EVALUATION OF FORTIFIED HUMIC ACIDS FROM GROW BAG MIXTURES AS PHYTOTONIC IN OKRA

[*Abelmoschus esculentus* (L.) Moench.]

by

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(2015-11-084)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Evaluation of fortified humic acids from growbag mixtures as phytotonic in Okra. [*Abelmoschus esculentus* (L.) Moench] "** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

%	- Per cent
Av.	- Available
B	- Boron
C. D	- Critical difference
Ca	- Calcium
cm	- Centi meter
°C	-Degree Celsius
CRD	- Completely Randomized Design
Cu	- Copper
DAS	- Days after Flowering
dS	- Deci Seimen
EC	- Electrical conductivity
et al.	- And others
Fe	- Iron
FW	- Farm waste
FYM	- Farm Yard Manure
g	- Gram
GC- MS	- Gas Chromatography- Mass Spectroscopy
HA's	- Humic acids
K	- Potassium
KAU	- Kerala Agricultural University
Kg ha^{-1}	- Kilogram per hectare
Kg	- Kilogram
KVK	- Krishi Vigyan Kendra
LMS	- Low molecular weight Substance
MAP	- Months after planting
mg ha^{-1}	- Milligram per hectare

LIST OF ABBREVIATIONS CONTINUED

mg kg^{-1}	- Milligram per kilogram
Mg	- Magnesium
Mn	- Manganese
N	-Nitrogen
N	- Normality
No.	- Number
NS	- Non significant
P	- Phosphorus
PDI	- Pest and Disease incidence
POP	- Package of Practices
ppm	- Parts per million
S	- Sulphur
viz.	- Namely
VC	- Vermicompost
WHC	- Water Holding Capacity
Zn	- Zinc

Introduction

1. INTRODUCTION

Vegetable production in grow bag is gaining momentum in homestead and terrace cultivation throughout the state. The compositions of growing medium directly influence the growth, yield and quality of the produce. Indirectly growing medium can affect aeration, water holding capacity, enzyme activity, microbial growth, organic matter mineralization, solubilisation and availability of nutrients. Constituents of the growth medium also influence its sustainability as nutrient source and other conducive condition of crop growth. The conventional type of potting medium is a proportional mixture of sand, soil and farmyard manure is recently popular as grow bag mixture. In grow bag medium, root zone effect on humus formation of soil organic matter is more pronounced due to the nature of root ramification, and the humic acids in soil organic matter has direct physiological effect on crop growth and yield (Schnitzer and Khan, 1978).

Organic materials present in the soil can be grouped in to humic and non humic materials. Humic substance arises from chemical and biological degradation of plant and animal residues from synthetic activities of microorganism. The products so formed tend to associate in to complex chemical structures that are more stable than the starting material. Humic substance commonly occur in water, soil, compost, peat, and in carbon containing minerals. (Stevenson, 1994). The group name for fractions of humic substances are humic acid, fulvic acid and humin and such does not imply a specific substance but designates a heterogeneous preparation obtained by specific extraction procedure. The alkali soluble fraction consisting of fulvic acid and humic acid are together designates as humic acids. Humic substances are of great importance due to multiple beneficial roles in productivity.

It is expressed that humic acid have an effect on the increase in the uptake of nutrients, enzyme, and nucleic acid activity, protein synthesis, membrane permeability change, respiration and photosynthesis (Serenella *et al.,* 2002). It is stated that, through humic acid application an increase has been achieved in fruit quality, early yield and nutrient uptake (Adani *et al.,* 1998). Humic acids is an excellent foliar fertilizer carrier and activator. Application of humic acids in combination with trace elements and other plant nutrients, as foliar sprays can improve the growth of plant foliage, roots and plant growth processes (Ravichandran, 2011).

According to zero budget natural farming concepts, dung of desi cow is a rich source of all the useful microorganisms which is required in very small quantity compared to commonly used farmyard manure. The present study includes the use of dung of desi cow also in the growing medium to validate the above concept of natural farming. Assessment of physicochemical and microbiological properties of growth mixtures formulated using viable constituents at periodical intervals coincides with the critical stages of the crop to be raised. Possible use of fortified humic acids extracted from the incubated mixture as a phytotonic was also evaluated.

In grow bag mixtures when soil is replaced by micronutrient poor organic sources, deficiency of micronutrients need to be anticipated. In short duration crops such as vegetables by the time deficiency is detected, it may be too late to save the crops (Vasuki, 2010). Developing biorelease micronutrient fertilizer is a future strategy in micronutrient research. Hence feasibility of fortifying humic acids with multinutrient fertilizer is attempted.

Even though commercial formulations of humic acids are available, the step of fortification still remains unique and evaluation of multinutrient fortified humic acids on vegetable crops is a pioneer study in this field. The test crop selected was Okra (variety Varsha Uphar), one of the most popular vegetable crops grown throughout the tropics of the world during *spring, summer* and *kharif* seasons, whose fruits can be either served raw, marinated in salads or cooked. Okra is being a short duration vegetable crop, its growth, yield and quality are largely influenced by the application of fertilizers and growth enhancing amendments.

By considering all these key points, major objectives of the present study are the following

- ❖ To evaluate the physicochemical characteristics and microbial enumeration of different grow bag mixtures.
- ❖ To study effect of humic acids fortified with multi nutrient mixture as phytotonic for okra.

Review of Literature

2. REVIEW OF LITERATURE

This chapter presents the literatures on characteristics of grow bag media based on their composition and different sources of humic acids, their characteristics and extraction. Effect of humic acids on soil and plant, and the role of humic acids fortified with multinutrient fertilizer mixtures in nutrient management of vegetable crops are also reviewed.

2.1 DIFFERENT SUBSTRATES USED IN GROW BAG MEDIA AND THEIR EFFECT ON FERTILITY OF CROPS

Organic substrates commonly used in grow bag media are coir pith, vermicompost, coco peat, sawdust, peat moss, wood chips, marc, bark etc. Constituents of the growth medium also influence its sustainability as nutrient source and other conducive condition of crop growth (Sharif *et al.*, 2002), substrates like perlite, vermiculite, zeolite, gravel, rock wool, sand, glass wool, pumice and sepiolite are the inorganic materials of geological origin. Choice of constituents is one of the key points to be considered due to technical and economic implications of grow bag cultivation (Giuffrida *et al.*, 2008). Artificially synthesized substrates in use are hydrogel, form mates and oasis.

2.1.1 Organic Substances

2.1.1.1 Farm Yard Manure

Patil *et al.* (2003) studied the effect of fly ash and FYM on soil properties of vertisols and found indicated that FYM and vermicompost when applied to soil, resulted an increase in available N, P and K content over the treatment with normal recommended dose of fertilizer, also the soil pH reduced from 7.9 to 7.6 by the addition of FYM.

The study conducted by Rathod *et al.* (2003) to evaluate the effect of amendments on soil properties and yield of cotton in vertisols revealed that addition of FYM resulted in the reduction of EC of the soil.

Ikram *et al.* (2012) studied the influence of different potting media in different combinations on morphological characters and shelf life of tuberose. The treatments of the study include combinations of FYM, poultry manure, sand, leaf compost and coconut coir in proportional ratio. The results of the study revealed that sand + FYM media gave maximum plant spread, number of leaves and shelf life of tuberose.

2.1.1.2 Coir pith Compost

Awang *et al.* (1997) studied the effect of different potting media on growth parameters of annual ornamental plants. The study reported that anthurium plants grown in coir pith medium recorded maximum plant height, number of leaves and flowers. Other ornamentals like zinnia, celosia and marigold also recorded better performance in coir pith medium.

Lokesh *et al.* (1988) reported an increase in rooting percentage in *Acalypha* and *Bougainvillea* with coir pith media

Coir pith which is primarily formed as waste product of coir industry has great potential as substrate for grow bag media. Savithri and Khan (1994) suggested that composted coir pith can be used as an alternative for peat in grow bags.

Warrier *et al.* (1998) studied the suitability of coir pith as a rooting medium for vegetative multiplication of *Eucalyptus* cuttings and reported increased rooting percentage in coir pith media.

Results of the study by Cuckoorani (2013) on influence of coir pith+ FYM (2:1 w/w) growing medium on growth parameters of Okra, indicated that characters like height, number of leaves, leaf area index were maximum in plants grown in coir pith compost +FYM medium.

Soumya (2015) studied the performance of tomato in different composition of soilless growth media. Results of the study indicated that, potting media comprising of coir pith compost mixed with FYM in the ratio 2:1 (v/v) recorded maximum plant height and number of leaves.

2.1.1.3 Vermicompost

Indira *et al.* (1996) studied the microbial characterization of vermicompost. Results of the study indicated that vermicompost recorded population of beneficial organisms like *Bacillus* and *Aspergillus* species, which promote phosphorus solubilization and various species of nitrogen fixing organisms.

Jiji *et al.* (1996) studied the effect of fertilizers on growth and yield of vegetables. The study found that vermicompost along with POP recommendations of fertilizers, resulted an increase in the yield of cowpea and bitter gourd by 16 and 21.2 per cent respectively.

Bachman and Metzger (2007) investigated the physical and chemical changes in grow bag media when amended with vermicompost produced from different waste sources, pig and beef cattle manure. The results of the study indicated that nitrate nitrogen, P, Ca, Mg, Zn, Cu, Fe content and EC of the media increased with increase in content of vermicomposts from pig and cattle wastes and Beef cattle vermicompost.

