958).

3.1.4.7. EC

Electrical conductivity meter was used to measure EC of organic manures (Jackson, 1958).

3.1.4.8. Organic carbon

Organic carbon content in the manures was estimated by loss on ignition method (Ball, 1964).

3.1.4.9. C : N ratio

C: N ratio was calculated by the formula,

$$\text{C: N ratio} = \frac{\text{Organic carbon}}{\text{Total nitrogen}}$$

3.1.4.10. Microbial population

The total microbial population (bacteria, fungi, actinomycetes, *Escherichia coli* and *Salmonella*) of the freshly collected organic manures were estimated by serial dilution and plate count technique (Agarwal and Hasija, 1986). The suitable media used for bacteria was nutrient agar (10^{-4}), Martin's Rose Bengal agar for fungi (10^{-3}), Kenknights and Munaier's agar for actinomycetes (10^{-3}), Eosine methylene blue agar for *Escherichia coli* (10^{-2}) and Salmonella media for *Salmonella* (10^{-1}) and were incubated at 28±2°C for 2 -14 days.

3.2. Experiment II

Influence of various organic manures on soil quality, growth and yield of okra

3.2.1. Experimental site

The experiment was conducted at the Plant Propagation and Nursery Management Unit (PPNMU), Kerala Agricultural University, Vellanikkara. Geographically, the site is located at 10° 31′ N latitude and 76° 13′ E longitude and at an altitude of 40.30 m above Mean Sea Level (MSL).

3.2.2. Soil

The soil of the experimental site was identified as well drained sandy clay loam texture and it comes under Ultisol order. The physico-chemical properties of the soil are provided in Table 2.

3.2.3. Climate

The meteorological data during the period of study recorded at College of Horticulture, Vellanikkara, are presented in Appendix I.

3.2.4. Season of the experiment

The field experiment of 'Influence of various organic manures on growth and yield of okra' was conducted from December, 2017 to March, 2018.

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Table 1: Method used for chemical characterization of organic manures

Sl. No.	Estimated characters	Method used	References
1.	Total N	Microkjeldhal method	Jackson,1958
2.	Total P	Diacid method using Vanadomolybdo phosphoric yellow colour method	Bray and Kurtz,1945
3.	Total K	Diacid method using Flame photometer method	Jackson,1958
4.	Total Ca, Mg	Diacid method using Atomic Absorption Spectrophotometer	Jackson,1958
5.	Total S	Turbidimetric method using spectrophotometer	Chesnin and Yein, 1951
6.	Total micronutrients (Fe, Mn, Zn, Cu)	Diacid method using Atomic Absorption Spectrophotometer	Jackson,1958
7.	Dehydrogenase enzyme	Triphenyl formazon extraction method- spectrophotometer	Tabatabai and Bremmer,1977
8.	Indole -3-acetic acid	L-Tryptophan using Atomic Absorption Spectrophotometer	Unyayar *et al.*, 1996
9.	Heavy metals (Cd, Pb, Cr, Ni)	Triacid digestion (HNO_3: H_2SO_4 : $HClO_4$) and ICP OES (Model : optima® 8 x 100 series)	GOI, 1985
10.	Arsenic (As)	HNO_3 : HCl method and ICP OES (Model : optima® 8 x 100 series)	GOI, 1985
11.	Mercury (Hg)	HNO_3: H_2SO_4: $KMnO_4$ digestion and ICP OES (Model : optima® 8 x 100 series)	GOI, 1985

3.2.5. Crop and variety

The variety "Arka Anamika" of okra (*Abelmoschus esculentus* (L). *Moench)* was used for the field study.

Characters of Arka Anamika

Plant vigour	:	Tall medium vigorous
Plant height	:	100 cm
Fruit length	:	15 – 20 cm
Fruit colour	:	Lush green
Duration (days)	:	130 – 135 days
Disease tolerance	:	Yellow vein mosaic virus
Average yield	:	12.5 t ha^{-1}

3.2.6. Methods

Technical programme

Design : RBD

Spacing : 60 cm × 45 cm

Plot size : 3.6 m × 2.7 m

Treatments

Based on the results of experiment I, all the manures were selected for the second experiment since there is no specification for organic manures in the Fertilizer Control Order (FCO , 1985) except that for vermicompost (Appendix II).

T_1 - Cow dung (Desi)

T_2 - Cow dung (Cross breed)

T_3 - Buffalo manure

T_4 - Goat manure

T_5 - Chicken manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR (Package of Practices Recommendations)

T_{13} - Absolute control

Cultural operations

The experimental location was ploughed using disc plough and cultivator. After levelling and removal of stubbles from the field, ridges and furrows were made at a spacing of 60 cm x 45 cm. Organic manures were applied as basal dose so as to give equivalent N in farm yard manure @ 20 t ha^{-1}. Seeds were soaked (except T_{12} and T_{13}) in the solution of *Pseudomonas* (1%) and panchagavya (30%) for 8 hours before sowing. The soaked seeds were dibbled in the furrows at a spacing of 45 cm. Uniform standing of crop was ensured by thinning and gap filling with seedlings raised in protrays at 10 days after sowing.

All the management practices were adopted as per the (*Ad hoc*) Package of Practices Recommendation for organic farming: Crops (KAU, 2009) except for T_{12}.

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Farm yard manure as basal dose (20 t ha^{-1}) along with recommended fertilizers (110:35:70 kg ha^{-1} NPK) were applied in T_{12}.

Neem cake (50 kg ha^{-1}) and groundnut cake (50 kg ha^{-1}) were applied at 30 and 60 DAS. Soil application of cow dung slurry @ 1 kg per 10 litres of water was given at fortnightly interval after flowering. KAU PGPR Mix II (1%) and chitin enriched *Pseudomonas* (10 g/ litre) were sprayed on 15 and 30 DAS as prophylactic spray. Jeevamurtham (30 ml/ litre) was sprayed 10 days after sowing.

Irrigation was given to the crop daily during early growth stage and later it was reduced to two days or three days towards maturity stage based on visual observation. Weeding was done in all the treatments uniformly as and when required.

3.2.7. Soil characters

Soil samples were collected from each plot before and after the experiment. Collected samples were air dried in shade and sieved through 2mm sieve for the estimation of available NPK and 0.5 mm sieve for organic carbon. Soil chemical characters such as pH, EC, organic carbon, available NPK and total microbial count (bacteria, fungi and actinomycetes) were analysed before and after the experiment using appropriate method as given in Tables 2 and 3.

Table 2. Physico- chemical properties of soil

Particulars	Content	Method used
Physical properties		
Particle size composition		Robinson International pipette method (Piper,1966)
Coarse sand (%)	31.90	
Fine sand (%)	27.30	
Silt (%)	18.64	
Clay (%)	22.16	
Water holding capacity (%)	37	Keen - Raczkowski brass cup (Piper, 1966)
Bulk density (g cc^{-1})	1.32	
Chemical properties		
pH	5.71	1:2.5 (soil : water) suspension by pH meter (Jackson, 1958)
EC (dS m^{-1})	0.82	Electrical conductometer method (Jackson, 1958)
Organic carbon (%)	0.85	Walkely and Black method (Jackson, 1958)
Available N (Kg ha^{-1})	176.4	Alkaline permanganate method (Subbiah and Asijah, 1956)
Available P (Kg ha^{-1})	34.6	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen, 1965)
Available K (Kg ha^{-1})	317.3	Neutral normal ammonium acetate method extractant flame photometry (Jackson, 1958)
Heavy metals – Cd (ppm)	-	Hcl extract method (GOI, 1985)
Heavy metals – Cr (ppm)	-	
Heavy metals – Pb (ppm)	-	
Heavy metals – Ni (ppm)	-	
Heavy metals – Hg (ppm)	-	
As (ppm)	-	$NaHCO_3$ method (GOI, 1985)

Table 3. Quantity of organic manures applied in soil

Treatments		Recommended dose based on N equivalent (0.5 % N) in FYM 20 t ha^{-1} (t ha^{-1})
T_1	Cow dung (desi)	6.3
T_2	Cow dung (cross bred)	12.5
T_3	Buffalo manure	14.3
T_4	Goat manure	7.1
T_5	Chicken manure	6.7
T_6	Rabbit manure	5.6
T_7	Pig manure	10
T_8	Elephant dung	20
T_9	Horse manure	20
T_{10}	Quail manure	5.9
T_{11}	Vermicompost	5.6

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Fig.1. Layout plan of the Experiment II

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	$R_3 T_1$	**R_3T_7**	**R_2T_3**	**R_2T_4**	**R_1T_3**	**R_1T_8**
	R_3T_6	**R_3T_{10}**	**R_2T_2**	**R_2T_1**	**R_1T_6**	**R_1T_{11}**
	R_3T_4	**R_3T_5**	**R_2T_6**	**R_2T_{11}**	**R_1T_{10}**	**R_1T_7**
R_3T_{11}	**R_3T_{12}**	**R_3T_{13}**	**R_2T_{12}**	**R_2T_7**	**R_1T_5**	**R_1T_4**
$R_3 T_3$	**R_3T_9**	**R_2T_{10}**	**R_2T_8**	**R_2T_5**	**R_1T_9**	**R_1T_1**
$R_3 T_8$	**R_3T_2**	**R_2T_9**	**$R_2 T_{13}$**	**R_1T_{12}**	**R_1T_{13}**	**R_1T_2**

T_1 - Cow dung (Desi)

T_2 - Cow dung (Cross breed)

T_3 - Buffalo manure

T_4 - Goat manure

T_5 - Chicken manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR (Package of Practices Recommendations)

T_{13} - Absolute control

Table 4. Media used for enumeration of microorganisms in soil

SI No.	Microbes	Dilution	Media used	References
1.	Bacteria	10^{-4}	Nutrient agar	Agarwal and Hasija, (1986)
2.	Fungi	10^{-3}	Martin's Rose Bengal agar, Potato Dextrose agar	
3.	Actinomycetes	10^{-4}	Kenknight Munaier's agar	

3.2.8. Biometric observations

Five plants in each plot were selected randomly as sample plants and tagged for taking biometric observation during 30 and 60 DAS and finally the average value was enumerated.

3.2.8.1. Plant height

Height of plants (cm) was recorded at 30 and 60 DAS from the base of the plant to the tip of the plant.

3.2.8.2. Number of leaves per plant

Number of leaves produced per plant was counted at 30 and 60 DAS and recorded.

3.2.8.3. Days to first flowering

The total number of days taken for first flowering from the date of sowing was recorded.

3.2.8.4. Days to first harvest

The number of days taken from the date of sowing to first harvest in all the treatments was recorded.

3.2.8.5. Number of harvests

The total number of harvests from the first harvest to final harvest was recorded.

3.2.8.6. Duration of the crop

The total duration of the crop from sowing to final harvest was recorded.

3.2.8.7. Total dry matter production

Three plants from each treatment were uprooted along with roots at final harvest and dried in hot air oven at 80° C temperature. The total weight of the biomass produced was recorded after drying and indicated in terms of hectare basis.

3.2.9. Yield and yield attributes

3.2.9.1. Number of fruits per plant

The total number of fruits per plant at each and every time of picking was recorded and finally the mean value was enumerated.

3.2.9.2. Weight of fruits per plant

Per plant fruit weight was recorded from each plot during each harvest and the average was enumerated.

3.2.9.3. Length of fruit

Fruit length was recorded immediately after picking from the tagged plants by taking the length from point of stalk to the tip of fruit and the average was calculated.

3.2.9.4. Girth of fruit

Girth of fruit was recorded immediately after picking from the tagged plants by using thread and ruler and the average was enumerated.

3.2.9.5. Average fruit weight

Total fruit weight from each plot was used for enumerating average fruit weight of okra.

3.2.9.6. Number of seeds per fruit

The number of seeds present in each fruit was counted manually and the average was calculated.

3.2.9.7. Yield per hectare

Yield per hectare was worked out from the per plot yield.

3.2.9.8. Fibre content in fruits

The crude fibre content in okra fruits were determined by Fibraplus method given by Sadasivam and Manickam (1996) and the value was expressed as percentage.

3.2.9.9 Incidence of pests and diseases

Pest and disease incidence were visually observed and recorded during the entire growth period of okra from sowing to harvest.

3.2.9.10. B: C Ratio

Benefit cost ratio was calculated as per the formula given below.

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

Plate 2. Field operations

Field cleaning

Field layout

Manure application

Plate 3. Sowing

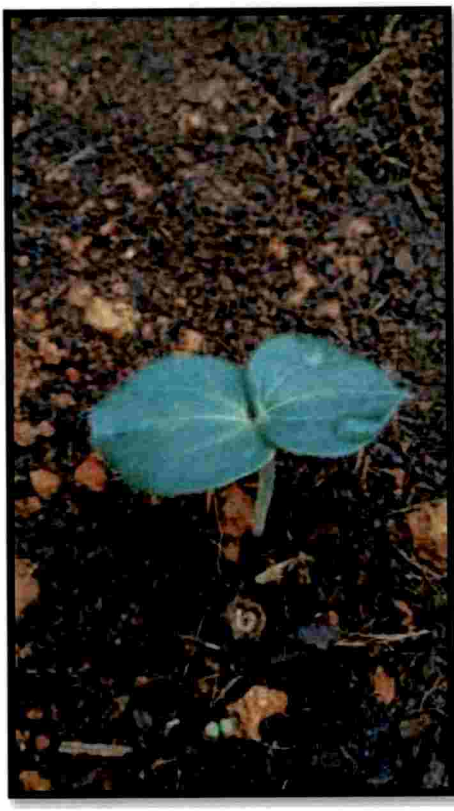

Plate 4. Germination

Plate 5. General Field view

Plate 6. Plant height at 30and 60DAS

Plate 7. Flowering and fruiting stage of okra

Plate 8. Total bacteria in cow dung (desi), total fungi in vermicompost and total *Escherichia coli* in goat manure

3.2.10. Statistical analysis

The data collected during different observations were arranged in a tabular form and then subjected to statistical analysis of variance by adopting statistical package WASP 2.0 developed by ICAR – Goa, and the significance between the treatments were estimated by Duncan's Multiple Range Test (DMRT) at 5% level of significance of probability (Gomez and Gomez, 1984).

Statistically analysed data of the first experiment were subjected further to a method of decision making as proposed by Arunachalam and Bandhyopadhyay (1984) for ranking.

Results

4. RESULTS

A laboratory as well as field experiment was carried out to evaluate the properties of organic manures and its effect on crop productivity. The results pertaining to the study on "Quality assessment of organic manures and their effect on okra" are presented in this chapter.

4.1. Experiment I

Evaluation of physical, chemical and biological properties of organic manures

4.1.1. Particle size

The particle size of different organic manures is furnished in Table 5. Hundred per cent manures have passed through 4 mm and 2 mm sieve. On an average, fifty per cent of all the animal manures have passed through 0.5 mm sieve except elephant dung and quail manure. The highest particle size was noticed for elephant dung (only 30 % have passed through 0.5 mm sieve) while the lowest particle size was found for vermicompost (65 % have passed through 0.5 mm sieve).

4.1.2. Moisture content

The moisture content of the organic manures is presented in Table 6. Freshly collected organic manures were having high moisture content and the range varied from 50 to 80 per cent. Among the different organic manures, the highest moisture content (80%) was observed in cow dung (cross bred) which was on par with that of quail manure. The lowest moisture content (24.3%) was observed in vermicompost.

4.1.3. Colour

The colour of manures varied and it is given in Table 7. Freshly collected animal manures were dark green to light green in colour and the chicken and quail manure were grey in colour.

Table 5. Particle size of organic manures

Treatments		Particle size (0.5 mm sieve)
T_1	Cow dung (desi)	50% passed
T_2	Cow dung (cross bred)	50% passed
T_3	Buffalo manure	55% passed
T_4	Goat manure	60% passed
T_5	Chicken manure	60% passed
T_6	Rabbit manure	60% passed
T_7	Pig manure	50% passed
T_8	Elephant dung	30% passed
T_9	Horse manure	50% passed
T_{10}	Quail manure	35% passed
T_{11}	Vermicompost	65% passed

Table 6. Moisture content of organic manures

Treatments		Moisture content (%)
T_1	Cow dung (desi)	71.7^c
T_2	Cow dung (cross bred)	80.0^a
T_3	Buffalo manure	75.3^b
T_4	Goat manure	72.3^c
T_5	Chicken manure	59.3^e
T_6	Rabbit manure	75.3^b
T_7	Pig manure	70.7^c
T_8	Elephant dung	62.0^d
T_9	Horse manure	50.0^f
T_{10}	Quail manure	80.0^a
T_{11}	Vermicompost	24.3^g

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 7. Colour and odour of organic manures

Treatments		Colour	Odour
T_1	Cow dung (desi)	Dark green	Mild foul
T_2	Cow dung (Cross bred)	Light green	Mild foul
T_3	Buffalo manure	Dark green	Mild foul
T_4	Goat manure	Light green	Mild foul
T_5	Chicken manure	Grey	Foul
T_6	Rabbit manure	Dark brown	Mild foul
T_7	Pig manure	Dark brown	Foul
T_8	Elephant dung	Dark green	Mild foul
T_9	Horse manure	Light brown	Mild foul
T_{10}	Quail manure	Grey	Foul
T_{11}	Vermicompost	Dark Brown	Earthy

4.1.4. Odour

The odour of the different organic manures is presented in Table 7. The chicken pig and quail manure gave bad foul odour whereas the vermicompost had an earthy smell.

4.1.5. pH

Significant difference was observed between the organic manures with regard to pH (Table 8). All the manures were slightly alkaline and the pH ranged from 7.3 to 8.6. The highest pH (8.6) was noticed in chicken manure and the lowest value was recorded in quail manure (7.3).

4.1.6. Electrical conductivity

The electrical conductivity of organic manures is furnished in Table 8. A significant difference was observed among the treatments. All the manures recorded an electrical conductivity which ranged from 0.01 to 0.16 dS m^{-1}. Quail manure had the highest EC value of 0.16 dS m^{-1} while the lowest was noticed in buffalo manure and goat manure (0.01 dS m^{-1}).

4.1.7. Organic carbon

The organic carbon content of organic manures is furnished in Table 9. The elephant dung showed the highest organic carbon content (49.12%) followed by cow dung (desi) (48.35%) whereas the lowest value (32.62%) was observed in chicken manure.

Table 8. pH and Electrical conductivity of organic manures

Treatments		pH	Electrical conductivity (dS m^{-1})
T_1	Cow dung (desi)	8.2^{bc}	0.02^{def}
T_2	Cow dung (cross bred)	8.3^{b}	0.04^{d}
T_3	Buffalo manure	8.0^{d}	0.01^{f}
T_4	Goat manure	8.2^{bc}	0.01^{f}
T_5	Chicken manure	8.6^{a}	0.10^{b}
T_6	Rabbit manure	8.3^{b}	0.05^{c}
T_7	Pig manure	7.7^{e}	0.05^{c}
T_8	Elephant dung	8.1^{cd}	0.02^{de}
T_9	Horse manure	7.4^{f}	0.03^{d}
T_{10}	Quail manure	7.3^{f}	0.16^{a}
T_{11}	Vermicompost	7.4^{f}	0.05^{c}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

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Table 9. Organic carbon, nitrogen and C:N ratio of organic manures

Treatments		Organic carbon (%)	N (%)	C:N ratio
T_1	Cow dung (desi)	48.35^{b}	1.6^{bc}	30:1
T_2	Cow dung (cross bred)	44.54^{de}	0.8^{e}	56:1
T_3	Buffalo manure	43.54^{e}	0.7^{e}	62:1
T_4	Goat manure	36.43^{fg}	1.4^{d}	26:1
T_5	Chicken manure	32.64^{h}	1.5^{cd}	23:1
T_6	Rabbit manure	38.10^{f}	1.8^{a}	21:1
T_7	Pig manure	47.15^{bc}	1.0^{e}	46:1
T_8	Elephant dung	49.12^{a}	0.5^{f}	98:1
T_9	Horse manure	45.54^{cd}	0.5^{f}	97:1
T_{10}	Quail manure	45.47^{cd}	1.7^{ab}	27:1
T_{11}	Vermicompost	34.95^{g}	1.8^{a}	19:1

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.1.8. C:N ratio

The carbon to nitrogen ratio is presented in Table 9. The highest C:N ratio was observed in elephant dung with a value of 98:1 due to low nitrogen content. This was followed by horse manure with a value of 97:1. The lowest C: N ratio of 19:1 was found in vermicompost.

4.1.9. Nutrient content

4.1.9.1. Macro nutrients

The total nitrogen, phosphorus and potassium content of different organic manures are given in Tables 9 and 10. All the manures were significantly different among each other. The value of N content in manures ranged from 0.47 to 1.8 per cent. The highest N content (1.8%) was observed in rabbit manure and vermicompost while the lowest (0.5%) was noticed in horse manure and elephant dung. The highest phosphorous (0.8%) content was observed in quail manure and pig manure and the lowest phosphorous content (0.13%) was noticed in cow dung (cross bred). The content of phosphorous in all the manures were in the range from 0.13 to 0.8%. The potassium content was the highest in rabbit manure (1.3%) and the lowest (0.33 %) was observed in cow dung (cross bred). The range of potassium in manures varied from 0.33 to 1.3 %.

Secondary nutrients in the organic manures are furnished in Table 11. Among the treatments, chicken manure showed the highest calcium and sulphur content being 2971.7 ppm and 1242.3 ppm respectively whereas the magnesium content was the highest in pig manure (111 ppm). The lowest calcium (1982.5 ppm) and sulphur (580.4 ppm) and magnesium (90.41ppm) content was found in horse manure.

4.1.9.2. Micro nutrients

The data regarding the micro nutrient content of organic manures is given in Table 12 which showed significant difference. The iron content was found to be the highest in vermicompost and the lowest in horse manure and the range of iron in organic manures varied from 672.5 to 1180.8 ppm. The manganese content was the highest in cow dung (desi) and the lowest in cow dung (cross bred). The range of manganese varied from 34.5 to115.6 ppm. The zinc content was the highest in pig manure and the lowest was observed in cow dung (cross bred). The highest copper content was found in quail manure (21.8 ppm) while the lowest was seen in buffalo manure (5.2 ppm). The content of zinc in manures ranged between 14.8 to 97 ppm whereas copper was in between 5.2 to 21.8 ppm.

4.1.10. Microbial population

There were significant variation in microbial population among the organic manures (Table 13). The total bacterial population was found to be the highest in vermicompost and chicken manure (35.33×10^4 cfu g^{-1}) whereas the lowest was noticed in elephant dung (13.33×10^4 cfu g^{-1}). Fungal population was the highest in quail manure (17.00×10^3 cfu g^{-1}) and the lowest value was in horse manure (4.67×10^5 cfu g^{-1}). All the organic manures were totally free of Actinomycetes and *Salmonella*.

The highest population of *Escherichia coli* was observed in cow dung (cross bred) with 22.33×10^2 cfu g^{-1} and the lowest was in cow dung (desi) with a value of 3.33×10^2 cfu g^{-1}. *Escherichia coli* was absent in rabbit manure, elephant dung, horse manure and vermi compost.

4.1.11. Indole -3- acetic acid

Indole -3- acetic acid content in different organic manures is furnished in Table 14. The highest (17.50 μg g^{-1}) hormone activity was observed in vermicompost and pig manure. The lowest hormonal (6.5 μg g^{-1}) activity was recorded in elephant dung.

Table 10. Total phosphorous and potassium content in organic manures

Treatments		P (%)	K (%)
T_1	Cow dung (desi)	0.27^{c}	0.40^{e}
T_2	Cow dung (cross bred)	0.13^{d}	0.33^{e}
T_3	Buffalo manure	0.20^{cd}	0.46^{de}
T_4	Goat manure	0.20^{cd}	0.60^{cd}
T_5	Chicken manure	0.63^{b}	0.71^{bc}
T_6	Rabbit manure	0.67^{b}	1.30^{a}
T_7	Pig manure	0.80^{a}	0.57^{cd}
T_8	Elephant dung	0.20^{cd}	0.60^{cd}
T_9	Horse manure	0.27^{c}	0.70^{bc}
T_{10}	Quail manure	0.80^{a}	0.77^{b}
T_{11}	Vermicompost	0.20^{cd}	0.80^{b}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 11. Total calcium, magnesium and sulphur content in organic manures

Treatments		Ca (ppm)	Mg (ppm)	S (ppm)
T_1	Cow dung (desi)	2616.6^{e}	94.4^{cd}	655.8^{h}
T_2	Cow dung (cross bred)	2213^{g}	93.1^{cd}	615.8^{i}
T_3	Buffalo manure	2070.9^{i}	97.5^{cd}	727.9^{g}
T_4	Goat manure	2203.3^{g}	96.3^{cd}	1182.1^{e}
T_5	Chicken manure	2971.3^{a}	90.2^{d}	1242.1^{a}
T_6	Rabbit manure	2806.7^{d}	108.2^{ab}	1092.9^{d}
T_7	Pig manure	2108.3^{h}	111.0^{a}	968.3^{f}
T_8	Elephant dung	2515.8^{f}	94.6^{cd}	1002.1^{e}
T_9	Horse manure	1982.5^{j}	90.4^{d}	580.4^{j}
T_{10}	Quail manure	2818.8^{c}	98.0^{cd}	1181.3^{e}
T_{11}	Vermicompost	2894.2^{b}	100.5^{bc}	1231.7^{b}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 12. Total micronutrient content in organic manures

Treatments		Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
T_1	Cow dung (desi)	969.6[e]	115.6[a]	24.6[f]	6.2[de]
T_2	Cow dung (crossbred)	742.1[h]	34.5[i]	14.8[g]	6.2[de]
T_3	Buffalo manure	707.5[i]	59.0[f]	18.9[g]	5.2[e]
T_4	Goat manure	1107.5[d]	83.8[cd]	34.5[e]	16.3[c]
T_5	Chicken manure	1128.3[c]	66.7[e]	46.8[d]	18.5[bc]
T_6	Rabbit manure	1132.5[b]	89.9[b]	72.5[c]	18.5[bc]
T_7	Pig manure	706.7[i]	82.0[d]	97.0[a]	19.8[ab]
T_8	Elephant dung	792.1[g]	47.2[h]	15.3[g]	8.8[d]
T_9	Horse manure	672.5[j]	53.2[g]	31.5[e]	7.8[de]
T_{10}	Quail manure	804.6[f]	44.4[h]	81.8[b]	21.8[a]
T_{11}	Vermicompost	1180.8[a]	87.9[bc]	30.7[e]	20.7[ab]

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.1.12. Dehydrogenase enzyme

The data pertaining to dehydrogenase enzyme activity in manures are presented in Table 14. Among the different treatments, the enzyme activity was found to be the highest (18.1 TPF g^{-1} soil day^{-1}) in vermicompost followed by goat manure (17 TPF g^{-1} soil day^{-1}) while the lowest (10.2 TPF g^{-1} soil day^{-1}) activity was noticed in horse manure.

4.1.13. Heavy metals

Heavy metals content in organic manures were analysed and the results are given in Table 15. Cadmium (3.26 ppm) was detected only in quail manure. Chromium content was observed in all the manures. The highest (10.54 ppm) value was noticed in goat manure followed by rabbit manure whereas the lowest value was in vermicompost (5.43 ppm).

Buffalo manure expressed the highest (4 ppm) nickel content among the organic manures followed by cow dung (desi) with 3.68 ppm. The lowest value (0.48 ppm) was found in pig manure whereas the elephant dung was free of nickel.

The treatments significantly influenced the content of lead in organic manures. The lead content was the highest (2.41 ppm) in rabbit manure followed by chicken manure (1.72 ppm) and the lowest (0.034 ppm) content was noticed in cow dung (desi). The highest mercury content was observed in goat manure, rabbit manure, pig and quail manure while the lowest (0.1 ppm) was in horse manure. The presence of arsenic was not detected in goat manure, chicken manure, and vermicompost. The highest value (13. 8 ppm) was examined in quail manure whereas the lowest (2.63 ppm) was found in rabbit manure.

4.1.14. Ranking of treatments

A score was allotted to each treatment for each character and the treatments were ranked based on their performance over the set of characters as per the method suggested by Arunachalam and Bandyopadhyay (1984). Based on the quality parameters, vermicompost showed the highest rank followed by chicken manure (Table 16).

Table 13. Total microbial population in organic manures

Treatments		Bacteria (10^4 cfu g^{-1})	Fungi (10^3 cfu g^{-1})	Actinomycetes (10^5 cfu g^{-1})	*E.coli* (10^2 cfu g^{-1})	*Salmonella* (10^1 cfu g^{-1})
T_1	Cow dung (desi)	31.00^{b}	12.67^{d}	-	3.33^{e}	-
T_2	Cow dung (cross bred)	27.67^{c}	15.33^{abc}	-	22.33^{a}	-
T_3	Buffalo manure	24.67^{d}	14.33^{cd}	-	5.00^{cde}	-
T_4	Goat manure	23.00^{d}	10.00^{e}	-	7.00^{bc}	-
T_5	Chicken manure	35.00^{a}	13.00^{d}	-	6.33^{cd}	-
T_6	Rabbit manure	34.33^{a}	15.67^{abc}	-	-	-
T_7	Pig manure	33.00^{ab}	16.33^{ab}	-	8.67^{b}	-
T_8	Elephant dung	13.33^{f}	8.00^{f}	-	-	-
T_9	Horse manure	14.67^{f}	4.67^{g}	-	-	-
T_{10}	Quail manure	20.00^{e}	17.00^{a}	-	4.33^{de}	-
T_{11}	Vermicompost	35.33^{a}	15.00^{bc}	-	-	-

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 14. Indole -3- acetic acid and dehydrogenase enzyme activity in organic manures

Treatments		Indole -3- acetic acid ($\mu g\ g^{-1}$)	Dehydrogenase enzyme (TPF g^{-1} soil day^{-1})
T_1	Cow dung (desi)	14.00^{b}	15.50^{e}
T_2	Cow dung (cross bred)	10.33^{e}	16.80^{bc}
T_3	Buffalo manure	7.83^{fg}	16.80^{bc}
T_4	Goat manure	13.50^{bc}	17.00^{b}
T_5	Chicken manure	12.33^{cd}	16.10^{d}
T_6	Rabbit manure	8.50^{f}	13.70^{g}
T_7	Pig manure	17.50^{a}	16.30^{cd}
T_8	Elephant dung	6.50^{h}	16.60^{bcd}
T_9	Horse manure	7.00^{gh}	10.20^{h}
T_{10}	Quail manure	12.17^{d}	14.80^{f}
T_{11}	Vermicompost	17.50^{a}	18.11^{a}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 15. Total heavy metals in organic manures

Treatments		Cd (ppm)	Cr (ppm)	Ni (ppm)	Pb (ppm)	Hg (ppm)	As (ppm)
T_1	Cow dung (desi)	-	5.50^{e}	3.68^{b}	0.03^{h}	0.13^{cd}	4.86^{e}
T_2	Cow dung (cross bred)	-	5.74^{e}	3.46^{b}	0.84^{d}	0.12^{de}	6.33^{d}
T_3	Buffalo manure	-	9.20^{abcd}	4.00^{a}	0.25^{g}	0.12^{de}	6.96^{c}
T_4	Goat manure	-	10.54^{a}	1.48^{c}	0.09^{h}	0.17^{a}	-
T_5	Chicken manure	-	9.78^{abc}	0.80^{ef}	1.72^{b}	0.16^{ab}	-
T_6	Rabbit manure	-	10.32^{ab}	1.20^{cd}	2.41^{a}	0.17^{a}	2.63^{g}
T_7	Pig manure	-	8.77^{cd}	0.48^{g}	1.12^{c}	0.17^{a}	3.24^{f}
T_8	Elephant dung	-	9.66^{abcd}	-	0.60^{e}	0.13^{cd}	6.90^{c}
T_9	Horse manure	-	8.34^{d}	0.93^{de}	0.41^{f}	0.10^{e}	7.40^{b}
T_{10}	Quail manure	3.26	9.03^{bcd}	0.88^{e}	0.81^{d}	0.17^{a}	13.68^{a}
T_{11}	Vermicompost	-	5.43^{e}	0.53^{fg}	1.15^{c}	0.14^{bc}	-

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 16. Rank of treatments after scoring

Rank	Treatments	
1	T_{11}	Vermicompost
2	T_5	Chicken manure
3	T_6	Rabbit manure
4	T_7	Pig manure
5	T_{10}	Quail manure
6	T_1	Cow dung (desi)
7	T_4	Goat manure
8	T_2	Cow dung (cross bred)
9	T_8	Elephant dung
10	T_3	Buffalo manure
11	T_9	Horse manure

4.2. Experiment II

4.2.1. Soil analysis

4.2.1.1. Water holding capacity

Data pertaining to the water holding capacity of soil given in Table 17 showed no significant difference among the treatments. The treatment receiving organic manures recorded 40 per cent water holding capacity whereas it was only 37 per cent in the absolute control plots. The initial value was 37 per cent.