Gutierrez *et al.* (2007) studied the suitability of vermicompost from sheep manure as soil amendment to enhance growth, productivity and fruit quality of tomato. The results of the study concluded that vermicompost addition has significantly increased the plant height and fruit yield in tomato.

Zaller (2007) evaluated the suitability of vermicompost (VC) as an alternate for peat in grow bag mixture and the study recorded a significant influence of vermicompost on growth and productivity of tomato and recommends VC as an ecofriendly substitute for peat.

Azarmi *et al.* (2008) studied the effects of vermicompost on physical and chemic al properties of soil, using test crop as tomato. Results of the study indicated that vermicompost application @ 15 t ha^{-1} increased the content of major and micronutrient content in tomato.

Study conducted by Peyvast *et al.* (2008) on the effects of vermicompost levels on growth and yield of spinach, revealed that vermicompost application (10%) growing media, increased the plant height, number of leaves, leaf area and plant nutrient contents.

Sangwan *et al.* (2010 a & b) studied the effect of potting media containing vermicompost prepared from cow dung (CD) and sugar mill waste water treatment sludge with horse dung, on growth and productivity of marigold. The study recorded that media with 30 % of CD vermicompost was superior to all other treatments and concluded the synergetic effect of vermicompost when used in definite quantities as amendment to potting media.

Theunissen *et al.* (2010) reported that vermicompost contain most of the major and micronutrients, and have a positive influence on plant growth and yield in vegetable production. Increased amount of humic acids in vermicompost help in synthesis of phenolic compounds and thereby quality of vegetables.

Warman and Anglopez (2010) conducted an experiment to assess quality of vermicompost produced from different types of organic substrates including kitchen paper waste, kitchen yard waste and dairy yard waste. Results of the study indicated that all the combinations of vermicomposts increased the leaf area and biomass of crops.

2.1.2. Other Organic Substances

Nash and Laiche (1981) conducted an experiment to evaluate the suitability of growth media for container plants. Pine bark, peat and sand were evaluated with rye grass as test crop for 3 period's *viz.* before, during and after planting of test crop. The results obtained were media showed shrinkage and compaction during the period of growth, notably in peat. Even though controlled release type fertilizers were used the nutrient content of the media dropped drastically.

Sparling *et al.* (2001) reported that application of dairy factory effluent has increased the available N and P status of soil.

Lopez-Mosquera *et al.* (2002) reported that influence of diary sludge on chemical properties of acid soil. Results of the study indicated that sludge incorporation had increased the pH from the acidic range, and enhancement in the exchangeable Ca, and available P status was noted.

The effect of growing media on production and quality of gerbera was studied by Aswath and Pillai (2004). The results of study indicated that potting mixture with 100 % coco peat treated with nutrient solution with EC (1.8 d Sm^{-1}) exhibited good physicochemical properties and produced good quality flowers

Treder (2008) studied the effects of potting media on flowering and vase life of oriental lily. The results of the study indicated lilies planted in coco peat showed early flowering and better vase life, and characters like length of flower bud, root system was higher when compared to control medium containing pear, bark and sand in the ratio 5: 1: 1 by volume.

Rahim (2015) studied the effect of growing media on growth and fruit production in okra. The plants were grown in three types of media *viz.* T1- top soil: sand, T2- top soil: coco peat and T3- coco peat alone. Results of the study pointed that T3 with coco peat gave significantly superior performance.

2.2 EXTRACTION AND CHARASTERISATION OF HUMIC ACIDS FROM DIFFEREENT SOURCES.

2.2.1 Different Extractants Used in Extraction Humic Acids

Soil scientists introduced different extraction solution to extract soil humic fractions. Dilute NaOH was used to extract humic substances by different scientists. Smith and Lorimer (1964) also reported HA's extraction with dilute Na_4 P_2O_7 from peat soils which were similar to dilute NaOH. The concentration of the NaOH affects the yield of the humic material extracted as well as its ash content.

Levesque and Schnitzer (1966) found 0.1 N NaOH to be more efficient than higher NaOH concentrations. However, the most suitable extraction solution for isolating humic materials low in ash was either 0.4 N or 0.5 N NaOH (Schnitzer and Khan, 1978).

Neutral salts of mineral and organic acids have been used for the extraction of humic substances, but yields are usually low (Schnitzer and Khan, 1978). The Na_4 P_2O_7 extracts not only humic substances but also organo-mineral complexes without destroying nonsilicate forms of sesquioxides. It has been shown that pyrophosphate was difficult to remove from humic materials during purification (Schnitzer and Khan, 1978).

Fuleky and Czinkota (1993) used another technique of hot water extraction that uses heat energy and pressure together which called Hot Water Percolation

(HWP). This method has several advantages such as: being easy and fast to use and its ability to measure several parameters from the same solution.

Adani *et al.* (1998) and Makarov *et al.* (2002) used diluted $NaHC0_3$ as an adequate soluble extract in order to extract humic substances from soils of different origin.

Takacs and Fuleky (2010) used HWP method for isolation and characterization of dissolved organic matter from soils.

2.2.2 Content, Elemental Composition and Functional Group of Humic Acids.

Schnitzer and Gupta (1964) found that the COOH', OH' and CO' groups account for 52-75% of the total oxygen of humic acid 86- 100% of the oxygen of fulvic acid (FA). The content of functional groups of humic acid were 660 Cmol (P) kg^{-1} of total acidity comprising of 450 Cmol (P^+) kg^{-1} of COOH, 210 Cmol (P^+) kg^{-1} of phenolic OH. Other functional group like alcoholic OH, quinonoid C-O and methoxyl groups account for 250, 190 and 30 Cmol (P^+) kg^{-1} respectively.

O'Donnell (1973) studied the auxin like effects of humic preparations from leonardite. He found high yield of humic acid (88%) on a moisture and ash free basis obtained from leonardite extracted with 1 N NaOH.

Ushashree *et al.* (1989) found that total acidity: carboxyl and phenolic groups in lignite humic acid were 5.44, 2.43 and 3.01 meq g^{-1} respectively. They also reported that percentage of C, H, O and N of lignite humic acid were 56.3, 4.7, 36.3 and 2.7 respectively and the C: N ratio of the above material was 20.0.

Deiana *et al.* (1990) extracted humic acid from different sources like sewage sludge, manure and vermicompost compost. Higher amount or humic acid was extracted from vermicompost i.e. 1.62% (on the basis percentage of raw material) than from manure (0.46%) and sewage sludge 0.38%. Higher amount of humic acid content signifies the high degree of humification in vermicompost.

Sao *et al.* (2010) had done a comparative study of humic acid derived from lignite and FYM and reported that the total acidity as 510 and 200 Cmol (P^+) kg^{-1} in lignite humic acid and FYM humic acid respectively.

2.2.3 Characteristics of Humic Acids

Besides the well-known functions, humic substance regulates the soil carbon pool, nitrogen cycling, growth and nourishment of different soil flora and fauna. Humic substance have specific physiological effects on plant growth (Schnitzer and Khan, 1978). Organic materials present in the soil can be grouped in to humic and non humic materials. Humic substance arises from chemical and biological degradation of plant and animal residues from synthetic activities of microorganisms. The products so formed tend to associate in to complex chemical structures that are more stable than the starting material.

Piccolo (2002) defined FA as clusters of hydrophilic molecules rich in acid functional group, this helps the fulvic clusters to stay dispersed in solution phase at any pH. Whereas, humic acid are dominated by hydrophobic compound (fatty acids, steroid compound and polymethylic chains), which are stabilized at neutral pH and above by hydrophobic dispersive forces (van der walls, π-π, and CH- π bonds). The size of confirmation of HA increases with number of intermolecular hydrogen bonding which are often induced by at lower pH and results in flocculation. Studies also suggested that complexity of HA structure reduces with distortion of intermolecular interactions.

Hayes (2006), noted that functionally defined fractions of HS depending on solubility criteria. Generally humic acids are defined as humus matter that solubilize under alkaline pH and get precipitated at highly acidic pH. Whereas, fulvic acids remain in solution phase in acidic as well as alkaline pH. These definitions are from older literatures, but chemically HS are the product of saponification reaction by alkaline extraction by any organic source.

Humic Substance plays a vital role in the soil health and productivity as they regulate physicochemical and biological properties of soil. Soil properties such as aggregation, aeration and water holding capacity are enhanced by humic substance

2.3 EFFECT OF HUMIC ACIDS ON SOIL HEALTH AND FERTILITY

Govindasamy *et al.* (1989) studied the nature and quantity of ammonia volatilization from the crop field. They used Lignin derived humic acid (LAH) for the study. Results of the study indicated that quantity of ammonia volatilized was lower when LAH + N was applied, compared to N application alone. It's because the LAH complexes with ammonium ion, preventing the volatilization. LAH application also improves availability of P in soil.

Madhumathi 1991, studied the effect of humic acids and zinc on growth and yield of hybrid sorghum and reported that HA's forms a protective cover on the sesquioxides and thereby reduce the P sorption. Application of humates can increase the availability of micronutrients like Fe, Zn etc. which otherwise get converted to insoluble form.

Piccolo *et al.* (1996) evaluated the influence of coal derived humic substances on physical properties of soil in laboratory conditions. The results of the study indicated that coal derived humic substances enhances the water holding capacity of and aggregate stability of surface soils.

Glaser *et al.* (2002) studied the ameliorating effect of charcoal derived humic acids on physical and chemical properties of tropical soils. Results of the study indicated that charcoal can act as sink for atmospheric CO_2, nutrient retention capacity of the soils were improved with minimal loss of leaching, this might be due to the reason that nutrients get accumulated in the soil pores of carbonized materials.