4.2.1.2. Bulk density

Bulk density of the soil showed no significant difference with application of manures (Table 18). The initial bulk density of soil was 1.32 mg m^{-3} and it remained as such in all the plots after the experiment.

4.2.1.3. pH

The initial value of soil pH was 5.71 and varied significantly after the experiment (Table 18). The highest pH (6.44) was observed in the chicken manure treated plot followed by that receiving goat manure. The lowest pH was noticed in the treatment receiving KAU POPR.

4.2.1.4. EC

The EC of the soil before the experiment was 0.82 dS m^{-1} and there was significant difference among the treatments (Table 18). The highest EC was noted in chicken manure (0.97 dS m^{-1}) treated soil followed by rabbit manure, pig manure and quail manure. The lowest value was found in cow dung (cross bred) and absolute control which were on par.

Table 17. Effect of treatments on water holding capacity and bulk density of soil

Treatments		Water holding capacity (%)	Bulk density (mg m^{-3})
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	40	1.32
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	40	1.32
T_3	Buffalo manure @ 14.3 t ha^{-1}	40	1.32
T_4	Goat manure 7.1 t ha^{-1}	40	1.32
T_5	Chicken manure 6.7 t ha^{-1}	40	1.32
T_6	Rabbit manure 5.6 t ha^{-1}	40	1.32
T_7	Pig manure @ 10 t ha^{-1}	40	1.32
T_8	Elephant dung @ 20 t ha^{-1}	40	1.32
T_9	Horse manure @ 20 t ha^{-1}	40	1.32
T_{10}	Quail manure @ 5.8 t ha^{-1}	40	1.32
T_{11}	Vermicompost @ 5.6 t ha^{-1}	40	1.32
T_{12}	KAU POPR	40	1.32
T_{13}	Absolute control	37	1.32
Initial value		**37**	**1.32**

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Table 18. Effect of treatments on pH and electrical conductivity of soil

Treatments		pH	EC (dS m^{-1})
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	5.77^{ef}	0.85^{d}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	5.75^{f}	0.82^{e}
T_3	Buffalo manure @ 14.3 t ha^{-1}	5.95^{cd}	0.85^{d}
T_4	Goat manure 7.1 t ha^{-1}	6.12^{b}	0.91^{c}
T_5	Chicken manure 6.7 t ha^{-1}	6.44^{a}	0.97^{a}
T_6	Rabbit manure 5.6 t ha^{-1}	5.78^{ef}	0.95^{b}
T_7	Pig manure @ 10 t ha^{-1}	5.86^{de}	0.95^{ab}
T_8	Elephant dung @ 20 t ha^{-1}	5.93^{cd}	0.94^{b}
T_9	Horse manure @ 20 t ha^{-1}	5.80^{ef}	0.94^{b}
T_{10}	Quail manure @ 5.8 t ha^{-1}	6.00^{c}	0.95^{ab}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	5.89^{de}	0.92^{c}
T_{12}	KAU POPR	5.72^{f}	0.85^{d}
T_{13}	Absolute control	5.71^{f}	0.82^{e}
Initial value		**5.71**	**0.82**

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.2.1.5. Organic carbon

The organic carbon content of soil before the experiment was 0.85% and it changed significantly after the experiment (Table 19). The highest OC was found in the plot receiving vermicompost (1.3%) followed by that receiving goat manure (1.24%). The organic carbon content was the lowest in KAU POPR (0.90%).

4.2.1.6. C: N ratio

The data pertaining to C: N ratio is furnished in Table 19. The highest C: N ratio (12:1) was observed in cow dung (desi) applied plot. The lowest value was noticed in KAU POPR (8:1) and with pig manure.

4.2.1.7. Available nitrogen

The initial status of available N in the soil was 176.4 kg ha^{-1} (Table 20). After the experiment, the highest content was in KAU POPR (244.4 kg ha^{-1}) followed by chicken manure (239.7 kg ha^{-1}) whereas the lowest was in absolute control plot (165.3 kg ha^{-1}).

4.2.1.8. Available phosphorus

The data on available P content of soil after the experiment is given in Table 20. The application of chicken manure resulted in the highest available P (64.7 kg ha^{-1}) whereas the lowest value of 32.9 kg $ha^{-1}$was recorded in absolute control. The initial available P content was 34.6 kg ha^{-1}.

4.2.1.9. Available potassium

The initial status of available potassium was 317.30 kg ha^{-1}. After the experiment it was increased (Table 20) and the chicken manure treated soil showed the highest available potassium content of 396.9 kg ha^{-1} while the least value was observed in absolute control plot (297.4 kg ha^{-1}).

Table 19. Effect of treatments on organic carbon and C: N ratio of soil

Treatments		Organic carbon (%)	C:N ratio
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	1.16^{bc}	12:1
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	1.03^{cd}	11:1
T_3	Buffalo manure @ 14.3 t ha^{-1}	1.00^{def}	10:1
T_4	Goat manure 7.1 t ha^{-1}	1.24^{ab}	11.:1
T_5	Chicken manure 6.7 t ha^{-1}	1.08^{cd}	11:1
T_6	Rabbit manure 5.6 t ha^{-1}	1.10^{cd}	10:1
T_7	Pig manure @ 10 t ha^{-1}	1.00^{def}	8:1
T_8	Elephant dung @ 20 t ha^{-1}	1.00^{def}	10:1
T_9	Horse manure @ 20 t ha^{-1}	0.94^{efg}	10:1
T_{10}	Quail manure @ 5.8 t ha^{-1}	1.05^{cde}	10:1
T_{11}	Vermicompost @ 5.6 t ha^{-1}	1.30^{a}	11:1
T_{12}	KAU POPR	0.90^{h}	8:1
T_{13}	Absolute control	0.95^{fg}	10:1
Initial value		**0.85**	**9 :1**

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 20. Effect of treatments on available NPK content in soil

Treatments		Available Nitrogen (kg ha^{-1})	Available phosphorous (kg ha^{-1})	Available potassium (kg ha^{-1})
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	198.7^{f}	53.7^{ef}	333.6^{ef}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	189.8^{g}	49.0^{gh}	328.2^{f}
T_3	Buffalo manure @ 14.3 t ha^{-1}	194.5^{f}	51.0^{fg}	331.3^{ef}
T_4	Goat manure @ 7.1 t ha^{-1}	201.6^{e}	47.9^{gh}	345.8^{c}
T_5	Chicken manure @ 6.7 t ha^{-1}	239.7^{b}	64.7^{a}	396.9^{a}
T_6	Rabbit manure @ 5.6 t ha^{-1}	196.6^{f}	47.3^{h}	330.5^{f}
T_7	Pig manure @ 10 t ha^{-1}	225.7^{c}	61.4^{bc}	368.0^{b}
T_8	Elephant dung @ 20 t ha^{-1}	183.2^{g}	42.3^{i}	326.9^{f}
T_9	Horse manure @ 20 t ha^{-1}	185.3^{g}	42.3^{i}	336.8^{de}
T_{10}	Quail manure @ 5.8 t ha^{-1}	196.6^{f}	55.9^{de}	328.3^{f}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	214.7^{d}	62.0^{ab}	337.4^{de}
T_{12}	KAU POPR	244.4^{a}	58.4^{cd}	341.2^{cd}
T_{13}	Absolute control	165.3^{h}	32.9^{j}	297.4^{g}
Initial value		**176.4**	**34.6**	**317.3**

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.2.1.10. Total microbial count in the rhizosphere of okra

The data pertaining to the total microbial population in the soil are given in Table 21. All the treatments were significantly different in the case of total microbial population. The initial status of bacteria, fungi and actinomycetes were 14.00 x 10^4, 17.67 x 10^3 and 5.33 x 10^4 cfu g^{-1} respectively in the soil. The highest bacterial population was found in vermicompost treatment (68.67 x 10^4 cfu g^-1) followed by pig manure(65.67 x 10^4 cfu g^{-1}) and chicken (65 x 10^4 cfu g^{-1}) manure applied plots. The lowest count (39.00 x 10^4 cfu g^{-1}) was noticed in control.

The vermicompost (57.00 x 10^3 cfu g^{-1}) and chicken manure (56.67 x 10^3 cfu g^{-1}) applied soils showed the highest fungal population while the lowest was in control with a value of 33.67 x 10^3 cfu g^{-1}.

The highest value of 9.67 x 10^4 cfu g^{-1} was observed in the treatments receiving goat manure, chicken manure, pig manure and vermicompost with respect to the population of actinomycetes. The lowest value (4.33 x 10^4 cfu g^{-1}) was noticed with cow dung (cross bred).

4.1.1.11. Heavy metals

Heavy metals content was analysed before and after the experiment (Table 22). Presence of cadmium, chromium, arsenic, nickel, lead and mercury was not detected in the soil before the experiment. But, after the application of different organic manures, nickel and lead were found in all the treatments while arsenic was detected only in cow dung (desi and crossbred) treated plots.

The nickel content in different organic manures treated soil was found to be non-significant and the highest content was only 0.04ppm. The vermicompost applied soil had the highest concentration (0.2 ppm) of lead followed by buffalo manure (0.19 ppm) and the lowest value (0.08 ppm) was noticed with cow dung (desi). The arsenic content was 0.06 ppm with cow dung (desi) and 0.03 ppm in cow dung (cross bred) applied plots.

4.2.2. Biometric observations

4.2.2.1. Plant height

Plant height at 30 Days after sowing and 60 Days after sowing of okra showed significant variation among the treatments as given in Table 23. The highest plant height of 27.15 cm and 121.7 cm was noticed in pig manure applied plot at 30 DAS and 60 DAS respectively followed by chicken manure. The lowest height was found with elephant dung at 30 DAS (18.9 cm) and 60 DAS (65.13 cm).

4.2.2.2. Number of leaves per plant

The treatments consisting of different organic manures revealed significant variation in the number of leaves (Table 23). KAU POPR showed more number of leaves at 30 DAS followed by chicken manure, pig manure and quail manure which were on par and the range varied from 9 to 12. The lowest (8) was observed in elephant dung. But, at 60 DAS, the highest number was found in chicken manure (26) which was on par with quail manure. The control treatment showed the least number at 30 as well as 60 DAS.

4.2.2.3. Days to first flowering

There was no significant variation among the treatments on days to first flowering (Table 24) in okra. The days to first flowering ranged from 34 to 36 DAS. The first flower appeared on 34 DAS in many of the treatments whereas the control plot flowered only at 36 DAS.

Table 21. Effect of treatments on microbial population in soil

Treatments		Bacteria (10^4 cfu g^{-1})	Fungi (10^3 cfu g^{-1})	Actinomycetes (10^4 cfu g^{-1})
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	48.33^{f}	45.00^{de}	4.67^{de}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	45.00^{gh}	43.00^{e}	4.00^{ef}
T_3	Buffalo manure @ 14.3 t ha^{-1}	46.33^{fg}	46.00^{d}	4.33^{ef}
T_4	Goat manure @ 7.1 t ha^{-1}	54.33^{e}	48.33^{c}	9.67^{a}
T_5	Chicken manure @ 6.7 t ha^{-1}	65.00^{b}	56.67^{a}	9.67^{a}
T_6	Rabbit manure @ 5.6 t ha^{-1}	57.00^{de}	49.33^{bc}	4.67^{de}
T_7	Pig manure @ 10 t ha^{-1}	65.67^{b}	51.33^{b}	9.67^{a}
T_8	Elephant dung @ 20 t ha^{-1}	41.00^{ij}	40.67^{f}	3.67^{f}
T_9	Horse manure @ 20 t ha^{-1}	43.00^{hi}	37.67^{g}	8.67^{b}
T_{10}	Quail manure @ 5.8 t ha^{-1}	57.67^{d}	51.33^{b}	8.67^{b}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	68.67^{a}	57.00^{a}	9.67^{a}
T_{12}	KAU POPR	62.00^{c}	39.33^{fg}	6.67^{c}
T_{13}	Absolute control	39.00^{j}	23.67^{h}	5.33^{d}
Initial value		**14.00**	**17.67**	**5.33**

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 22. Effect of treatments on heavy metal content in soil

Treatments		Cd (ppm)	Cr (ppm)	Ni (ppm)	Pb (ppm)	As (ppm)	Hg (ppm)
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	-	-	0.04^{a}	0.08^{j}	0.06^{a}	-
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	-	-	0.04^{a}	0.13^{g}	0.03^{b}	-
T_3	Buffalo manure @ 14.3 t ha^{-1}	-	-	0.04^{a}	0.19^{b}	-	-
T_4	Goat manure @ 7.1 t ha^{-1}	-	-	0.04^{a}	0.15^{d}	-	-
T_5	Chicken manure @ 6.7 t ha^{-1}	-	-	0.04^{a}	0.14^{e}	-	-
T_6	Rabbit manure @ 5.6 t ha^{-1}	-	-	0.03^{b}	0.17^{c}	-	-
T_7	Pig manure @ 10 t ha^{-1}	-	-	0.04^{a}	0.13^{f}	-	-
T_8	Elephant dung @ 20 t ha^{-1}	-	-	0.04^{a}	0.11^{i}	-	-
T_9	Horse manure @ 20 t ha^{-1}	-	-	0.04^{a}	0.13^{g}	-	-
T_{10}	Quail manure @ 5.8 t ha^{-1}	-	-	0.04^{a}	0.11^{i}	-	-
T_{11}	Vermicompost @ 5.6 t ha^{-1}	-	-	0.04^{a}	0.20^{a}	-	-
T_{12}	KAU POPR	-	-	0.04^{a}	0.10^{h}	-	-
T_{13}	Absolute control	-	-	-	-	-	-
Initial value		-	-	-	-	-	-

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.2.2.4. Days to first harvest

The days to first harvest of okra fruits is provided in Table 24. The treatments showed no significant effect on days to first harvest. Fruiting was started at 40 DAS in cow dung (desi), cow dung (cross bred), goat manure, chicken manure, rabbit manure, pig manure, vermicompost and KAU POPR while the remaining treatments produced fruits at 41 DAS except the control plot.

4.2.2.5. Number of harvests

Table 24 represent the number of harvests of okra fruits. There was no significant variation among the treatments. The total number of harvests varied from 17 to 19.

4.2.2.6. Duration of the crop

The duration of the crop showed no significant variation (Table 24). Okra was maintained in the experimental site up to 94 days in cow dung (desi), cow dung (cross bred), goat manure, chicken manure, pig manure while it was 92 days in control plot.

4.2.2.7. Total dry matter production at last harvest

Dry matter production of okra plant showed significant variation with treatments as given in Table 25. The chicken manure applied plot recorded the highest dry matter (5.3 t ha^{-1}) followed by that with quail manure (3.91 t ha^{-1}). The lowest dry matter was recorded in elephant dung applied plot (1.14 t ha^{-1}).

Table 23. Effect of treatments on plant height and number of leaves of okra

Treatments		Plant height (cm)		Number of leaves	
		30 DAS	60 DAS	30 DAS	60 DAS
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	23.21^{cd}	101.33^{c}	10^{bc}	23^{ab}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	18.38^{e}	76.34^{f}	9^{c}	19^{cd}
T_3	Buffalo manure @ 14.3 t ha^{-1}	22.55^{d}	96.02^{de}	10^{bc}	19^{cd}
T_4	Goat manure @ 7.1 t ha^{-1}	23.66^{cd}	94.38^{e}	9^{c}	22^{abc}
T_5	Chicken manure @ 6.7 t ha^{-1}	25.68^{ab}	116.82^{ab}	11^{ab}	26^{a}
T_6	Rabbit manure @ 5.6 t ha^{-1}	24.73^{bc}	100.21^{cd}	10^{bc}	21^{bcd}
T_7	Pig manure @ 10 t ha^{-1}	27.15^{a}	121.17^{a}	11^{ab}	22^{abc}
T_8	Elephant dung @ 20 t ha^{-1}	18.90^{e}	65.13^{g}	6^{d}	20^{a}
T_9	Horse manure @ 20 t ha^{-1}	19.25^{e}	76.94^{f}	9^{c}	21^{bcd}
T_{10}	Quail manure @ 5.8 t ha^{-1}	22.73^{d}	114.07^{b}	11^{ab}	25^{a}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	23.33^{cd}	98.86^{cd}	10^{bc}	22^{abc}
T_{12}	KAU POPR	23.87^{bcd}	118.12^{ab}	12^{a}	25^{bcd}
T_{13}	Absolute control	19.48^{e}	92.28^{e}	9^{c}	18^{d}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

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Table 24. Effect of treatments on days to first flowering and harvest, number of harvests and duration of the okra

Treatments		Days to first flowering	Days to first harvest	Total number of harvests	Duration of the crop (Days)
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	34[a]	40[a]	18[a]	94[a]
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	34[a]	40[a]	18[a]	94[a]
T_3	Buffalo manure @ 14.3 t ha^{-1}	35[a]	41[a]	18[a]	93[a]
T_4	Goat manure @ 7.1 t ha^{-1}	34[a]	40[a]	18[a]	94[a]
T_5	Chicken manure @ 6.7 t ha^{-1}	34[a]	40[a]	18[a]	94[a]
T_6	Rabbit manure @ 5.6 t ha^{-1}	35[a]	40[a]	18[a]	93[a]
T_7	Pig manure @ 10 t ha^{-1}	34[a]	40[a]	19[a]	94[a]
T_8	Elephant dung @ 20 t ha^{-1}	35[a]	41[a]	17[a]	93[a]
T_9	Horse manure @ 20 t ha^{-1}	35[a]	41[a]	17[a]	92[a]
T_{10}	Quail manure @ 5.8 t ha^{-1}	35[a]	41[a]	19[a]	93[a]
T_{11}	Vermicompost @ 5.6 t ha^{-1}	34[a]	40[a]	19[a]	93[a]
T_{12}	KAU POPR	34[a]	40[a]	18[a]	93[a]
T_{13}	Absolute control	36[a]	42[a]	17[a]	92[a]

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.2.3. Yield and yield attributes

4.2.3.1. Number of fruits per plant

Data pertaining to the number of fruits per plant are furnished in Table 26. The results revealed the significant influence among the treatments. The highest number of fruits (26.3) was obtained from chicken manure and pig manure applied plot which were on par followed by that of receiving vermicompost (24). The elephant dung applied plot produced the lowest number of fruits (14).

4.2.3.2. Weight of fruits per plant

Treatments showed significant variation in the weight of fruits per plant (Table 26). The highest fruit yield was obtained from vermicompost (454.28 g) which was on par with chicken manure (451.7 g) applied plot whereas the lowest fruit yield was observed with horse manure (244.32g).

4.2.3.3. Length of fruits

Table 26 represent the length of fruits from different treatments and it showed significant variation. Length of fruit was the highest (17.2 cm) in rabbit manure applied plot which was on par with chicken manure (16.6 cm). The horse manure applied plot had the lowest value of 13.4 cm.

4.2.3.4. Girth of fruits

The treatments significantly influenced the girth of fruits (Table 26). Vermicompost and pig manure applied plots recorded the highest girth of fruits (6.7 cm) whereas the lowest value was noticed in cow dung (desi) applied site (5.4 cm).

Table 25. Effect of treatments on dry matter production of okra at last harvest

Treatments		Dry matter production (t ha^{-1})
T_1	Cow dung (Desi) @ 6.3 t ha^{-1}	2.07^{de}
T_2	Cow dung (crossbred) @ 12.5 t ha^{-1}	1.83^{ef}
T_3	Buffalo manure @ 14.3 t ha^{-1}	1.74^{ef}
T_4	Goat manure @ 7.1 t ha^{-1}	2.50^{cd}
T_5	Chicken manure @ 6.7 t ha^{-1}	5.30^{a}
T_6	Rabbit manure @ 5.6 t ha^{-1}	1.93^{ef}
T_7	Pig manure @ 10 t ha^{-1}	3.51^{b}
T_8	Elephant dung @ 20 t ha^{-1}	1.14^{g}
T_9	Horse manure @ 20 t ha^{-1}	1.52^{fg}
T_{10}	Quail manure @ 5.8 t ha^{-1}	3.91^{b}
T_{11}	Vermi compost @ 5.6 t ha^{-1}	3.42^{b}
T_{12}	KAU POPR	2.83^{c}
T_{13}	Absolute control	1.69^{ef}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 26. Effect of treatments on yield attributes

Treatments		Number of fruits per plant	Weight of fruits per plant	Length of fruits (cm)	Girth of fruits (cm)
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	22.7^{bc}	381.2^{e}	15.6^{bcde}	5.4^{f}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	19.0^{ef}	332.0^{f}	14.6^{ef}	6.1^{cde}
T_3	Buffalo manure @ 14.3 t ha^{-1}	18.7^{efg}	318.4^{g}	14.9^{de}	6.2^{bcd}
T_4	Goat manure @ 7.1 t ha^{-1}	21.7^{bcd}	411.6^{d}	14.5^{efg}	6.0^{de}
T_5	Chicken manure @ 6.7 t ha^{-1}	26.3^{a}	451.7^{a}	16.6^{ab}	6.5^{ab}
T_6	Rabbit manure @ 5.6 t ha^{-1}	21.0^{cde}	406.3^{d}	17.2^{a}	6.2^{bcd}
T_7	Pig manure @ 10 t ha^{-1}	26.0^{a}	437.8^{b}	16.5^{abc}	6.7^{a}
T_8	Elephant dung @ 20 t ha^{-1}	14.7^{h}	261.0^{i}	14.9^{de}	6.3^{abcd}
T_9	Horse manure @ 20 t ha^{-1}	16.3^{gh}	244.3^{j}	13.2^{g}	6.3^{abcd}
T_{10}	Quail manure @ 5.8 t ha^{-1}	20.0^{def}	424.4^{c}	16.2^{abc}	6.5^{abc}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	24.0^{ab}	454.3^{a}	16.1^{abcd}	6.7^{a}
T_{12}	KAU POPR	22.3^{bcd}	414.0^{d}	15.3^{cde}	6.4^{abc}
T_{13}	Absolute control	17.7^{fg}	296.5^{h}	13.4^{fg}	5.8^{ef}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

4.2.3.6. Number of seeds per fruit

The highest number of seeds per fruit (66.33) was found in cow dung (desi) treated plots. The lowest number (52) of seeds was in absolute control plot (Table 27).

4.2.3.7. Yield per hectare

Treatments showed significant effect on the yield of okra (Table 27). Chicken manure treated plot produced the highest yield of 25.24 t ha^{-1} and was on par with vermicompost 25.09 t ha^{-1} followed by pig manure (24.32 t ha^{-1}). The lowest yield was found in absolute control plot (13.48 t ha^{-1}).

4.2.3.8. Fibre content in fruits

The data regarding crude fibre content in okra fruits is furnished in Table 28 and the treatments varied significantly. The crude fibre content was the highest with elephant dung (13.96%) followed by absolute control. The lowest crude fibre content was noticed in vermicompost (8.4%) applied plot.

4.2.4. Incidence of pest and diseases

The percentage incidence of pests and diseases are presented in Table. 29. There was no severe attack of pests and diseases during the period of crop growth. Sucking insect population (*Aphis gossypi*) was the highest during early growth stage of the crop and fruit borer attack was observed during the harvesting stage. Neem soap (1%), *Beauveria brassiana* (1%), Neem garlic chilli emulsion (3%), chitin enriched *pseudomonas* (1%) were alternatively sprayed at weekly intervals for the control of the pests. Powdery mildew symptom was observed (only in the control plot) and was made under control by spraying *Trichoderma* @ 2 per cent.

Table 27. Effect of treatments on fruit characteristics

Treatments		Average fruit weight	Number of seeds per fruit	Yield (t ha^{-1})
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	16.25^{de}	66.33^{a}	21.18^{e}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	15.67^{e}	55.00^{d}	18.44^{f}
T_3	Buffalo manure @ 14.3 t ha^{-1}	17.67^{cde}	63.33^{bc}	17.68^{g}
T_4	Goat manure @ 7.1 t ha^{-1}	19.23^{abc}	63.67^{abc}	22.86^{d}
T_5	Chicken manure @ 6.7 t ha^{-1}	20.33^{ab}	65.00^{ab}	25.24^{a}
T_6	Rabbit manure @ 5.6 t ha^{-1}	19.30^{abc}	61.33^{c}	22.57^{d}
T_7	Pig manure @ 10 t ha^{-1}	19.30^{abc}	64.33^{ab}	24.32^{b}
T_8	Elephant dung @ 20 t ha^{-1}	15.73^{e}	57.33^{d}	14.50^{i}
T_9	Horse manure @ 20 t ha^{-1}	16.17^{de}	57.00^{d}	15.57^{h}
T_{10}	Quail manure @ 5.8 t ha^{-1}	18.87^{abc}	56.00^{d}	23.58^{c}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	20.53^{a}	64.00^{abc}	25.09^{a}
T_{12}	KAU POPR	18.17^{bcd}	61.33^{c}	23.00^{d}
T_{13}	Absolute control	14.30^{de}	52.00^{e}	13.48^{j}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 28. Effect of treatment on crude fibre content in fruits of okra

Treatments		Crude fibre (%)
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	9.82^{ef}
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	9.98^{de}
T_3	Buffalo manure @ 14.3 t ha^{-1}	10.37^{bc}
T_4	Goat manure @ 7.1 t ha^{-1}	10.24^{cd}
T_5	Chicken manure @ 6.7 t ha^{-1}	9.26^{g}
T_6	Rabbit manure @ 5.6 t ha^{-1}	9.00^{gh}
T_7	Pig manure @ 10 t ha^{-1}	10.40^{bc}
T_8	Elephant dung @ 20 t ha^{-1}	13.96^{a}
T_9	Horse manure @ 20 t ha^{-1}	9.58^{f}
T_{10}	Quail manure @ 5.8 t ha^{-1}	8.70^{hi}
T_{11}	Vermicompost @ 5.6 t ha^{-1}	8.40^{i}
T_{12}	KAU POPR	10.62^{b}
T_{13}	Absolute control	10.67^{b}

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Table 29. Effect of treatments on incidence of pests and diseases

Treatments		Aphids (%)	Fruit borer (%)	Powdery mildew (%)
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	6.7	2.5	-
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	8.3	3.5	-
T_3	Buffalo manure @ 14.3 t ha^{-1}	5.4	2.7	-
T_4	Goat manure @ 7.1 t ha^{-1}	4.9	11.1	-
T_5	Chicken manure @ 6.7 t ha^{-1}	7.3	3.7	-
T_6	Rabbit manure @ 5.6 t ha^{-1}	7.5	4.5	-
T_7	Pig manure @ 10 t ha^{-1}	6.5	10	-
T_8	Elephant dung @ 20 t ha^{-1}	10.4	6.8	-
T_9	Horse manure @ 20 t ha^{-1}	10.2	2.9	-
T_{10}	Quail manure @ 5.8 t ha^{-1}	8.9	13.8	-
T_{11}	Vermicompost @ 5.6 t ha^{-1}	6.5	5.55	-
T_{12}	KAU POPR	10.5	11.1	-
T_{13}	Absolute control	15	16.6	8.3

4.2.5. B: C Ratio

The economic analysis of okra is furnished in Table 30. The organic manure treatments significantly influenced the benefit to cost ratio of okra. The total cost of cultivation varied from Rs. 3,44,018 to Rs. 4,75,792. The treatment supplied with basal application of chicken manure showed the highest gross return (Rs.10, 09, 600 ha^{-1}), net return (Rs.5, 80, 558 ha^{-1}) and B: C ratio (2.35) followed by vermicompost (2.29).The lowest B: C ratio was estimated in the absolute control (1.28).

Table 30. Effect of treatments on total cost of cultivation, gross return, net return and B: C ratio of okra

	Treatments	Total cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	Cow dung (desi) @ 6.3 t ha^{-1}	4,24,032	8,47,200	4,23,168	2.00
T_2	Cow dung (cross bred) @ 12.5 t ha^{-1}	4,28,992	7,37,600	3,08,608	1.72
T_3	Buffalo manure @ 14.3 t ha^{-1}	4,69,042	7,07,200	2,38,158	1.51
T_4	Goat manure @ 7.1 t ha^{-1}	4,75,792	9,14,400	4,38,608	1.92
T_5	Chicken manure @ 6.7 t ha^{-1}	4,29,042	10,09,600	5,80,558	2.35
T_6	Rabbit manure @ 5.6 t ha^{-1}	4,38,592	9,02,800	4,64,208	2.06
T_7	Pig manure @ 10 t ha^{-1}	4,29,992	9,72,800	5,42,808	2.26
T_8	Elephant dung @ 20 t ha^{-1}	4,34,992	5,80,000	1,45,008	1.33
T_9	Horse manure @ 20 t ha^{-1}	4,34,992	6,22,800	1,87,808	1.43
T_{10}	Quail manure @ 5.8 t ha^{-1}	4,28,045	9,43,200	5,15,155	2.20
T_{11}	Vermicompost @ 5.6 t ha^{-1}	4,39,876	10,09,400	5,69,524	2.29
T_{12}	KAU POPR	4,27,962	9,20,000	4,92,038	2.15
T_{13}	Absolute control	3,44,018	4,39200	95,182	1.28

In a column, means followed by common letters do not differ significantly at 5% level of DMRT

Discussion

5. DISCUSSION

An experiment on "Quality assessment of organic manures and their effect on okra" was conducted during 2017-2018 at College of Horticulture, Vellanikkara, Thrissur. The major findings are discussed in this chapter.

5.1. Experiment I

Evaluation of physical, chemical and biological properties of organic manures

5.1.1. Physical and chemical properties of organic manures

The organic manures viz., cow dung (desi), cow dung (cross bred), buffalo manure, goat manure, chicken manure, rabbit manure, pig manure, elephant dung, horse manure, quail manure, vermicompost were subjected to analysis of particle size, moisture content, colour and odour. Among the organic manures, elephant dung showed the largest particle size. Elephants are non-ruminants and under Kerala conditions they are mainly fed with palm leaves as roughage which are rich in crude fibre (31%). The elephant is capable of digesting only 44 per cent of the materials which they consume and that might be the reason for the higher fibre content as reported by Sreekumar (2009). The vermicompost had the lowest particle size (65 % passed through 0.5mm sieve). The raw materials of the compost will be passing through the alimentary canal of the earth worm and get converted to fine particles and therefore the surface area of vermicompost has increased. All the manures have passed through 0.5mm sieve except quail manure. The difference in colour of manures may be due to the difference in the feed materials. The variation in the smell might be due to the presence of alcohols, aldehydes, ketones and fatty acids in organic manures (Jager and Jager, 1980). The moisture content of the cow dung (cross bred) was the highest and it might have been influenced by the moisture content of feed and water intake (Fig. 2).