Pettit (2004) reported energy trapped in the carbon bonds of humic substance are the major source of energy for soil microbes, also large surface area and electrical charges of humic substance helps to enhance the water holding capacity of the soil.

sangeetha *et al.* (2006) studied the effect of lignite derived HA's and fertilizers on soil available nutrients and yield of onion grown in greenhouse condition. The treatments consisted of two levels of NPK, 100 %and 75% along with varying levels of humic acids as soil application (10 kg and 20 kg) combined with 0.1 % solution of HA as foliar spray and seed bulb soaking. It was concluded that soil application of humic acid 20 kg ha^{-1} combined with full dose of NPK gave the highest yield.

Khaled and Fawy (2011) studied the influence of different levels of humic acids on crop growth and development of corn, and impact on soil properties under saline condition. Foliar and soil application of humic acids was done @ 0, 2, 4g kg^{-1} and 0, 0.1 and 0.2 % respectively. Results of the study concluded that soil and foliar application of humic acids enhanced the nutrient uptake in corn.

2.4 EFFECT OF HA's ON PLANT GROWTH AND YIELD

2.4.1 Effect of Humic Acids on Physiological Parameters

O'Donnell (1973) studied the response of *Pelargonium hortum* cuttings to different humic materials at different levels, sodium humate, humic acid, fulvic acid and leonardite in comparison with IAA applied at 0.05% each. Observations on the root study confirmed the auxin like effect of humic acids.

Liu *et al.* (1998) studied the effect of humic acid application on chlorophyll content, photosynthesis and root development of bentgrass grown hydropinically. The results of the study indicated that plants grown in 400 mg L^{-1} showed increased photosynthetic rate and increased tissue concentration of Mg, Mn and S.

Nardi *et al.* (2002) investigated the physiological effect of humic substances from different source, concentration and molecular weight of humic substance on plant growth. Results of the study indicated that low molecular size can easily reach the plasmalemma of the cells. HS positively influenced the nutrient absorption particularly nitrate. The study also reported a hormone like effect of humic substance and stimulatory effect on plant growth and development.

Eyheraguibel (2008) studied the effect of humic like substances (HLS) on physiological parameters of maize under hydroponic cultivation. The study recorded that HLS significantly influenced the characters like root length, shoot and leaf biomass and early flowering. The increased biomass production might be the result of increased mineral consumption of the treated plants.

Asli and Neumann (2010) studied the interaction of rhizosphere humic acid with root cells under water stressed condition. The test crop selected was maize (*Zea mays* L). The results of the study concluded that, under stressed condition HA's can reduce the root hydraulic conductivity by 44 %, and resulted reduction in shoot growth and transpirational rate however HA's application positively affected the root growth and development.

Haghighi (2012) investigated on effect of humic acids on N metabolism and growth photosynthetic activity of lettuce. Lettuce grown in hydroponic solution under greenhouse condition was treated with 0, 100 and 1000 mg of humic acids L^{-1} to the nutrient solution. The study recorded an increased uptake of N. Photosynthetic efficiency of the crop was enhanced with every levels of HA's due to increased chlorophyll content.

Canellas *et* al. (2000) studied the effect of humic acid from earthworm compost on growth and root characters of maize seedlings. The study reported presence of exchangeable auxin from the macrostructure of humic acids extracted from vermicompost using GC-MS, and such complexes can stimulate the increase shoot length, root length, increased number of lateral roots, and enhance the activity of membrane H^+ ATPase.

2.4.2 Effect of Humic Acid on Growth Parameters and Yield

In a field experiment, Govindasmy and Chandrasekaran (1992) sprayed humic acids extracted from lignite on to sugarcane and they found that the addition of humic acids improved sugar yield and nutrient concentration in leaf blades and sheaths.

Padem *et al.* (1997) documented the effects of humic acid added to foliar fertilizer (HAAFF) on eggplant and pepper seedlings. HAAFF was applied to growing media during pre-sowing period at varying concentrations and foliar application to seedling. Both the application had significantly influenced the seedling stem diameter, number of leaves, shoot dry weight and shoot and fruit dry matter and thereby quality of seedlings. All parameters increased with increasing the concentration of HAAFF treatment in seedlings.

Atiyeh *et al.* (2002) studied the influence of humic acids derived from earthworm-processed organic wastes on growth and yield of tomato and cucumber. Characters like plant height, leaf area, root and shoot dry weight, and yield were significantly increased due to humic acid application.

Dhanasekaran and Bhuvaneswari (2005) reported that application of humic acid either alone or in combination with NAA and nutrient mixture significantly improved the yield of tomato. The combined application of humic acid with NAA and nutrient mixture resulted in the superior yield and quality.

Arancon *et al.* (2006) reported the effect of humic acid derived from cattle, food and paper waste vermicompost on growth of green house plants. The effects of the humic acids on the plant height, leaf area, shoot dry weight, root dry weight of pepper, tomatoe and marigold and number of fruits of strawberries were assessed. Substitution of humates ranging from 250-1000 mg kg^{-1} increased root growth of marigold and pepper, and increased root growth and number of fruits of strawberries significantly ($P \leq 0.05$). Leaf area, plant height and above ground dry matter weight increased considerably in plants grown in pots containing humic acids.

Paksoy *et al.* (2010) reported the growth enhancing effects potassium and humic acid on Okra, *Abelmoschus esculentus* (L.) in saline conditions. Different levels of humic acid (0, 500, 1500 mg kg^{-1}) and potassium were applied to the growing media, which was treated with 50 mg NaCl Kg^{-1}, and the results indicate that the biometric characters like seed emergence, root and shoot size, leaf number, shoot and root dry weight were significantly superior than control. The study concluded the potential ability of humic substance in the enhancement of in plant nutrient uptake and growth parameters of Okra under saline conditions.

In a study conducted by Kirn *et al.* (2010), indigenous humic acids were extracted from lignite coal (10 % potassium humate) were applied in soil. Okra plants were treated with different levels of humic acid (10, 15 and 20 mg kg^{-1}) along with half and full recommended dose of chemical fertilizer (60-50-30 kg ha^{-1} and 120-100-60 N: P: K kg ha^{-1}). Results indicated that humic acids applied along with full fertilizer dose showed significant increase in yield.

Trevisan *et al.* (2010) studied the HA's effect on root characters of maize seedlings by growing them in nutrient media, with and without HA. The results indicated that HA application @ 50 mg L^{-1} gave higher number of lateral roots, compared to control. Study also concluded that response of plants to HA depend on many factors like plant species, mode of application, rate of application, organic source used for extraction and finally the environmental condition.

2.5 MICRONUTRIENT NUTRITION THROUGH FOLIAR APPLICATION

Micronutrients are those elements essential for plant growth which are needed in only very small quantities. Even though micronutrients are required in minute quantities, they are essential for healthy plant growth and profitable crop production. These micronutrients are often needed in quantities greater than the soil can supply, so they should be supplemented through foliar application to enhance the yield. They have important role in metabolism, growth and involved in enzymatic processes, assimilation, oxidation and reduction reactions and help in increasing the biomass and pod yield.

Hazra *et al.* (1987) studied the effect of foliar application of micronutrients on growth and yield of okra. Zn, Fe and Cu in two concentrations (0.1% and 0.2%) singly and in their respective concentration combinations were sprayed. The experiment recorded an increase in plant height (114.96 cm) with Zn at 0.2 % concentration. The results also revealed marked increase in fruit number per plant, fruit length, fruit weight and fruit yield with the application of Zn and Cu at both concentrations singly and also at their respective combinations.

Khalate *et al.*, (1990) studied the foliar effect of micronutrients on yield and quality of onion. The results of the study showed an increase in the yield of onion by foliar spray of $ZnS0_4$, (0.5 and 1 %), $CuSO_4$ (1%) and $MnSO_4$ (0.6%), over the recommended fertilizer dose.

The foliar application of micro nutrient formulations (anusar, polymax, agromin and multiplex) significantly increased the number of pods per plant and yield in okra. Among the formulations, multiplex registered the highest net profit and benefit: cost ratio. (Medhi and Kakati, 1994).

Naruka *et al.* (2000) studied the effect of foliar application of zinc and molybdenum on growth and yield of okra cv. Pusa Sawani. The results revealed that increase in the zinc levels during foliar application resulted an increased fruit yield.

Bhatt and Srivastava (2005) studied the response of foliar application of micronutrients, *viz.* boron, zinc, molybdenum, copper, iron, manganese, mixture of all and multiplex, on physical characteristics and quality attributes of tomato fruits. The application of mixture of micronutrients resulted in maximum fruit density, average fruit weight, dry matter accumulation and protein content.

Narimani *et al.* (2010) studied the effect of foliar application of micronutrients on durum wheat. Fe, Cu, and Zn was applied alone and in combinations, at different duration of crop at different levels. Significant results were recorded from foliar application of Fe + Cu + Zn mixture, regarding the kernel weight and spike number per unit area.

Barche *et al.* (2011) conducted an experiment to study the response of foliar application of micronutrients on tomato and reported that the maximum fruit yield (375.94 q ha^{-1}) was obtained with application of boric acid + $ZnSO_4$ + $CuSO_4$ @ 250 ppm each respectively.