Plate 9. Fruits from different treatments

Cow dung (desi)

Cow dung (cross bred)

Buffalo manure

Goat manure

Chicken manure

Rabbit manure

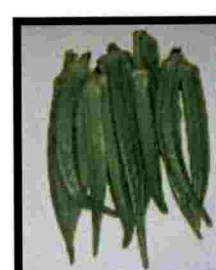
Pig manure

Elephant dung

Horse manure

Quail manure

Vermicompost



KAU POPR

Control

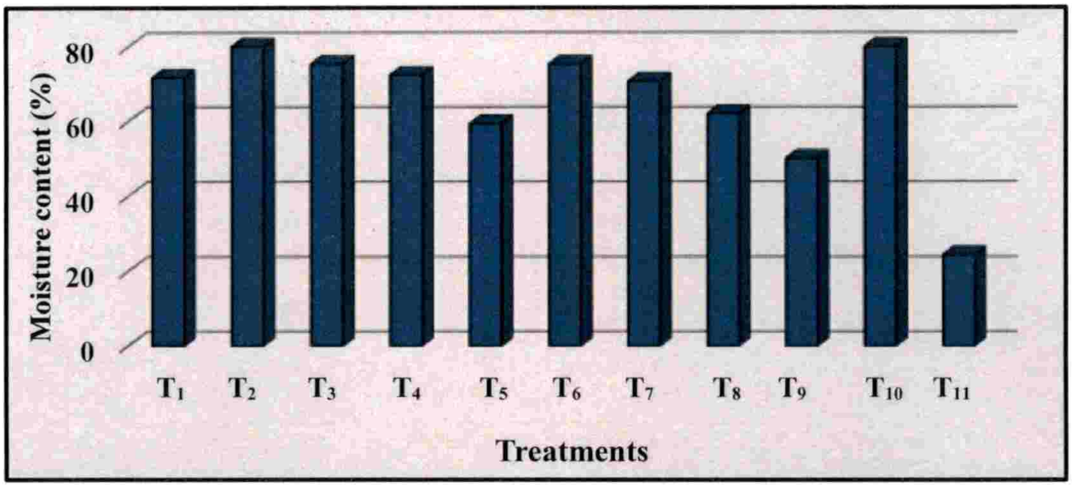


Fig. 2. Moisture content in organic manures

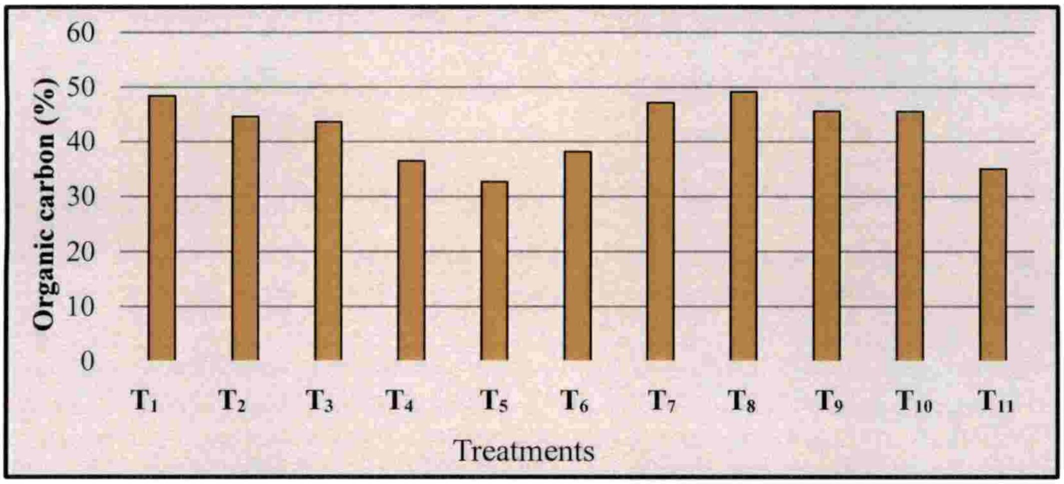


Fig. 3. Organic carbon content in organic manures

T_1 - Cow dung (Desi)

T_2 - Cow dung (Cross bred)

T_3 - Buffalo manure

T_4 - Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

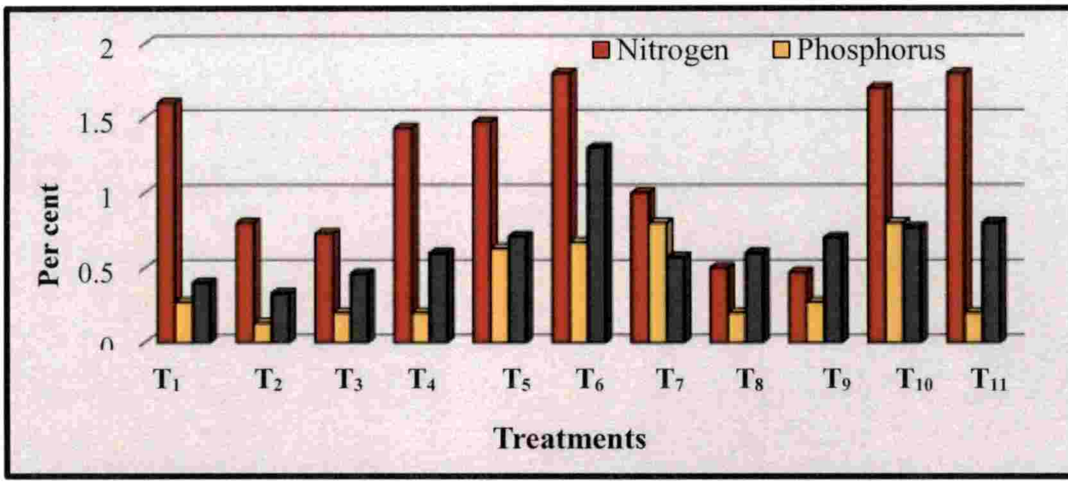


Fig.4. Macronutrients in organic manures

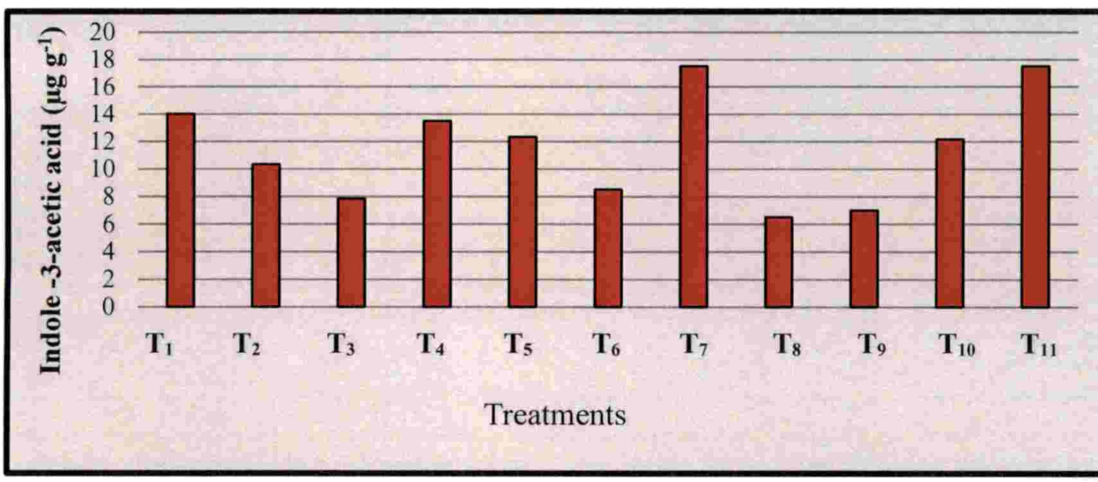


Fig.5. Indole-3-acetic acid activity in organic manures

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

In general, the pH of all the organic manures was neutral to slightly alkaline and the electrical conductivity was less than 0.5 dS m^{-1}. These results are in agreement with the findings of Irshad *et al.* (2013). The organic carbon content (Fig. 3) of elephant dung was the highest and showed the lowest nitrogen content which resulted in high C: N (98:1) ratio. The lowest C: N ratio was observed in vermicompost (19:1) due to faster decomposition of substrates by earth worms as observed by Ryan (2016).

Among the organic manures, the vermicompost and rabbit manure were rich in N (1.8%) as depicted in Fig.4. It is the most important element for the synthesis of protoplasm, which is responsible for rapid cell division and similar result in vermicompost (0.6-1.2% N) was reported by Pawar and Patil (2007). The quail and pig manure (0.8%) had the highest P content. Secondary nutrients like Ca, Mg and S and the micronutrients *viz.*, Fe, Mn, Zn and Cu also exhibited significant variation among the treatments. These might be due to the different climatic conditions, feeding habit, feed intake and digesting capacity of feed by the animals and birds. Vallejera *et al.*, 2014 observed that the chicken manure had the highest content of essential nutrients (P, K, Ca and Cl) compared to mud press, vermicast and swine manure and it has good potential as a source of organic fertilizer for vegetable production. Farhad *et al.* (2009) also observed improvement in soil fertility and organic matter content by the application of chicken manure. The nutrient content in elephant dung was less, may be resulted in less absorption of nutrients by plants.

5.1.2. Biological properties of organic manures

All the manures were significantly different in total microbial count (Fig.3). The bacterial activity was in the range from 13.33 to 35.33 $x10^4$ cfu g^{-1} and the highest bacterial count was observed in vermicompost (35.33 x 10 ^{4}cfu g^{-1}). Fungi was present in all the manures and the range varied from 8 to 17 x 10^3 cfu g^{-1}. Actinomycetes were not present in any of the manures. This might be due to the unfavourable conditions for the growth of actinomycetes.

Livestock excreta are found to be a potential vehicle for transmitting pathogens into cultivated field. Cow dung (desi), cow dung (cross bred), buffalo, goat, chicken, pig and quail manures were containing *Escherichia coli* and this bacterium is sometimes found in the intestinal tract of animals and birds. *E. coli* in soil may cause crop contamination as observed by Overbeek *et al.* (2010). All the manures were free of *Salmonella*. The neutral to alkaline pH of the organic manures might have influenced the population of bacteria. The decrease in fungal population might be attributed to the change in pH and higher moisture content in manures (Compost Microbiology and the Soil Food Web, 2008).

The commercially available growth hormones *viz.*, IAA and GA are costly and many farmers find it difficult to purchase and use. The IAA content was the highest in vermi compost and pig manure (17.5 $\mu g\ g^{-1}$) as depicted in Fig. 5. The growth promoting hormones like auxins, cytokinins and gibberellins present in vermicompost are mainly secreted by earth worms and this might have helped to improve the germination and seedling vigour as reported by Adhikary, 2012.

Among the different organic manures, the dehydrogenase enzyme (Fig. 6) activity was found to be higher in vermicompost (18.1 TPF g^{-1} soil day^{-1}) followed by goat manure (17 TPF g^{-1} soil day^{-1}). Presence of dehydrogenase enzymes in manure is directly proportional to the respiratory action of microorganisms in manures as pointed out by Chhonkar *et al.* (2007).

5.1.3. Heavy metal content in organic manures

The main problem due to the continuous application of animal manures is said to be the accumulation of heavy metals in soil and these may also get absorbed by the plants. This will not only affect the soil fertility and quality, but also promote the metal migration through leaching and runoff thereby leading to potential health hazards (Zhang *et al.*, 2005). Cadmium was present in quail manure (3.26 ppm) though it was within the safe limit (5ppm as maximum) as per the FCO standard for organic fertilizer (GOI, 1985).

The chromium content ranged from 6 to 10 ppm whereas the standard value was 30 ppm. None of the manures had more than 5 ppm of nickel which was lesser than the standard of 50 ppm. The lead content of manures varied from 0.01 to 2 ppm whereas the safer limit was 100 ppm. The mercury content in organic manures exceeded the safer limit of 0.15 ppm in goat (0.17 ppm), chicken (0.16 ppm), rabbit (0.17 ppm), pig (0.17 ppm) and quail manure (0.17 ppm).

Arsenic was present in all the manures (< 10 ppm) except quail manure (13.68 ppm) which exceeded the FCO standard value of 10 ppm. In general, heavy metal content in organic manures was less than the standards prescribed in the FCO except in the case of mercury and arsenic in quail manure. The variation in the heavy metal content in different organic manures might be due to the feeding habit, different types of feed consumed by the animals and the efficiency of conversion. Hence, it is better to avoid continuous application of same organic manure for a long period.

5.2. Experiment II

Effect of organic manures on growth and yield of okra

5.2.1. Influence of organic manures on soil physical and chemical properties

The water holding capacity and bulk density of soil before the experiment was 37 per cent and 1.32 mg m^{-3} respectively. The water holding capacity of soil increased by 3 per cent after the experiment. Use of FYM and other organic manures might have created a good soil condition, increased soil organic matter and water holding capacity of soil as observed by Tadesse *et al.* (2013). There was no significant difference among the treatments in bulk density of soil before and after the experiment. The bulk density observed as minimum might be due to the addition of manures to the soil which enhanced the microbial decomposition and liberated various organic products and acted as strong binding agents in the formation of large and stable aggregates and reduced the bulk density. The results agree with the findings of Koushal *et al.* (2011).

The soil had a pH of 5.71 before the experiment. The treatments significantly influenced the pH of the soil after the experiment and an increase was observed in all the plots as depicted in Fig. 7. Soil pH varied from 5.7 to 6.5 after the application of manures. Krishnan (2014), Vemaraju (2014), Rameeza (2016) and Dhanalakshmi (2017) also reported similar increase in soil pH after cropping due to the basal application of organic manures. When organic residues collected from plant or animal were added to the soil, they released organic anions which had neutralized the hydrogen ions of the acid soil and thereby increased the soil pH as observed by Zaman *et al.* (2017).

The electrical conductivity of the soil after the experiment was increased from 0.82 dS m^{-1} to 0.97 dS m^{-1} and it might be due to slightly alkaline pH of organic manures. Initially, the organic carbon content of the soil was 0.85 per cent. The value increased in all plots treated with organic manures. The highest organic carbon content (1.3%) in vermicompost applied soil might be due to slightly wider C: N ratio which might have increased the soil organic matter content. The increase in soil organic carbon has improved the soil health, multiplication of microbes and enzyme activities in the soil. The optimum C: N ratio (12:1) in cow dung (desi) applied plot might be due to the highest organic carbon which has improved the available N in the soil.

The available macronutrients like N, P and K was significantly affected by the different organic manure treatments (Fig. 8, Fig. 9 and Fig. 10). The highest available N (244.37 kg ha $^{-1}$) in the soil was observed in KAU POPR followed by chicken manure applied soil (239.7 kg ha^{-1}). This might be due to the increased release of N through mineralization. The remaining treatments showed lesser availability of N due to slow mineralization and release of N which might have left residues in the soil and this would be beneficial to the crop grown in succeeding seasons. Zaman *et al.* (2017) also found significant increase in all plant nutrients (available N, P, K, Ca, Mg, S, Zn and B) and organic matter in the soil with the application of organic manures.

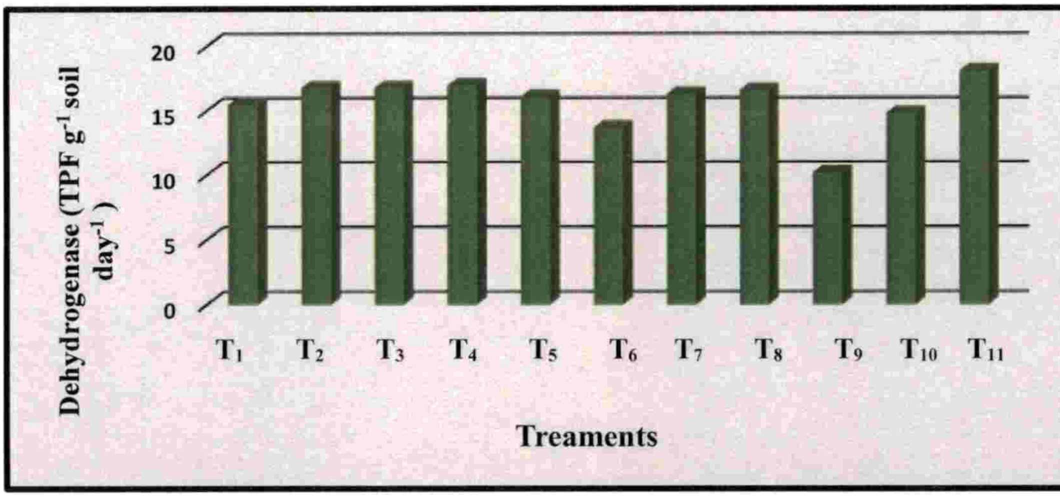


Fig.6. Dehydrogenase enzyme activity in organic manures

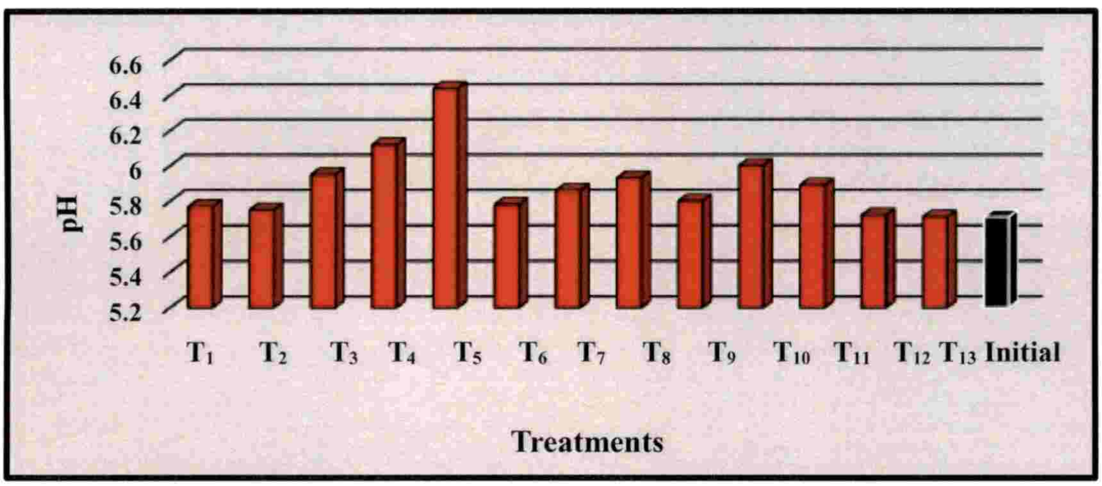


Fig.7. Effect of treatments on pH of soil

T1 - Cow dung (Desi)

T2 - Cow dung (cross bred)

T3 - Buffalo manure

T4- Goat manure

T5 - Poultry manure

T6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

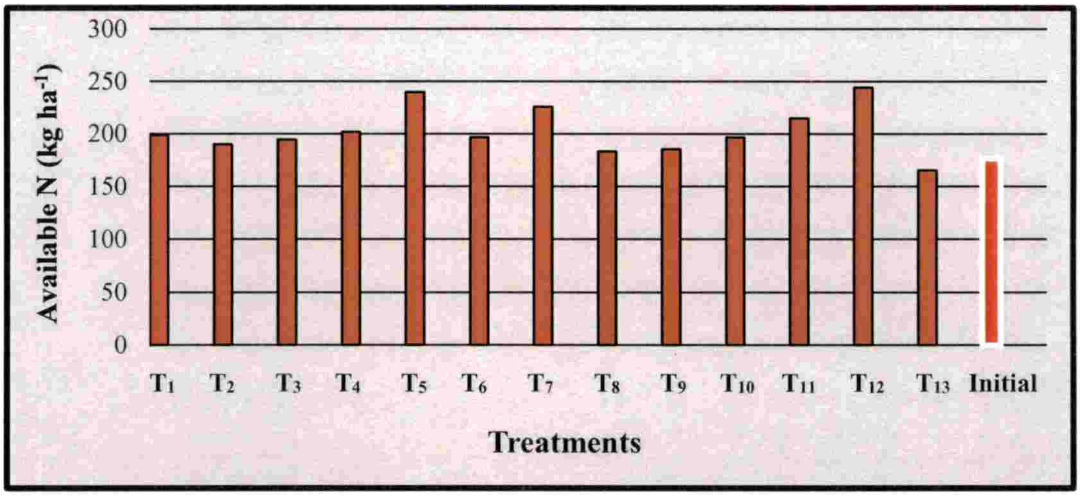


Fig. 8. Effect of treatments on available N in soil

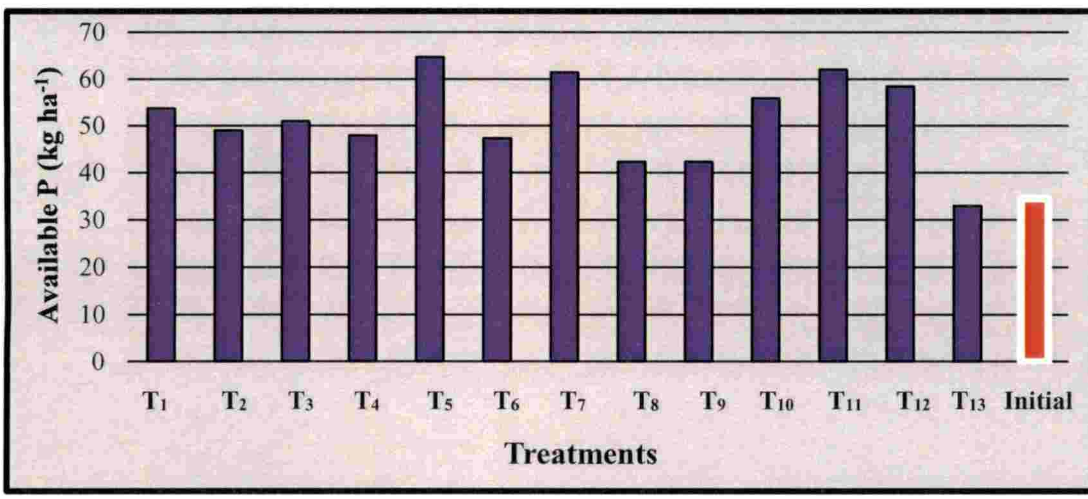


Fig.9. Effect of treatments on available P in soil

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

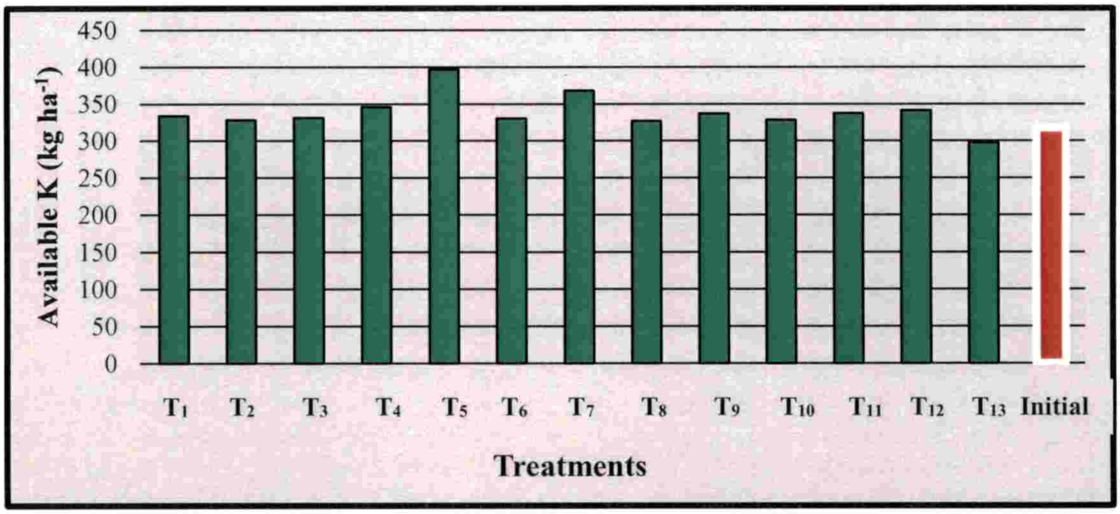


Fig.10. Effect of treatments on available K in soil

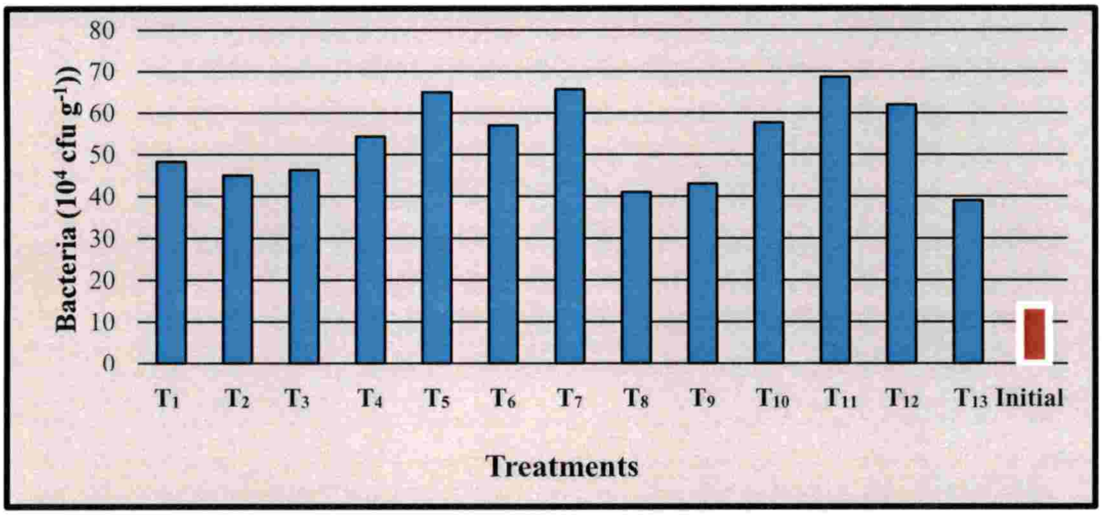


Fig.11. Effect of treatments on total bacteria in soil

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermi compost

T_{12} - KAU POPR

T_{13} - Absolute control

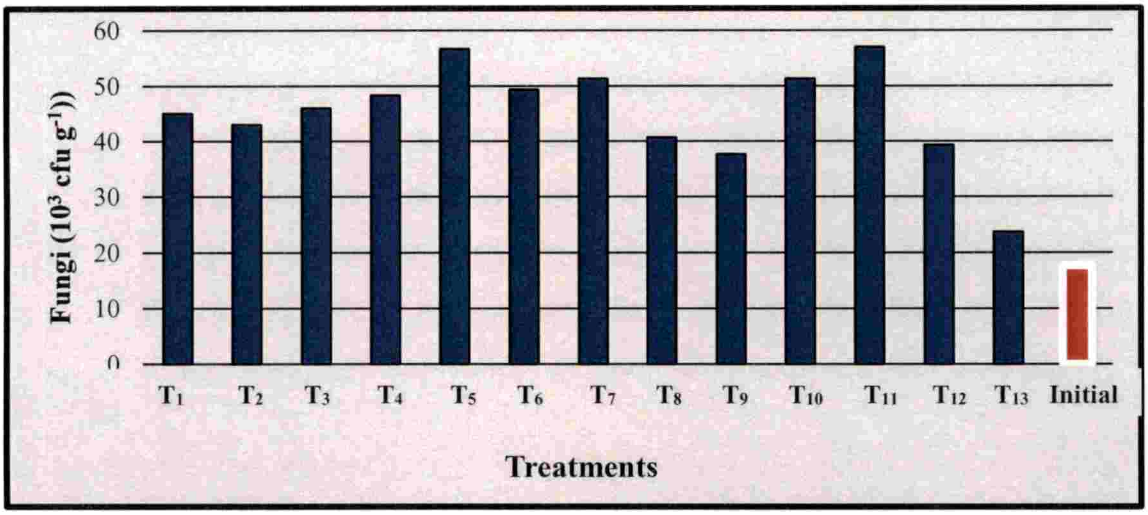


Fig.12. Effect of treatments on total fungi in soil

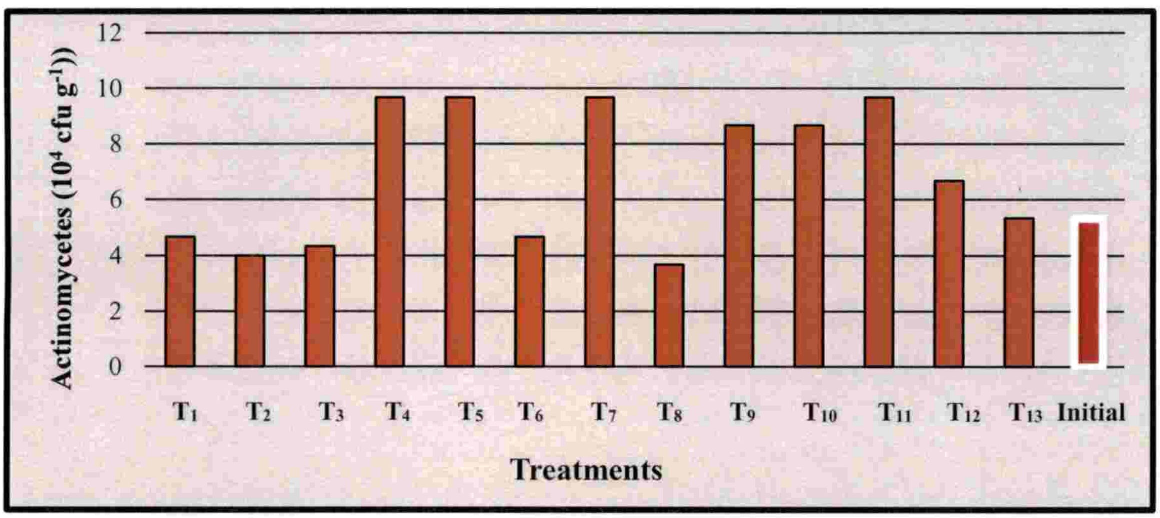


Fig.13. Effect of treatments on total actinomycetes in soil

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermi compost

T_{12} - KAU POPR

T_{13} - Absolute control

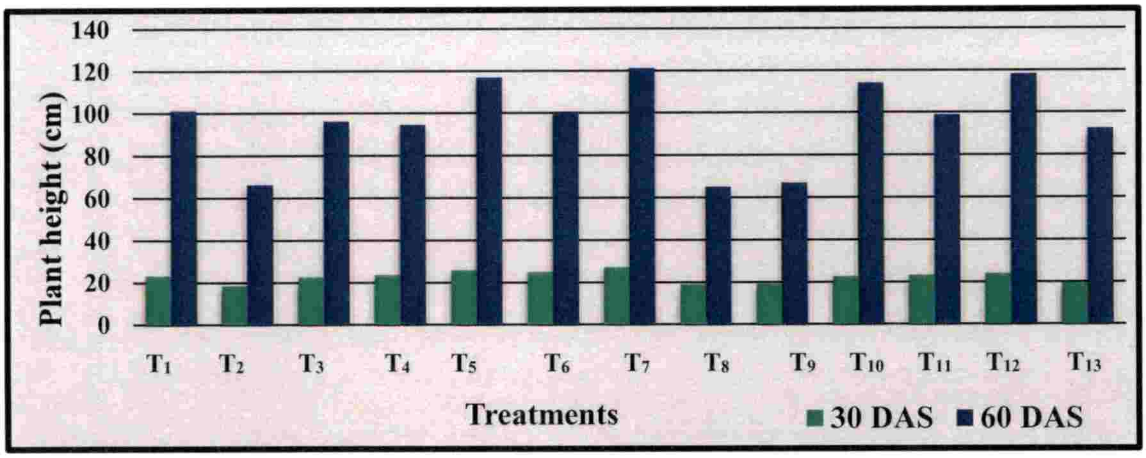


Fig.14. Effect of treatments on plant height at 30 and 60 DAS

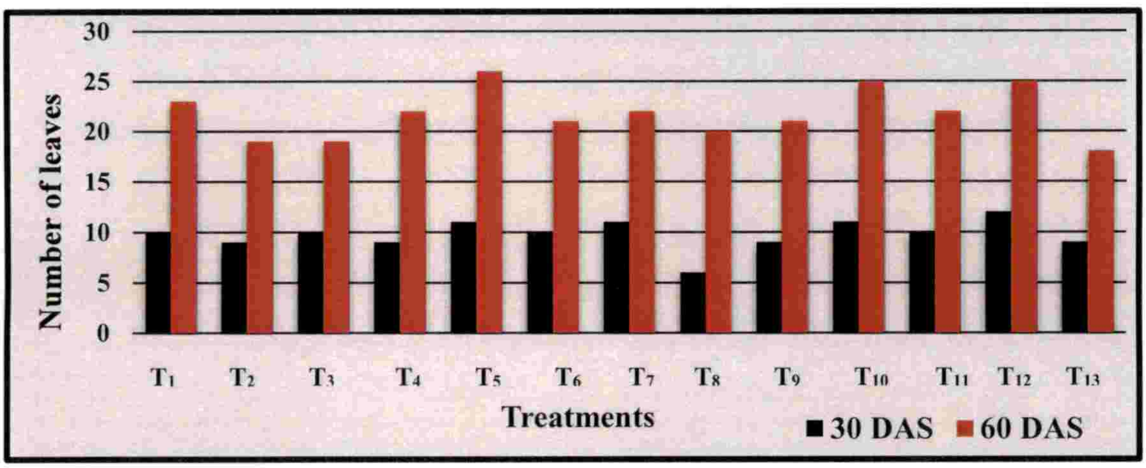


Fig.15. Effect of treatments on number of leaves at 30 and 60 DAS

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

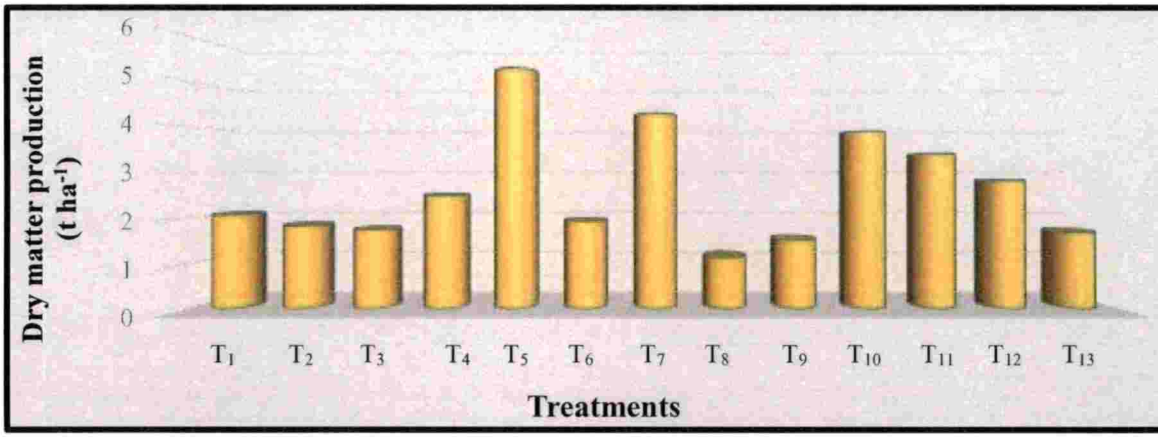


Fig.16. Effect of treatments on dry matter production of okra at harvest

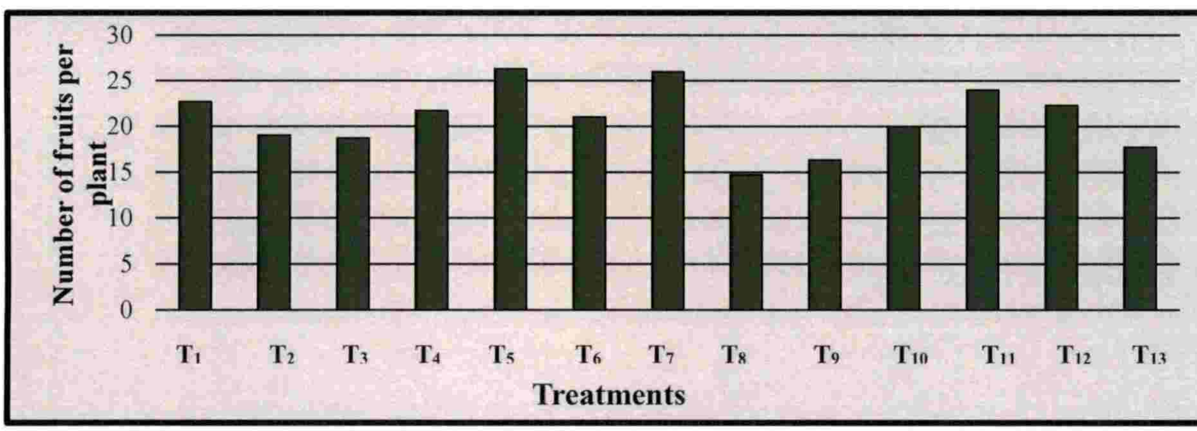


Fig.17. Effect of treatments on total number of fruits per plant of okra

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

Compared to the initial status, the available P content increased in all the treatments and similar trend was reported by Vemaraju (2015), Rameeza (2016) and Dhanalakshmi (2017). Among the different organic manure treatments, chicken manure applied soil had the highest available P (64.67 kg ha^{-1}) in soil. The addition of organic substances to the soil have narrowed the C:N ratio and registered more production of humic acid and humic substances and this might have produced chelates with phosphorus and made available to the crop (Akshay *et al.*, 2018). The P availability in soil might also have increased due to the presence of phosphate solubilizing bacteria in soil as reported by Ninan *et al.* (2013).

The available K content in the soil was significantly influenced by the different organic manures. The initial status of available K in soil was 317.3 kg ha^{-1} and it was increased after the experiment. The highest value was found in chicken manure (396.9 kg ha^{-1}) applied plot as observed by Vemaraju (2015) and Rameeza (2016) and Kumar *et al.* (2017).

5.2.2. Influence of organic manures on soil biological properties

The rhizosphere of okra having microorganisms like bacteria, fungi and actinomycetes was significantly influenced by the different organic manure treatments (Fig. 11 Fig. 12 Fig. 13). The bacterial (68.67x 10^4cfu g^{-1}) and fungal (57 x 10^3 cfu g^{-1}) population were the highest in vermicompost treated soil. The actinomycetes population in soil was relatively lower in all the treatments than bacteria and fungi. The highest value of 9.67 x 10^4 cfu g^{-1} was found in goat manure, poultry manure, pig manure and vermicompost applied plot. Addition of organic manures had improved the soil physico-chemical properties which in turn has enhanced the microbial population in soil as observed by Masto *et al.* (2006). Application of organic manures might have stimulated the growth and activities of soil microorganisms as observed by Upadhyay *et al.* (2011). The roots of higher plants secreted organic acids around the rhizosphere, which is an easily available source of food for soil microorganisms and it had led to improved microbial population (Dotaniya *et al.*, 2013). Adhikary, 2012 also found that the enzymes like amylase, lipase, cellulase and chitinase in the vermicompost might have helped to break down the organic matter in the soil to release the nutrients and made it available to the plant roots (Adhikary, 2012).

5.2.3. Influence of organic manures on heavy metals content in soil

The presence of cadmium, chromium, mercury was not detected in the soil whereas arsenic was present in cow dung (desi) and cow dung (cross bred) treated soils. The nickel content in different organic manure treated soils was found to be non-significant. The vermicompost applied plot had the highest value of lead followed by that received buffalo manure. This might be due to the presence of water soluble fraction in organic manures which had strongly adsorbed the heavy metals and made complex with the metals and thereby reduced the mobility of heavy metals (Budai *et al.*, 2009).

5.2.4. Influence of organic manures on biometric observations of okra

The plant height and number of leaves per plant in the initial growth stage (30 DAS) was not having significant variation among the treatments (Fig.14). The highest plant height was noticed in pig manure with a value of 27.15 and chicken manure treated plot while the highest number of leaves (12) was observed in the KAU POPR treatment. But at 60 DAS, the highest plant height (121.17 cm) was found with pig manure and the highest number of leaves was recorded with chicken manure (26) as depicted in Fig.15. The difference in the physical, chemical and biological properties of soil by the addition of different organic manures might be the reason for increased plant growth as reported by Dhanalakshmi (2017).