Mini (2015) conducted a study on assessment and management of micronutrient deficiencies using okra as attest crop in a typic aquic psamment. A multinutrient fertilizer mixture was developed by considering the results of initial soil analysis. Results of the study indicated that treatment with soil test based POP recommendations + 0.5% foliar spray of multinutrient mixture at 15 DAS and 35 DAS resulted in superior growth characters and the highest yield.

2.6 EFFECT OF MULTINUTRIENT FORTIFIED HUMIC ACIDS ON PLANT GROWTH AND YIELD.

Zientara (1983) has reported that many investigators had observed increased nutrient uptake in plants treated with humic acids. This observation led them to propose that humic materials affect membrane permeability and stimulate ion uptake. This is also related to the surface activity of humic substances resulting from the presence of both hydrophilic and hydrophobic sites. Therefore, the humic substances may interact with the phospholipid structures of the cell membranes and act as carriers of nutrients through them (Chen and Aviad, 1990).

Geranium crop were supplied with the humic acid derivative fertilizer Super-start plus (6 N, 12 P_20, 6 K_20) at 100, 200 or 300 mg N L^{-1} or with a standard soluble fertilizer (20 N, 20 P_20, 20 K_20) at 300 mg N L^{-1} (control). After 12 weeks of culture, the dry weight, leaf area and chlorophyll content were greater for all Super-start+ concentrations than for controls. However Plant height and width were greater in the controls (Newman and Follett, 1989).

Besides being nutrient use efficient, the HA/FA component of the complex fertilizer also greatly influence the crop quality and soil properties. HA-NPK-Zn complex fertilizers reduced the nitrate nitrogen content and increase the fresh weight, superoxide dismutase and peroxidase activities of rape. HA.-NPK-Zn compound fertilizer was the best among all the fertilizers tested for physiological and composition effects. HA also effectively enhanced the chlorophyll content and made the blade thick, glossy dark green and fresh, which improved the commodity value of rape (Ping *et al.*, 2001).

Bama *et al.* (2005) stated that application of 20 kg HA combined with 75% recommended dose of fertilizers stimulated catalase, dehydrogenase and phosphatase activities of soil samples collected from rice rhizosphere. The dehydrogenase, phosphatases and arylsulphatasase activities are in the higher side with the application of HA multinutrient fertilizers. This might be due to greater nutrient use efficiency of fertilizers in the presence of humic acid (Sellamuthu and Govindaswamy, 2003).

Delfine *et al.* (2005) investigated the effect of foliar application of N and humic acids on the growth and yield of corn and reported that the foliar application of humic acids caused a transitional production of plant dry mass with respect to the unfertilized control.

Jariene *et al.* (2007) evaluated the impact of organic and chemical fertilizers on the chemical composition of seeds of different cultivars of pumpkin and reported that higher amounts of crude fats were found in seeds of the control (non-fertilized) pumpkins. Humic acid and complex fertilizers had non-significant effects on the synthesis of crude fats. However, they increased the amount of crude fiber in seeds and the highest amount was found in seeds of the pumpkins fertilized with humic acid and complex fertilizers. A mixture of complex and humic acid fertilizers significantly reduced the amount of crude fat in oil-cakes. Complex fertilizers and mixtures of fertilizers stimulated the process of crude protein accumulation in seeds.

Kar *et al.* (2007) done fortification of humic acid with Zn, using $ZnSO_4$ at pH 6.5 and temperature 45°C. The results of the study showed an increased Zn uptake and yield on maize.

Ying *et al.* (2007) studied the effect of humic fertilizers application on leaf nutrition in grapes and concluded that humic acid in the fertilizers increased the nutrient availability and the physiological and nutrient composition effects that resulted in higher utilization and accumulation of nutrients in the plants.

In a study conducted by Elayaraja *et al.*, (2010), application of 100 per cent NPK + humic plus a spray registered a fruit and stover yield which was 46.86 and 35.53 per cent increase over 100 per cent NPK alone. The improvement in fruit and stover yield with foliar spray of humic acid and NPK fertilizer could be ascribed to the promoted cell division and cell elongation. Combined application of humic acid and NPK improved the uptake of P and also enhanced the growth, yield and quality of okra.

Azarpour *et al.* (2012) studied the effect of nitrogen fertilizer and foliar spraying of humic acid of vermicompost origin on yield of eggplant and results showed that the foliar humic acid spraying had significant improvement. The highest fruit yield was obtained from use of 50 mg L-1 humic acid spraying and also from 80 kg/ha nitrogen fertilizer.

Erro *et al.* (2012) used the super phosphate-humic acid complexes (CSPs) in plant-soil studies and showed that the CSPs were more efficient than SSP in providing available phosphate for wheat plants cultivated in various soils with different physiochemical features.

Application of humic acid in combination with trace elements and other plant nutrients, as foliar sprays can improve the growth of plant foliage, roots and plant growth processes (Ravichandran, 2011). Dhanasekaran *et al.* (2009) reported that soil applied humic acids @ 30 mg/kg maximized the yield of tomato.

Materials and Methods

3. MATERIALS AND METHODS

The investigation was carried out in the College of Agriculture, Vellayani, Trivandrum, Kerala during 2015-2017. Objective of the research was to study the physico-chemical characteristics and microbial enumeration of grow bag mixtures and the effect of humic acids fortified with multi nutrient mixture as foliar spray on growth, yield and quality of okra. The investigation consisted of three parts 1) Incubation study using six different potting mixtures in grow bags for a period of three months, 2) Extraction of humic acids and fortification with multinutrient mixture, 3) Crop study in grow bags to assess the effect of multinutrient fortified humic acids on okra as test crop.

PART- I

3.1. INCUBATION STUDY

The study was conducted in polythene grow bags filled with growth media of different composition maintained at 60% WHC at room temperature for a period of three months. The growth media for incubation study was prepared by mixing equi-proportional quantities by weight (2 kg each) of sand, soil and an organic component. The details of incubation study are presented below.

3.1.1 Details and Layout of Experiment

Design : CRD

Treatments : 6

Replication : 3

3.1.2 Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coir pith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cow dung (500g) mixed with assorted farm waste

T_5 - soil + sand + desi cow dung (500g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Surface samples were drawn from the grow bags at fortnightly intervals for six times to monitor the changes in pH, EC, available nutrients and microbial enumeration using standard analytical procedures (Table. 1).

Table 1. Analytical methods followed in soil analysis

Sl. No.	Parameter	Method	Reference
1.	pH	pH meter	Jackson (1973)
2.	Electrical conductivity	Conductivity meter	Jackson (1973)
3.	Organic Carbon	Walkey and Black chromic acid wet digestion method	Walkley and Black (1934)
4.	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
5.	Available P	Bray extraction and photoelectric colorimetry using Spectrophotometer	Bray and Kurtz (1945)
6.	Available K	Flame photometry using neutral normal Ammonium acetate.	Jackson (1973)
7.	Available Ca and Mg	Extraction using neutral normal ammonium acetate and estimation using Atomic Absorption Spectrophotometer	DOA (2013)
8.	Available Fe, Cu, Zn, Mn	Extraction using 0.1 N HCL and estimation using Atomic Absorption Spectrophotometer	Sims and Johnson (1991)
9.	Available B	Extraction with hot water and estimated calorimetrically by Azomethine-H using Spectrophotometer	Gupta (1967)

After two months of incubation samples were drawn from the growth media for extraction of humic acids. The extracted humic acids were analyzed for total acidity and the time taken for pH stabilization were monitored.

3.1.3 Microbial Count

The microbial population from the incubated grow bag mixtures was enumerated using Serial Dilution Agar Plating method (Timonin, 1940). The media used for the enumeration of microorganisms are given in Table 2.

Table 2. Media used for enumeration of microorganisms

Sl. No.	Microorganism	Media used	Reference
1	Bacteria	Nutrient agar	Atlas and Parks (1993)
2	Fungi	Martin's Rose Bengal agar	Martin (1950)
3	Actinomycetes	Ken Knight's agar	Cappuccino and Sheman (1996)

PART II

3.2 EXTRACTION OF HUMIC ACIDS

Humic acids were extracted from growth media after two months of incubation. Extraction was carried out using classical procedure recommended by International Humic Substance Society, which uses a mild alkali for extraction of HA's. Alkaline extraction leads to separation of organic matter into fractions that are mixtures of compounds with similar chemical characteristics (McBride, 1994).

In the present study 0.5 N NaOH was used as extractant. 50 g of the growth media was agitated with 200 ml of 0.5 N NaOH for an extraction period of 12 hrs. The whole content was then filtered to separate the filtrate with HA's and to remove the insoluble humin. The extracted humic acids were quantified gravimetrically and

Plate 1. General view of experiment I- incubation study

Plate 2. Humic acids extracted from the incubated growth media

expressed as per cent of oxidisable organic carbon. Humic acids were analyzed for their total acidity by titration method (Wright and Schnitzer, 1959). Time taken for pH stabilization were monitored.

3.3 FORMULATION OF MULTINUTRIENT MIXTURE.

A multinutrient mixture was formulated by making slight variations in the nutrient mixture developed by Mini (2015). The carriers used for the preparation of the mixture were $ZnSO_4$, $Na_2B_4O_7.10\ H_2O$, $MgSO_4$, H_3BO_3, $CuSO_4.\ 5H_2O$, $FeSO_4$ and $MnSO_4$. The final composition of multinutrient mixture are given in Table 3.

Table. 3 Composition of multinutrient fertilizer mixture

Sl. No.	**Fertilizers used**	**Quantity of fertilizers (g)**
1	$ZnSO_4.\ 7\ H_2O$	25 g
2	$Na_2B_4O_7.\ 10\ H_2O$	25 g
3	$MgSO_4$	25 g
4	H_3BO_3	10 g
5	$CuSO_4.\ 5\ H_2O$	2 g
6	$FeSO_4$	8 g
7	$MnSO_4$	5 g
	Total	100 g

3.2.2 Fortification with Multinutrient Mixture

Humic acids extracted from different growth media were subjected to uniform fortification procedure. Fortification was done by addition of multinutrient mixture. The composition is given in table 3. Fortification of humic acids was done by the method explained here under.

Multinutrient fertilizer mixture (10 g) was mixed with humic acids and made up to 100 ml using the same humic acids, to form a concentrate solution. Fortified humic acids were applied as foliar spray @ 0.05% concentration at weekly intervals to evaluate their effect on okra raised in grow bags.

PART III

3.3 CROP STUDY

The study was conducted at the pot culture yard of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during January - April 2017. The crop study was done in grow bags to evaluate and compare the effects of fortified HA's on growth, yield and quality of Okra.

The experiment was laid out in completely randomized design, with eight treatments in three replications:

Treatments

- T_1 - HA_1 (fortified HA from soil + sand + farm yard manure)
- T_2 - HA_2 (fortified HA from soil + sand + coir pith compost)
- T_3 - HA_3 (fortified HA from soil + sand + vermicompost)
- T_4 - HA_4 (fortified HA from soil + sand + desi cow dung (500 g) + assorted farm waste)
- T_5 - HA_5 (fortified HA from soil + sand + desi cow dung (500 g) with straw and *Gliricidia*)
- T_6 - HA_6 (fortified HA from soil + sand + composted kitchen waste)
- T_7 - Water spray (control)
- T_8 - Extractant spray (0.5 N NaOH)

Uniform potting media containing soil, sand and FYM (1: 1: 1), 6 kg each were used in all grow bags and crop was raised as per POP recommendations.

Multinutrient fertilizer mixture (10 g) was mixed with humic acids and made up to 100 ml using the same humic acids, to form a concentrate solution. Fortified humic acids were applied as foliar spray @ 0.05% concentration at weekly intervals to evaluate their effect on okra raised in grow bags.

Plate 3. General view of experiment III- Crop study

3.3.1 **Planting Material and Variety**

Seeds of variety 'Varsha Uphar' were collected from KVK, Thrissur. It has a duration of 105 days and the fruit colour is green. Grow bags were arranged to get a spacing of 60 cm x 30 cm.

3.3.2 Manures and Fertilizer

Nutritional management practices were done as per POP recommendations. Fertilizer application @ 110: 35: 70 N: P_2O_5: K_2O kg ha^{-1} as Urea, Rajphos, and Muriate of potash, were given basally and 1 MAP. Foliar application of treatments were given after two weeks of sowing at fortnightly intervals throughout the crop period.

3.3.3 Biometric Observations

The following biometric observations were recorded from the crop study.

3.3.3.1 Plant Height

Plant height was noted at 3 growth stages *viz.* first flowering, and final harvest. Plant height was measured from terminal leaf bud to base of the plant and expressed in centimeters.

3.3.3.2 Internodal Length

It was recorded only at first harvest. Internodal length was expressed as the distance between two adjacent leaf axils and expressed in centimeters.

3.3.3.3 Number of Branches per Plant

Number of branches per plant was recorded at three stages viz., first flowering, first harvest and final harvest.

3.3.3.4 Node of First Flower Emergence

The node at which first flower emerged was noted for each treatment.

3.3.3.5 Days to First Flowering

Days taken to first flowering was counted form date of dibbling to the date at which first flower appeared in each treatment.

3.3.3.6 Days to Fifty Percentage Flowering

Number of days taken to reach fifty percent flowering were counted from date of dibbling to date on which flowering was noticed in fifty percent of the population in the treatment.

3.3.3.7 Harvest Stage

Number of days to first harvest and final harvest were noted. Also the total number of harvests from each treatment during the entire crop period was recorded.

3.3.3.8 Fruit Length

Length of fruits harvested from plants of each treatment was noted and mean value was calculated and expressed in centimeters.

3.3.3.9 Fruit Girth

Girth of fruits was recorded from the same fruits from which length was recorded. Girth was measured by winding a thread around individual fruits at the center of the fruit. Mean values were calculated and expressed in centimeters.

3.3.3.10 Average Fruit Weight

Weight of individual fruit was noted. Mean values were worked out and expressed in grams.

3.3.3.11 Number of Fruits per Plant

The total number of fruits harvested from each treatment plant was noted, and mean was calculated.

3.3.3.12 Yield

Total weight of fruits obtained from each harvest from each treatment were noted and expressed as yield per plant.

3.3.4. Scoring of Pest and Disease

Percentage of pest and disease incidence was calculated using formula

$$\text{PDI (\%)} = \frac{\text{Number of affected plants}}{\text{Total number of plants}} \times 100$$

3.3.5. Keeping Quality

Keeping quality of fruits were noted as the number of days up to which the fruit remains green fresh and firm, without any symptom of shrinkage.

3.3.6. B: C ratio

Benefit cost ratio of each treatment was calculated using the formula

$$\text{B: C ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.3.7 Analysis of Plant Samples

Plant samples were drawn at 50 per cent flowering and at final harvest and analysed for nutrient content.

Shoot and fruit samples were collected at both stages. The collected plant samples were dried at 70° C and powdered for nutrient analysis. Chemical analysis of shoot and fruit was carried out by standard analytical procedures outlined in Table 4.

Table 4. Analytical methods followed in plant analysis

Sl. No	Element	Method
1	Nitrogen	Microkjeldhal distillation after digestion in H_2SO_4 (Jackson, 1973)
2	Phosphorus	Nitric- perchloric (9: 4) acid digestion and colorimetry using vanado-molybdo phosphoric yellow colour method (Piper, 1966)
3	Potassium	Nitric- perchloric (9: 4) acid digestion and Flame photometry (Jackson, 1973)
4	Calcium and Magnesium	Nitric-perchloric (9: 4) acid digestion and filtration. The filtrate was analyzed in Atomic Absorption Spectro photometer (DOA, 2013)
5	Sulphur	Nitric-perchloric (9:4) acid digestion followed by turbidimetry (Tabatabai and Bremner, 1970)
6	Iron, Zinc, Manganese and copper	Nitric-perchloric (9:4) acid digestion followed by filtration. The filtrate was then analyzed in Absorption Spectro photometer (DOA, 2013)
7	Boron	Nitric-perchloric (9:4) acid digestion and estimated calorimetrically by Azomethine-H using Spectrophotometer (Wolf, 1971)

3.3.7.1 Fruit Analysis

Fruit samples were collected from each treatment plant at fifty percent flowering and at final harvest. Fruit samples were dried at 70° C and powdered for nutrient analysis. N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn, B and crude protein content. Procedures followed were same as plant analysis.

3.3.7.2 Protein Content

Protein content of fruits were worked out from the nitrogen content of fruits multiplied by the factor 6.25 and the values were expressed in fresh weight basis. (Simpson *et al.,* 1965)

3.3.8 Statistical Analysis

The data obtained from the study were subjected to statistical analysis. The data from the incubation study and crop study were statistically analyzed using analysis of variance techniques (ANOVA) in CRD (Cochran and Cox, 1965). Wherever significant differences between treatments were detected through ANOVA critical difference (CD) are provided for effective comparison of treatment. Correlation analysis was also done between the fruit yield and plant nutrient concentration at fifty per cent flowering stage of the crop. Correlation coefficient (r) was calculated for yield and nutrient content of shoot at fifty per cent flowering stage by using the standard procedure given by Searle (1961).

$$r(x,y) = \frac{Cov.(x,y)}{\sqrt{Var(x).Var(y)}}$$

Where,

$r(x,y)$ = Correlation coefficient between characters x and y

$Cov.(x,y)$ = covariance between x and y

$Var(x)$ = Variance of x character

$Var(y)$ = Variance of y character

Table 5. Initial analysis of soil and organic substrates used for the study

a) Physico-chemical properties of soil

Sl. No	Parameters	Units	Content
A. Physical properties			
1.	Mechanical composition		
	Sand	%	60.08
	Silt	%	9.36
	Clay	%	25.46
2.	Texture		Sandy Clay Loam
3.	Bulk Density	Mgm^{-3}	1.52
4.	Water Holding Capacity	%	25.65
5.	pH		6.19
6.	EC	$dS\ m^{-1}$	1.51
7.	CEC	$cmol\ kg^{-1}$	5.61
B. Chemical Properties			
8.	Organic carbon	%	0.75
9.	Available Nitrogen	$kg\ ha^{-1}$	203.26
10.	Available Phosphorus	$kg\ ha^{-1}$	32.21
11.	Available Potassium	$kg\ ha^{-1}$	229.10
12.	Exchangeable Ca	$cmol\ kg^{-1}$	2.12
13.	Exchangeable Mg	$cmol\ kg^{-1}$	0.84
14.	Micronutrients		
	Fe	$mg\ kg^{-1}$	18.08
	Mn	$mg\ kg^{-1}$	4.98
	Cu	$mg\ kg^{-1}$	1.09
	Zn	$mg\ kg^{-1}$	2.38

b) Chemical properties of different organic sources used for incubation

Sl. No.	Organic source	pH	EC (d Sm^{-1}).	OC (%)	N (%)	P (%)	K (%)
1.	FYM	6.5	1.6	37.5	1.5	0.8	0.7
2.	Coir pith compost	6.2	0.9	24.5	2.0	0.5	1.6
3.	Vermicompost	6.9	0.8	27.9	2.3	1.7	0.9
4.	Kitchen waste compost	8.0	8.2	41.3	2.6	1.4	2.1
5.	Desi cow dung	6.4	1.4	29.6	1.9	0.2	1.4
6.	*Gliricidia*	-	-	-	3.5	-	-

Results

4. RESULTS

The results obtained from the observations recorded during the course of investigation are presented in this chapter.