However, the different organic manure treatments had no significant effect on days to first flowering, days to first harvest, number of harvests and duration of the crop though the treatments receiving cow dung (desi), cow dung (cross bred), goat manure, chicken manure and pig manure had longer duration compared to that received KAU POPR and control.

The highest (5.30 t ha^{-1}) total dry matter production was found in chicken manure applied plots (Fig. 16) and similar result was observed by Ezeocha *et al.* (2014) in *Dioscorea bulbifera* where the application of poultry manure increased the dry matter, starch, fibre and protein and decreased the fat content. Application of poultry manure to *Andrographis paniculata* Nees. resulted in the highest stem dry weight (11.06 g $plant^{-1}$), leaf dry weight per plant (10.95 g) as found by Detpiratmongkol *et al.* (2014).

5.2.5. Influence of organic manures on yield and yield attributes

The yield and yield attributes like number of fruits per plant, weight of fruits per plant, length of fruit, girth of fruit, average fruit weight, number of seeds per fruit, yield per ha of okra were significantly influenced by the different organic manure treatments. The highest number of fruits was found in poultry manure (26.33) treated plot followed by vermicompost as depicted in Fig.17. The results agree with the findings of Farhad *et al.* (2009), where the highest number of rows per cob, number of grains per row, 1000 grain weight, grain yield, biological yield and harvest index of maize were obtained with the application of chicken manure @ 12 t ha^{-1}. The study revealed that the highest weight of fruits per plant (454.28 g) was obtained in vermicompost (Fig.18) treated soil. The presence of micronutrients *viz.*, Zn, Cu, Fe, Mn, growth hormones and enzymes in the organic manures might be the reason for the excellent fruit production. The application of rabbit manure recorded the highest fruit length (17.21 cm) whereas the girth of fruit (6.7 cm) was the highest in pig manure and vermicompost treated soil (Fig.19). The highest average fruit weight of 20.53 cm was observed in vermicompost applied plot followed by the chicken manure (20.33 cm) received plot. Soil application of chicken manure or vermicompost recorded the highest yield (Fig. 20) for okra due to the highest nutrient content, microbial activity, IAA activity, dehydrogenase activity, highest dry matter production, number of fruits and weight of fruits compared to other treatments. The highest number of seeds per pod was in cow dung (desi) treated plot (66.33) followed by chicken (65) manure applied plot.

The different treatments revealed significant variation in crude fibre content of okra fruits (Fig. 21). The crude fibre content was the highest in elephant dung applied site (13.96%) followed by KAU POPR. Presence of more fibre in elephant dung might be the reason for the accumulation of more fibre in fruits of okra. The lowest crude fibre was noticed with vermicompost (8.4%). Similar report was also given by Premsekhar *et al.* (2009) where the application of organic manures gave better quality fruits with less crude fibre content of 10.31%. The results agree with the findings of Oyedeji *et al.* (2014) where the ash and total carbohydrate content of amaranthus was found to be higher in poultry manure applied soil while the protein and crude fibre content was the highest in NPK fertilizer applied plot. Poultry manure improved the soil nutrient status by improving the soil organic carbon, available NPK, Ca and Mg and it is a good source of nutrients for improving the soil fertility and yield of vegetables. Addition of organic manures *viz.*, poultry manure and vermicompost could supply nutrients at the optimum level which might have resulted in higher yield and quality of the produce as observed by Singh (2011).

5.2.6. Incidence of pests and diseases

The major constraint in organic production system is the control of pests and diseases. Aphids and fruit borer were the two major pests found in the okra field. None of the pest population crossed the economic threshold limit. Presence of soluble nutrients, free enzymes, soluble phenolic compounds and a wide range of microorganisms in vermicompost which passed into tissues of plants might have resulted in the suppression of pests (Edwards *et al.*, 2010). Neem garlic chilli emulsion (3%) was sprayed at weekly intervals along with other bio control agents to prevent the attack of pests and diseases. The presence of volatile antimicrobial substances (allicin) in garlic might be the reason for the beneficial effects as reported by Gurjarl *et al.*, 2012. It is presumed that organic agriculture offered a high functional diversity of

Plate 10. Pest incidence in the field

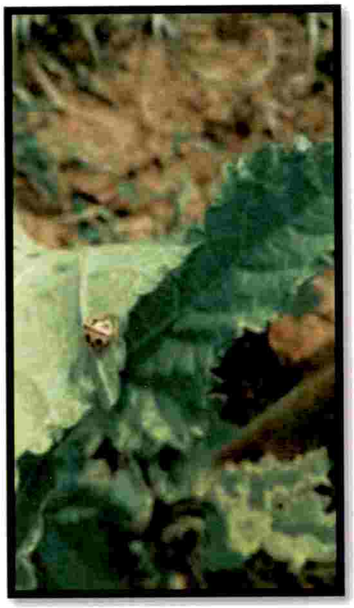


Plate 11. Presence of ladybird beetle in the field

microorganisms in the soil and helped to develop resistance in the plants against pest and disease infestation as observed by Aracon *et al.* (2008).

5.2.7. Economic analysis

The economic analysis revealed the difference among the treatments (Fig. 22). The treatment receiving basal application of chicken manure @ 6.7 t ha^{-1} was superior to other treatments and it recorded the highest gross, net return and B: C ratio (2.35) followed by that received vermicompost (2.29). The increase in yield of okra was due to the application of organic manures where they supplied all the essential nutrients required for the crop. The highest B: C ratio was achieved due to the highest yield of okra and it was profitable to the farmers than the KAU POPR which had a B: C ratio of 2.15 only. The same trend was observed by Nandini (1998) where the poultry manure (100 kg N ha^{-1}) received plot recorded the maximum net return.