PART I:

4.1 INCUBATION STUDY

Changes in the physicochemical properties and microbial count of growth media during incubation, as influenced by their composition are presented in Tables 6 to 18.

4.1.1. pH

Mean values of pH of the incubated growth media of different composition are given in Table 6. pH of the growth media was significantly influenced by the composition, throughout the period of incubation. It ranged from 5.4 to 10.4, among which the highest value (10.4) was by from T_6 which contained composted kitchen waste. At first fortnight the highest pH (9.0) was in T_6, followed by T_4 which was on par with T_1. During second fortnight, T_6 recorded highest value of 8.9 followed by T_4 which was on par with T_5. During 3rd, 4th, 5th and 6th fortnight also the treatment T_6 recorded maximum mean values of 8.8, 10.1, 10.2 and 10.4 respectively followed by T_4. The lowest mean value of 5.4 was noted from growth medium containing coir pith compost (T_2). pH was almost neutral (6.8-7.5) in T_5 containing desi cowdung (500 g) mixed with straw and *Gliricidia.* In the media containing vermicompost (T_3) and desi cowdung mixed with assorted farm waste (T_4) the pH ranged from 6.7 to 9.6 during incubation.

Table 6. pH of different growth media at fortnightly intervals during incubation

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	7.3	6.7	7.2	7.9	8.2	8.4
T_2	5.4	5.5	5.6	6.7	6.6	7.5
T_3	7.1	6.7	6.9	8.8	9.0	9.3
T_4	7.4	7.1	7.2	8.9	9.1	9.6
T_5	6.8	6.8	6.6	7.2	7.4	7.5
T_6	9.0	8.9	8.8	10.1	10.2	10.4
CD (0.05)	0.25	0.33	0.93	0.26	0.60	0.75

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

4.1.2. Electrical Conductivity

The composition of the growth media had significant effect on electrical conductivity of the media (Table 7).

EC of different growth media ranged between 0.20 dS m^{-1} to 8.50 dS m^{-1} during incubation. Generally EC was high in T_6 throughout incubation. The EC of growth media in T_1, T_2, T_3 and T_4 was in the safe limit for crop growth throughout the period of incubation. Lowest mean value was recorded in T_2 (0.20 dS m^{-1}) at fifth fortnight of incubation.

4.1.3. Available Nitrogen

Available N status of incubation study is given in Table 8. Available nitrogen status was significantly influenced by the composition of the growth media composition during 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} fortnights of incubation.

Available N content of different media ranged between 192.3- 703.0 kg ha^{-1}. Highest mean value was reported from T_6 (703.0 kg ha^{-1}) during sixth fortnight of incubation. Among the different growth media, kitchen waste compost containing one (T_6) recorded maximum N throughout the period of incubation. Available N content was low to medium range in all treatments except T_6 in which it was high during first four fortnights. Lowest N content was observed in T_2 containing coir pith compost (192.3 kg ha^{-1}) at the first fortnight of incubation.

4.1.4. Available Phosphorus

Available P content of growth media during incubation are presented in Table 9. Effect of treatments on available phosphorus was significant throughout the period of incubation. P content ranged from 12.3-93.9 kg ha^1 among the different treatments. Available P was the least in (T_2) coir pith compost. Except T_2 all other

Table 7. EC of different growth media at fortnightly intervals during incubation (dS m^{-1})

Treatments	Incubation period (fortnights)					
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
T_1	0.80	0.51	0.69	0.73	0.47	0.81
T_2	1.10	0.15	0.18	0.16	0.20	0.33
T_3	1.63	2.22	1.66	1.72	1.60	1.99
T_4	1.03	0.65	0.72	0.94	0.93	1.30
T_5	1.65	1.71	1.83	2.18	2.27	1.97
T_6	7.15	8.50	8.34	7.42	7.53	5.75
CD (0.05)	1.500	0.355	1.608	0.782	0.848	2.956

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 8. Available Nitrogen of different growth media at fortnightly intervals during incubation (kg ha^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	225.8	258.7	259.4	263.2	266.0	278.9
T_2	192.3	205.0	218.2	213.9	195.1	294.1
T_3	246.7	285.3	279.9	267.2	305.4	316.5
T_4	238.3	274.9	249.1	292.1	330.0	338.4
T_5	255.1	278.1	263.9	256.4	270.9	278.3
T_6	620.3	637.9	638.0	646.0	668.9	703.0
CD (0.05)	8.103	13.781	6.774	8.309	9.741	11.165

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 9. Available Phosphorus of different growth media at fortnightly intervals during incubation (kg ha^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	46.1	39.5	32.1	53.8	57.8	48.2
T_2	22.8	15.0	12.3	15.4	19.5	17.8
T_3	93.9	56.4	47.1	57.7	68.1	54.9
T_4	61.6	39.6	43.4	63.3	66.0	67.9
T_5	56.5	32.2	34.6	30.7	44.5	32.3
T_6	72.3	60.4	47.6	61.7	66.5	56.1
CD (0.05)	6.31	4.36	11.52	9.04	11.16	10.18

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

treatments showed high levels of available P. During second fortnight T_6 (60.4 kg ha^{-1}) recorded highest P content which was on par with T_3 (56.4 kg ha^{-1}). At 3rd fortnight T_6 noted highest P content and it was on par with T_3 and T_4. At 4th fortnight T_4 recorded highest mean value (63.3 kg ha^{-1}) and it was on par with T_1, T_3 and T_6. During 5th fortnight T_3 noted the highest mean value (68.1 kg ha^{-1}) and it was on par with T_1, T_4 and T_6. At 6th fortnight T_4 showed highest (67.9 kg ha^{-1}) P content followed by T_6.

4.1.5. Available Potassium

Available K content of different treatments of incubation study is given in Table 10. Potassium availability was significantly influenced by composition of growing media throughout the period of incubation.

Available K was high in all media and it was very high in T_6 the kitchen waste compost and maximum value recorded was 9893.3 kg ha^{-1} at 1st fortnight. Throughout the period of incubation the highest value of available K was noted in T_6. Availability of K showed a decreasing trend towards the later periods of incubation. However the status of available K was high in all growth media during the incubation period except in T_2. Lowest K content was noted from T_2 (110.6 kg ha^{-1}) at first fortnight of incubation.

4.1.6. Available calcium

Available Calcium content was significantly influenced by composition of the growing media. Calcium content of different growth media during incubation are presented in Table 11.

Kitchen waste inoculum compost recorded highest calcium content of 1032.6 mg kg^{-1} in the 3rd fortnight of incubation. Available Ca status recorded an increasing trend in the second fortnight of incubation in all growth media. However availability

Table 10. Available Potassium of different growth media at fortnightly intervals during incubation (kg ha^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	560.3	523.6	540.2	504.0	373.3	429.3
T_2	110.6	167.3	140.5	156.41	151.6	159.3
T_3	1527.1	1593.8	1608.2	1829.3	1456.0	1456.0
T_4	1632.0	1232.0	1932.0	765.3	541.3	728.0
T_5	1418.6	1773.3	1596.0	1232.0	1045.3	1250.6
T_6	9893.3	9669.3	9781.3	8400.0	8864.0	8250.6
CD (0.05)	470.25	292.37	73.01	376.44	396.13	119.96

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coir pith compost

T_3 - soil + sand + vermi compost

T_4 - soil + sand + desi cow dung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cow dung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 11. Available Ca of different growth media at fortnightly intervals during incubation (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	476.6	533.3	426.1	407.1	410.6	402.6
T_2	103.3	506.6	542.6	359.0	419.1	355.5
T_3	666.6	670.0	390.5	748.6	808.6	639.1
T_4	733.3	740.0	659.0	408.3	416.5	479.3
T_5	410.0	720.0	485.5	464.8	543.5	468.5
T_6	764.0	772.6	1032.6	685.6	853.6	688.8
CD (0.05)	127.05	58.68	183.29	106.58	71.97	82.13

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

showed fluctuations from third fortnight of incubation onwards, maintaining the status in the sufficient range. Available Calcium content was lowest in coir pith compost (103.33 mg kg^{-1}) in the 1st fortnight, which was in the deficient range. However available Ca status attained a sufficient range from second fortnight onwards in (T_2) coir pith containing media.

4.1.7. Available Magnesium

Available Mg content of different growth media are presented in Table 12. Magnesium availability was significantly influenced by the composition of the growth media.

T_5 recorded the highest available Mg content of 184.3 mg kg^{-1} in the 1st fortnight of incubation, followed by T_1 (158.6 mg kg^{-1}). In the 2nd fortnight, T_5 recorded the highest Mg content of 168.1 mg kg^{-1} and was on par with T_1, T_2, T_3, T_4 and T_6. During 3rd fortnight T_6 recorded the highest value of 155.0 mg kg^{-1} and was on par with T_5 (151.1 mg kg^{-1}). In the 4th, 5th and 6th fortnights T_5 recorded highest available Mg content. Available Mg was the lowest in vermicompost growth medium (90.0 mg kg^{-1}) during the first fortnight.