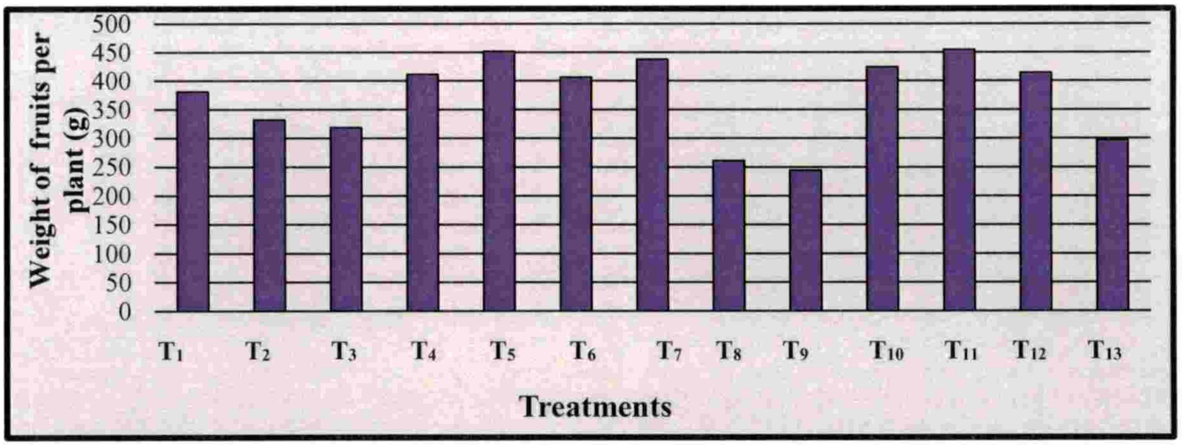


Fig.18. Effect of treatments on weight of fruits per plant of okra

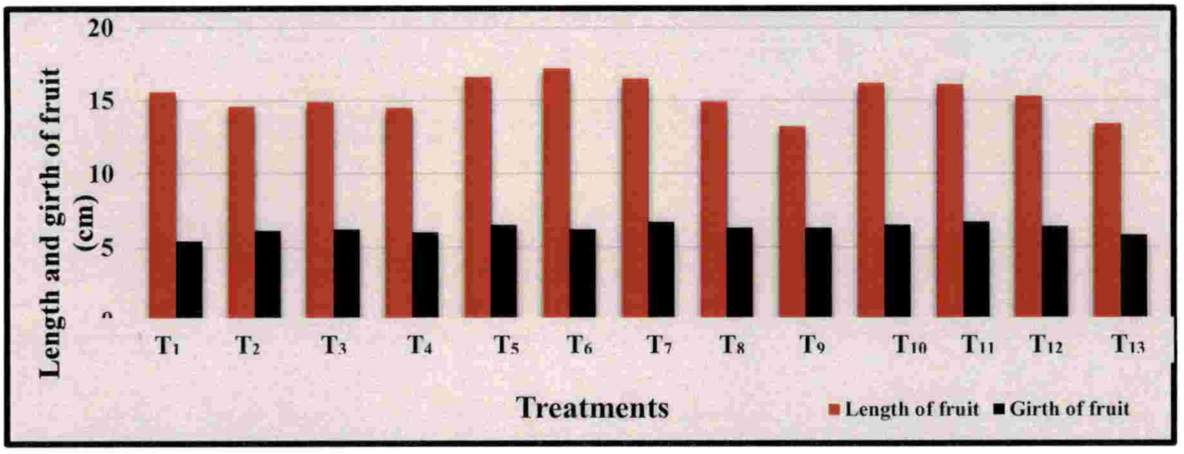


Fig.19. Effect of treatments on length and girth of okra fruit

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

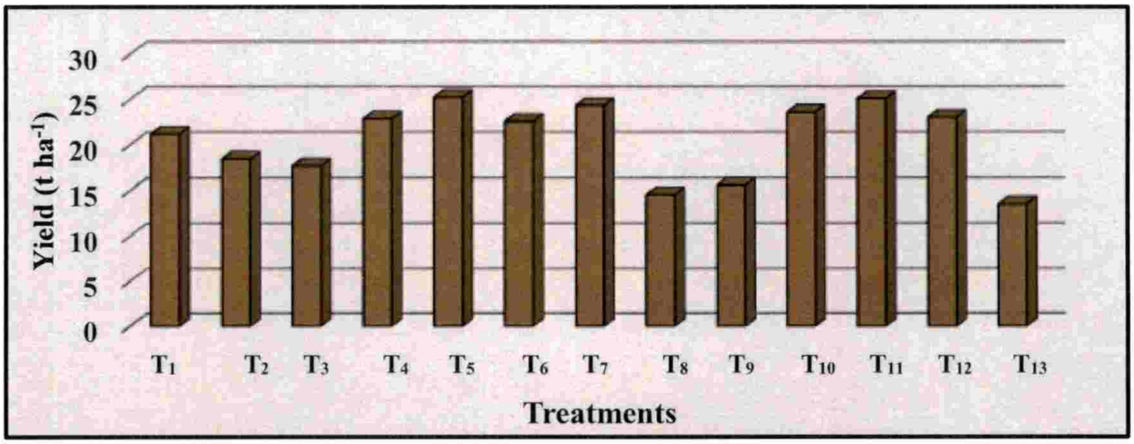


Fig.20. Effect of treatments on yield of okra

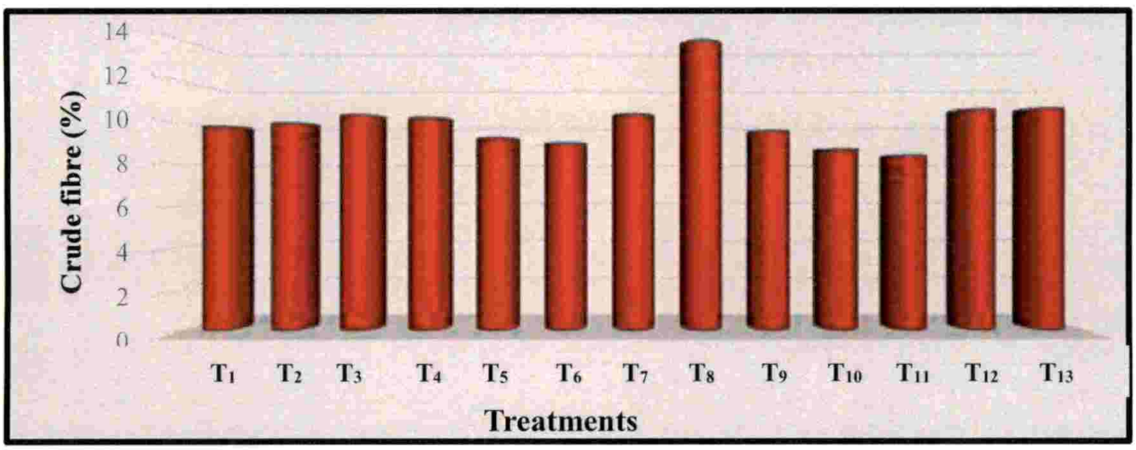


Fig. 21. Effect of treatments on crude fibre content in fruits of okra

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

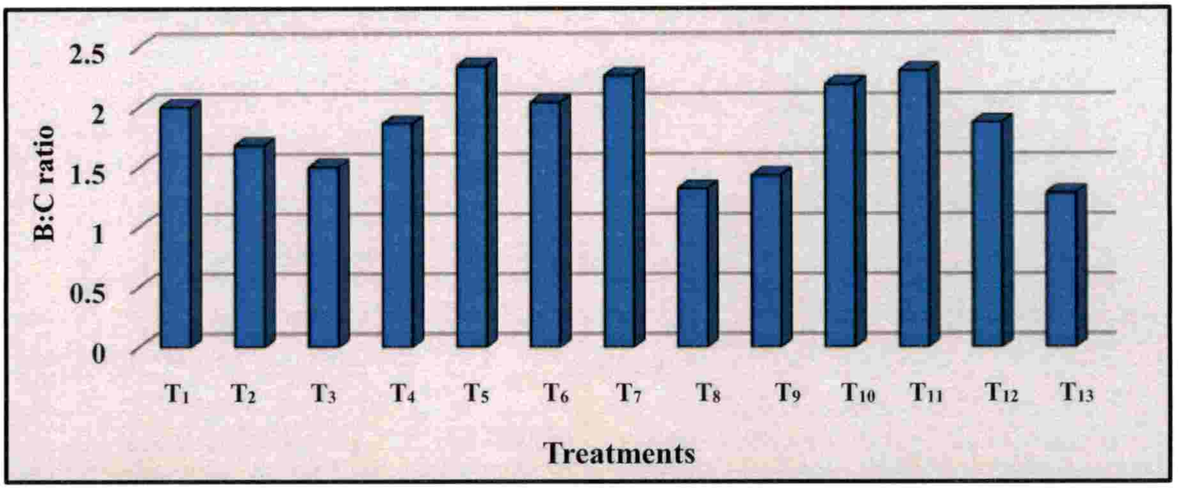


Fig.22. Effect of treatments on B: C ratio of okra

T_1 - Cow dung (Desi)

T_2 - Cow dung (cross bred)

T_3 - Buffalo manure

T_4- Goat manure

T_5 - Poultry manure

T_6 - Rabbit manure

T_7 - Pig manure

T_8 - Elephant dung

T_9 - Horse manure

T_{10} - Quail manure

T_{11} - Vermicompost

T_{12} - KAU POPR

T_{13} - Absolute control

CONCLUSION

The study entitled "Quality assessment of organic manures and their effect on okra" revealed the quality of different organic manures *viz.,* cow dung (desi), cow dung (crossbred), buffalo manure, goat manure, chicken manure, rabbit manure, pig manure, elephant dung, horse manure, quail manure and vermicompost. Physical, chemical as well as biological properties of these manures were studied in detail. Vermicompost had the desirable particle size, pH, C:N ratio, nutrient status, microbial population followed by chicken manure, rabbit manure and quail manure. IAA and dehydrogenase activity were higher in vermicompost.

Basal application of chicken manure @ 6.7 t ha^{-1} with Adhoc POPR recorded the highest growth and yield parameters. This also has resulted in the highest gross and net return and B: C ratio (2.35). The lowest crude fibre content (8.4%) in fruits was observed in the fruits of vermicompost (@ 5.6 t ha^{-1}) applied plot. The results revealed the advantage of application of chicken manure or vermicompost to improve the soil quality, growth and yield of okra.

Future line of work

1. Study on the effect of continuous application of different organic manures on soil and crop quality
2. Identification of beneficial microbes in organic manures
3. Effect of organic manures on fruit quality and keeping quality
4. Composting with different organic manures in various proportion

Summary

6. SUMMARY

The investigation on "Quality assessment of organic manures and their effect on okra" was carried out during 2017-2018 at Kerala Agricultural University, College of Horticulture, Velanikkara, Thrissur. Organic manures viz., cow dung (desi), cow dung (cross bred), buffalo manure, goat manure, chicken manure, rabbit manure, pig manure, elephant dung, horse manure, quail manure and vermi compost were selected for the experiment. The okra variety Arka Anamika was used for the field study.

Experiment I

Evaluation of physical, chemical and biological properties of organic manures

- The particle size of elephant dung (30% passed through 0.5mm sieve) was the highest among the organic manures.
- All the manures were neutral to alkaline with a pH ranging from 7.3 to 8.6 and the electrical conductivity ranged from 0.01 to 0.16 dS m^{-1}.
- The organic carbon content was high in elephant dung (49.12 %) and thereby the C: N ratio was also the highest (98:1) in elephant dung.
- The macro and micro nutrients content in organic manures showed significant difference. The highest N(1.8%) was in rabbit manure and vermicompost while the pig and quail manure contained the highest P(0.8%). Rabbit manure recorded the highest K content (1.3%).
- Chicken manure had the highest calcium (2971.3 ppm) and sulphur (1242.1 ppm) content whereas the magnesium (111 ppm) content was the highest in pig manure.
- Among the micro nutrients, iron content was the highest (1180.8 ppm) in vermicompost. Manganese was the highest (115.6 ppm) in cow dung (desi) and the zinc in pig manure (97 ppm) and copper in quail manure (21.8 ppm).
- The highest bacterial population was found in chicken manure (35 x 10^4 cfu g^{-1}) and fungi in quail manure (17 x 10^3 cfu g^{-1}). Actinomycetes and *salmonella* were not

detected in any of the manures. *Escherichia coli* was present in cow dung (desi), cow dung (cross bred), buffalo, goat manure, chicken manure, pig and quail manure.

- The Indole-3-acetic acid in vermicompost and pig manure showed the highest value (17.5 $\mu g\ g^{-1}$) while the dehydrogenase (18.11 TPF g^{-1} soil day $^{-1}$) was more in vermicompost.
- Heavy metals *viz.*, Cd, Cr, Ni, Pb, As and Hg were detected in most of the manures though the content was below the permissible limit specified in the FCO.

Experiment II

Influence of organic manures on growth and yield of okra

- Application of organic manures showed no significant variation in water holding capacity and bulk density of soil.
- There was a significant variation in pH, EC and organic carbon due to different treatments after the experiment. The chicken manure applied plots showed the highest pH and EC whereas the OC was the highest in vermicompost applied soil.
- The C: N ratio of soil varied from 8 to 12: 1 in all the treatment plots.
- The available N was the highest in the treatment receiving KAU POPR (244.4 kg ha^{-1}) and the available P (64.7 kg ha^{-1}) and K (396.9 kg ha^{-1}) in chicken manure treated plots.
- Bacterial and fungal population were the highest in vermicompost applied soil (68.67 $x10^4$ cfu g^{-1} and 57.00 x 10^3 cfu g^{-1} respectively). The highest value of 9.67 x 10^4 cfu g^{-1} was observed in the treatments receiving goat manure, chicken manure, pig manure and vermicompost with respect to the population of actinomycetes.
- Presence of cadmium, chromium and mercury was not detected in the soil with the application of organic manures. The vermicompost applied soil had the highest concentration (0.2 ppm) of lead. The arsenic content was the highest (0.06 ppm) in cow dung (desi).
- The highest plant height at 30 and 60 DAS was observed in the treatment receiving pig manure (121.7 cm).

- KAU POPR plot showed the highest (12) number of leaves at 30 DAS and 60 DAS the highest number of leaves (26) was noticed in chicken manure.
- There was no significant difference in days to first flowering, days to first harvest, total number of harvests and duration of the crop.
- Dry matter production of okra at last harvest (5.3 t ha^{-1}), total number of fruits per plant (26.3) and weight of fruits per plant (451.7 g) were the highest in chicken manure treated soil.
- Rabbit manure treated plot produced the highest length of fruits (17.2 cm) whereas the highest girth (6.7 cm) of fruits was noticed with pig manure.
- Average fruit weight of okra was the highest in vermicompost (20.53g) applied plot and the highest total number of seeds per fruit (66.33) was in cow dung (desi) applied soil.
- The highest yield (25.24 t ha^{-1}) was found in chicken manure (@ 6.7 t ha^{-1}) applied plot followed by vermicompost (@ 5.6 t ha^{-1}) treated soil (25.09 t ha^{-1}).
- The crude fibre content was the highest in elephant dung applied soil (13.96 %) followed by KAU POPR. The lowest crude fibre content was noticed in vermicompost (8.40 %) applied plot.
- Application of chicken manure showed the highest gross (Rs.10, 09, 600 ha^{-1}) return, net return (Rs.5, 78, 105 ha^{-1}) and B: C ratio (2.34) followed by vermicompost (2.3).

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Appendix

Appendix I. Meteorological data during the crop growing period

Date	Max. Temperature (°C)	Min. Temperature (°C)	Mean RH (%)	Mean sunshine hours (h)	Rainfall (mm)	Number of rainy days (Mean)	Evaporation (cm)
03/12/17 - 09/12/17	32.9	21.0	73	7.3	0	0	2.6
10/12/17 - 16/12/17	32.6	21.4	72	5.1	0	0	2.5
17/12/17 - 23/12/17	32.3	21.5	54	9.1	0	0	5.2
24/12/17 - 30/12/17	32.7	20.5	52	9.4	0	0	5.3
31/12 /17- 6/1/18	33.2	19.0	58	8.8	0	0	3.8
07/1/18 - 13/1/18	32.7	21.8	56	7.4	0	0	4.6
14/1/18 - 20/1/18	33.8	20.7	48	8.6	0	0	5.2
21/1/18 -27/1/18	34.1	21.4	53	8.1	0	0	3.8
28/1/18 - 3/2/18	34.3	20.5	37	9.0	0	0	5.8
04/2/18 - 10/2/18	35.3	22.3	59	8.5	005.2	1	4.2
11/2/18 - 17/2/18	35.3	23.3	51	9.4	0	0	5.4
18/2/18 - 24/2/18	36.3	22.5	42	10.2	0	0	6.3
25/2/18 - 3/3/18	37.7	23.1	43	9.9	0	0	6.4
04/3/18 - 10/3/18	38.2	23.5	47	9.6	0	0	5.9

Appendix II. FCO Standard for vermicompost

1	Moisture content (%)	15.0 – 25.0
2	Colour	Dark brown to black
3	Odour	Absence of foul odour
4	Particle size	Minimum 90% material should pass through 4.0 mm IS sieve
5	Bulk density (g/cm^3)	0.7 -0.9
6	Total organic carbon (%)	18.0
7	Total Nitrogen (%)	1.0
8	Total phosphate (P_2O_5)-%	0.8
9	Total potassium (K_2O)-%	0.8
10	Cadmium (ppm)	5.0
11	Chromium (ppm)	50.0
12	Nickel (ppm)	50.0
13	Lead (ppm)	100.0

QUALITY ASSESSMENT OF ORGANIC MANURES AND THEIR EFFECT ON OKRA

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(2016-11-095)

ABSTRACT OF THE THESIS

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ABSTRACT

The present study entitled "Quality assessment of organic manures and their effect on okra" was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during 2017-2018 to evaluate the properties of organic manures, and their effect on soil quality and crop productivity.

The physical, chemical and biological properties of organic manures *viz.*, cow dung (desi), cow dung (cross bred), buffalo manure, goat manure, chicken manure, pig manure, elephant dung, horse manure, quail manure and vermicompost were studied in the first experiment. The moisture content was the highest in cow dung (cross bred) and quail manure (80%). All the manures were neutral to alkaline with a pH ranging from 7.3 to 8.6 and the electrical conductivity ranged from 0.01 to 0.16 dS m^{-1}. Values for the highest organic carbon and C: N ratio were recorded in elephant dung (49.12 and 98:1). The N, P and K content of organic manures showed significant variation among the treatments. Rabbit manure and vermicompost recorded the highest N (1.8%), while the highest P content was found in pig manure (0.8%), and highest K content in rabbit manure (1.3%). The highest population of bacteria was found in chicken manure (35.00 x 10^4 cfu g^{-1}), while quail manure had the highest fungal population of 17.00 x 10^3 cfu g^{-1}.The presence of *Escherichia coli* was detected in cow dung (desi and cross bred), chicken manure, pig manure and quail manure. Heavy metals like Cd, Cr, Ni, Pb, As and Hg were within the safe limit. Mercury and arsenic exceeded the FCO specifications in goat, rabbit, pig and quail manure. Therefore, these manures could be used in smaller quantities, instead of bulk application in field. The heavy metal contents of animal manures depend mainly on the feed consumed and the efficiency of feed conversion by the animals. The activity of IAA and dehydrogenase was found to be the highest in vermicompost (17.5 g^{-1} soil day^{-1} and 18.11 TPF g^{-1}soil day^{-1}).

Based on the results of experiment I, all the manures were used for the second experiment to study their influence on soil quality, growth and yield of okra. All the manures were applied as basal dose so as to give N equivalent to that in FYM @ 20 t

ha^{-1}. All the other management practices were adopted as per the Adhoc POP recommendation for organic farming: crops (KAU, 2009) except for Kerala Agricultural University (Package of practices recommendation) and control. Application of organic manures increased the water holding capacity of soil by three per cent whereas there was no significant variation in bulk density. The increase in pH was the highest in chicken manure treated plots. The organic carbon and available NPK content in soil increased in all the plots supplied with organic manures. The total bacteria, fungi and actinomycetes populations were found to be high in all the treated plots as compared to control. Traces of Ni and Pb were observed in the soil after the experiment.

Basal application of chicken manure @ 6.9 t ha^{-1} recorded the highest number of leaves at 60 DAS (26), total dry matter production at last harvest (5.3 t ha^{-1}), number of fruits (26.3), weight of fruits per plant (451.79 g), number of seeds per fruit (65) as well as yield (25.24 t ha^{-1}), resulting in the highest gross and net returns and B: C ratio (2.34). The lowest crude fibre content (8.4%) in fruits was observed in vermicompost applied plots.

The results revealed the advantage of application of all the common organic manures since the quality parameters are according to the specifications prescribed in the FCO. Application of chicken manure and vermicompost improved the soil quality, growth and yield of okra.