4.1.8 Available Boron

Available boron content of different growth media are presented in the Table 13. The effect of composition of growth media on availability of boron was significant.

Available B was deficient in T_1, T_2, T_3 and T_4 throughout the incubation period. It was in the sufficient in T_5 (>0.5 mg kg^{-1}) during first three fortnights and was deficient in the remaining period of incubation. The available boron was the highest in T_6 (3.58 mg kg^{-1}) during 1st fortnight of incubation the lowest B content during incubation was recorded from T_1 (0.01mg kg^{-1}) at 6th fortnight. Compared to

Table 12. Available Mg of different growth media at fortnightly intervals during incubation (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
T_1	158.6	156.5	126.8	137.6	148.5	156.8
T_2	106.4	112.6	110.5	116.5	105.2	146.3
T_3	90.0	150.3	117.6	131.5	106.1	149.0
T_4	112.4	118.0	123.3	103.3	139.3	119.3
T_5	184.3	168.1	151.1	139.6	157.2	149.5
T_6	100.5	159.2	155.0	126.1	124.2	134.3
CD (0.05)	88.27	63.6	11.77	21.42	24.70	31.61

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 13. Available Boron content of different growth media at fortnightly intervals during incubation (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	0.27	0.46	0.28	0.06	0.32	0.01
T_2	0.24	0.40	0.07	0.05	0.09	0.03
T_3	0.21	0.42	0.12	0.06	0.40	0.40
T_4	0.20	0.30	0.13	0.15	0.33	0.14
T_5	0.52	0.59	0.58	0.17	0.17	0.18
T_6	3.58	2.37	1.64	0.92	0.71	1.23
CD (0.05)	0.441	1.037	0.144	0.103	0.366	0.550

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

other growth media kitchen waste inoculum compost recorded higher status of available B throughout the period of incubation.

4.1.9 Available Iron

Fe status of different growth media are represented in Table 14. Available Fe status was not significantly influenced by the composition of the growing media except the 6th fortnight of incubation.

During 6th fortnight the highest Fe content was recorded from T_3 (103.3 mg kg^{-1}) which was on par with T_1 (97.4 mg kg^{-1}), T_5 (94.3 mg kg^{-1}) and T_6 (88.7 mg kg^{-1}). Generally iron was sufficient in all the media except T_2.

4.1.10 Available Copper

Cu content of different growth media are presented in Table 15. Available Cu Status was not significantly influenced by composition of the growth media.

Available Cu status was the least in coir pith compost medium. It was in the deficient range in T_2, during first three fortnights of incubation. It was sufficient in T_5 and T_6 throughout the incubation.

4.1.11 Available Zinc

Zn content of different growth media are presented in Table 16. Available Zn content of growing media was not significantly influenced by the composition.

During the incubation Zn availability was seen to be higher during the later periods of incubation than during initial periods of incubation.

Table 14. Available Fe of different growth media at fortnightly intervals during incubation (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	33.2	116.3	170. 6	80.1	86.4	97.4
T_2	10.1	17.6	20.5	19.5	90.7	49.4
T_3	86.7	104.5	122.8	68.2	88.6	103.3
T_4	30.1	90.6	115.5	43.6	99.9	74.5
T_5	56.3	63.1	137.6	44.4	83.4	94.3
T_6	108.1	119.7	109.3	80.3	82.1	88.7
CD (0.05)	NS	NS	NS	NS	NS	33.15

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 15. Available Cu of different growth media at fortnightly intervals during incubation (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
T_1	0.37	1.25	2.40	2.24	2.30	1.62
T_2	0.21	0.05	0.32	1.90	1.85	1.09
T_3	0.98	1.09	4.17	2.35	1.55	1.52
T_4	0.92	2.73	2.86	1.76	1.93	2.46
T_5	1.60	1.28	1.67	2.36	1.47	2.49
T_6	1.90	5.81	4.21	3.48	5.49	2.00
CD (0.05)	NS	NS	NS	NS	NS	NS

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 16. Available Zn of different growth media at fortnightly intervals during incubation in (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
T_1	1.83	2.19	1.83	2.16	3.67	2.90
T_2	0.22	0.28	0.21	1.99	3.84	2.93
T_3	1.86	2.17	1.74	3.34	2.52	3.03
T_4	1.70	1.84	0.82	1.87	2.58	2.26
T_5	1.46	1.56	0.68	1.96	3.69	3.19
T_6	2.02	4.03	0.65	3.45	3.27	2.80
CD (0.05)	NS	NS	NS	NS	NS	NS

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

4.1.12 Available Manganese

Available Mn content of different growing media during incubation are presented in Table 17.

Available Mn status of growth media was significant only at 1st fortnight. T_3 recorded the highest content of 18.63 mg kg^{-1}, followed by T_4 (6.00 mg kg^{-1}), which was on par with T_6 (5.94 mg kg^{-1}), T_1 (5.24 mg kg^{-1}) and T_5 (5.23 mg kg^{-1}). From the second fortnight onwards the available Mn status was not influenced by the composition of the growth media.

4.1.13. Microbial enumeration

4.1.13.1. Bacteria

Bacterial count of different growing media are presented in Table 18. Bacterial population was found to be significant only from 4th fortnight of incubation.

The highest bacterial count was recorded in T_3 (8.88 log cfu g^{-1} soil) during the 5th fortnight. At 4th fortnight of incubation the bacterial count was maximum in T_2 (8.80 log cfu g^{-1} soil) which was on par with T_3 (8.57 log cfu g^{-1} soil) and T_1 (8.57 log cfu g^{-1} soil). At the 6th fortnight highest count was recorded from T_3 (8.87 log cfu g^{-1} soil) which was on par with T_1 (8.07 log cfu g^{-1} soil) and T_4 (7.94 log cfu g^{-1} soil).

4.1.13.2. Fungi

Fungal count of different growth media during incubation are presented in Table 19. Fungal population was found to be significant only after 3th fortnight of incubation.

Table 17. Available Mn of different growth media at fortnightly intervals during incubation in (mg kg^{-1})

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	5.24	9.59	8.28	22.49	29.13	1.75
T_2	2.00	1.29	1.62	33.42	28.12	5.19
T_3	18.63	15.53	6.20	37.78	35.65	5.26
T_4	6.00	24.83	4.14	26.88	31.35	5.33
T_5	5.23	5.93	7.51	39.80	32.82	5.26
T_6	5.94	17.98	9.87	31.87	33.30	6.30
CD (0.05)	9.987	NS	NS	NS	NS	NS

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 18. Bacterial population in different growth media at fortnightly intervals during incubation (log cfu g^{-1} soil)

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T1	8.56	8.50	8.46	8.57	8.36	8.07
T2	8.80	8.68	8.46	8.80	7.60	7.53
T3	8.57	8.64	8.53	8.57	8.88	8.87
T4	8.38	8.45	8.29	8.09	7.89	7.94
T5	8.51	8.54	8.39	8.19	7.70	7.63
T6	8.42	8.47	8.17	8.14	7.45	7.32
CD (0.05)	NS	NS	NS	0.365	0.509	0.953

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 19. Fungal population in different growth media at fortnightly intervals during incubation (log cfu g^{-1} soil)

Treatments	Incubation period (fortnights)					
	1st	2nd	3rd	4th	5th	6th
T_1	4.94	4.79	4.89	4.99	4.99	4.91
T_2	5.39	5.20	5.12	5.13	5.23	5.26
T_3	4.93	5.16	5.00	4.92	4.82	4.58
T_4	5.06	5.01	5.07	4.28	4.41	4.67
T_5	5.31	5.16	5.17	5.08	5.16	5.19
T_6	4.88	4.92	4.91	4.90	4.76	4.57
CD (0.05)	NS	NS	NS	0.51	0.35	0.23

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

The fungal population was higher in the coir pith compost medium throughout the incubation period compared to all other treatments. At 4th fortnight of incubation highest fungal count was recorded from T_2 was 5.13 log cfu g^{-1} soil and it was on par with T_5, T_1 and T_3.

4.1.13.3. Actinomycetes

Actinomycetes population was found to be significant only from 4th fortnight of incubation onwards. Actinomycetescount of different growth media during incubation are presented in Table 20.

Highest Actinomycetes count was recorded from T_4 (5.61 log cfu g^{-1} soil) at 6th fortnight of incubation and was on par with T_5 (5.30 log cfu g^{-1} soil). Lowest actinomycetes count was recorded from T_1 (3.90 log cfu g^{-1} soil) at fifth fortnight.

4.2. CHARACTERISTICS OF HUMIC ACIDS (HA's)

4.2.1. Total acidity

Total acidity of HA's extracted from different growth media was significantly influenced by the composition and nature of organic source used. Total acidity of HA's obtained from the different growth media are presented in Table 21.

The highest total acidity of 12 meq g^{-1} of humic material was recorded from T_3, the media containing vermicompost, followed by T_6 (10.5 meq g^{-1} of humic material), which was on par with T_2 (10 meq g^{-1} of humic material), T_1 (9.5 meq g^{-1} of humic material) and T_5 (9.0 meq g^{-1} of humic material). Lowest value for total acidity was recorded from T_4 (8.5 meq g^{-1} of humic material).

Table 20. Actinomycetes population in different growth media at fortnightly intervals during incubation (log cfu g^{-1} soil)

Treatments	Incubation period (fortnights)					
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
T_1	4.26	4.26	3.89	4.74	3.90	4.25
T_2	4.44	4.41	3.79	4.84	4.18	4.06
T_3	4.25	4.25	4.00	4.49	4.25	4.36
T_4	4.64	4.91	5.01	5.52	5.40	5.61
T_5	3.9	3.80	4.05	5.36	5.03	5.30
T_6	4.06	4.17	4.15	5.04	4.46	4.39
CD (0.05)	NS	NS	NS	NS	0.776	0.950

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

Table 21. Characteristics of humic acids extracted from different growth media of the incubation study

Treatments	Total Acidity (meq g^{-1} of humic material)	Humic acids content (% of organic matter)	Time taken for pH Stabilization (hrs)
T1	9.5	20.1	60
T2	10.0	18.7	50
T3	12.0	25.7	55
T4	8.5	23.3	70
T5	9.0	24.6	65
T6	10.5	25.2	45
CD (0.05)	1.034	1.794	1.771

Treatments:

T_1 - soil + sand + farm yard manure

T_2 - soil + sand + coirpith compost

T_3 - soil + sand + vermicompost

T_4 - soil + sand + desi cowdung (500 g) mixed with assorted farm waste

T_5 - soil + sand + desi cowdung (500 g) mixed with straw and *Gliricidia*

T_6 - soil + sand + composted kitchen waste using composting inoculum

4.2.2 Humic acids content (per cent of organic matter)

Content of humic acids extracted from different growth media was significantly influenced by the composition and nature of organic source used. The content of HA's obtained from different growth mediaare expressed as per cent of organic matter and presented in Table 21.

The quantity of humic acids extracted was maximum in T_3 (25.7 %), which was on par with T_6 (25.2 %) and T_5 (24.6 %), followed by T_4 (23.3 %) and T_1 (20.1 %). Lowest HA's content was recorded from T_2 (18.7 %).

4.2.3 Time taken for pH stabilization

Time taken for pH stabilization of humic acids were significantly influenced by the composition and nature of the organic source used. Time taken by different HA's for pH stabilization is presented in Table 21.

T_4 recorded the highest duration of 70 hrs for stabilization, followed by T_5 (65 hrs), T_1 (60 hrs), T_3 (60 hrs) and T_2 (50 hrs). Time required for stabilization was lowest in T_6 (45 hrs).

PART II

4.3 CROP STUDY IN GROW BAGS

This study was conducted using okra variety varsha uphar as test crop, as per POP recommendations in grow bags containing conventional potting mixture (sand+ soil+ FYM, 2:2:2), to evaluate the effect of foliar application of multinutrient fortified humic acids on growth yield and quality of crop.

4.3.1. Biometric Observations

4.3.1.1. Plant height

Plant height was recorded at three growth stages *viz.*, first flowering, first harvest and final harvest and are given in Table 22.

Effect of treatments on plant height was not significant at first flowering, whereas, the treatments showed significant effect on plant height at first harvest and final harvest.

T_6 recorded the highest plant height at first harvest (74.17 cm) and at final harvest (127.70 cm) and was on par with T_3, (63.13 cm and 102.73 cm

4.3.1.2. Internodal length

Effects of different treatments on internodal length of crop at first harvest (Table 22) was found to be non-significant.

4.3.1.3. Number of branches

Observations on number of branches per plant was noted at first flowering, first harvest, final harvest, and are presented in Table 22.

Effect of treatments on number of branches were non-significant at first flowering, whereas, treatments showed significant effect on number of branches per plant at first harvest and final harvest.

At first harvest and final harvest T_3 recorded the highest number of branches per plant, it was 4.7 and 6.3 at first harvest and final harvest respectively. At first harvest T_3 was followed by T_5 (3.0) which was on par with T_1, T_2, T_4, T_6, T_7 and T_8. At final harvest T_3 was followed by T_6 (3.0) which was on par with T_1, T_2, T_4, T_5, T_7

Table 22. Effect of Fortified humic acids (HA + Multinutrient mixture) on shoot characters

Treatments	Plant height (cm)			Inter-nodal length (cm)	No. of branches per plant		
	At first flowering	At first harvesting	At final harvest	At first harvest	At first flowering	At first harvesting	At final harvest
$T_1 - HA_1$	31.50	41.33	65.67	6.17	1.3	2.3	4.0
$T_2 - HA_2$	43.33	56.07	71.33	7.17	1.3	2.7	3.7
$T_3 - HA_3$	52.67	63.13	102.73	7.00	2.3	4.7	6.3
$T_4 - HA_4$	39.00	48.67	95.43	5.83	1.0	2.7	3.7
$T_5 - HA_5$	45.77	48.33	93.40	5.60	1.3	3.0	4.0
$T_6 - HA_6$	43.33	74.17	127.70	7.00	1.0	3.0	4.0
T_7 - Water	42.50	48.83	81.23	7.67	0.0	2.0	3.3
T_8-Extractant	43.50	51.33	88.13	6.50	0.7	2.3	3.7
CD (0.05)	NS	17.58	30.17	NS	NS	1.18	1.70

Treatments-

$T_1 - HA_1$ (fortified HA from soil + sand + farm yard manure)

$T_2 - HA_2$ (fortified HA from soil + sand + coirpith compost)

$T_3 - HA_3$ (fortified HA from soil + sand + vermicompost)

$T_4 - HA_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

$T_5 - HA_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

$T_6 - HA_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

and T_8. The lowest number of branches per plant was noted from T_7, which received water spray.

4.3.2 Effect of Fortified Humic Acids on Flowering and Duration

To study the effect of Multinutrient fortified humic acid on flowering and crop duration, characters such as node of first flower emergence, days to first flowering, days to 50 % flowering, productive duration and total duration of the crop were considered (Table 23 and 24).

4.3.2.1 Node at which first flower appeared

The node of first flower emergence was noted and mean values are presented (Table 23). Effect of treatments on node of first flower emergence was found to be non-significant.

4.3.2.2 Days to first flowering

Treatments showed a significant influence on days to first flowering of the crop (Table.23). Number of days to first flowering was the least in T_3 (36.7 days) which received foliar application of vermicompost HA's fortified with multi nutrient mixture and days to flowering was the maximum in T_7 (41.0 days), which was on par with T_8.

4.3.2.3 Days to fifty percent flowering

Treatments showed significant influence on days to fifty percent flowering (Table 24). The days to fifty per cent flowering was maximum in T_2 (45 days), which received fortified HA's from coir pith compost growth medium, followed by T_1 (43.3 days) and T_7 (43 days) the water spray. It was minimum in T_3 (41 days) which received foliar application of vermicompost HA's fortified with multi nutrient mixture.

Table 23. Effect of fortified humic acids on flowering

Treatments	1st flower emerging node	Days to first flowering	Days to 50 per cent flowering
T_1 – HA 1	5.00	38.3	43.3
T_2 – HA 2	4.67	39.7	45.0
T_3 – HA 3	4.67	36.7	41.0
T_4 – HA 4	4.33	37.0	42.0
T_5 – HA 5	4.33	38.7	42.3
T_6 – HA 6	4.67	37.7	41.3
T_7 – Water	5.33	41.0	43.0
T_8 - Extractant	4.33	40.0	42.7
CD (0.05)	NS	2.17	2.06

Treatments:

T_1 – HA 1 (fortified HA from soil + sand + farm yard manure)

T_2 - HA 2 (fortified HA from soil + sand + coirpith compost)

T_3 – HA 3 (fortified HA from soil + sand + vermicompost)

T_4 – HA 4 (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA 5 (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA 6 (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

4.3.2.4. Productive duration

Days from flowering to final harvest of crop was noted as productive duration (Table 24). Foliar application of fortified HA's showed significant effect on productive duration of crop. The highest productive duration was recorded from T_3 (71 days) which received foliar application of vermicompost HA's fortified with multi nutrient mixture, followed by T_6 (66.6 days), which was Fortified HA's from kitchen waste compost medium. Lowest productive duration was noted from T_7 (33.1) which was water spray.

4.3.2.5. Total duration

Different treatments showed a significant influence on the total duration of crop (Table 24). The longest crop duration was recorded from T_3 (114.0 days), which received foliar application of vermicompost HA's fortified with multi nutrient mixture, followed by T_6 (105.3 days) which was application of fortified HA's from kitchen waste compost medium. Crop duration was the shortestin T_7 (73.0 days) which received water spray.

4.3.2.6. Number of harvests

Number of harvests was significantly influenced by the application of fortified HA's (Table 24). It was maximum in T_3 (15.6) which was foliar application of vermicompost HA's fortified with multi nutrient mixture, followed by T_6 (13.7) which was the application of fortified HA's from kitchen waste compost medium. Number of harvests was minimum in T_7 (7.6), which received water spray.

4.3.3. Effect of Fortified Humic Acids on Fruit Characters

4.3.3.1. Fruit length

Fortified HA's have brought significant effect on length of fruit (Table 25).

Table 24. Effect of fortified humic acids on duration of the crop

Treatments	Productive duration (days)	Total duration (days)	Number of harvests
T_1 – HA $_1$	57.0	95.0	9.6
T_2 – HA $_2$	54.2	98.3	10.7
T_3 – HA $_3$	71.0	114.0	15.6
T_4 – HA $_4$	61.0	102.0	12.0
T_5 – HA $_5$	64.6	101.3	13.2
T_6 – HA $_6$	66.6	105.3	13.7
T_7 – Water	33.1	73.0	7.6
T_8- Extractant	51.0	93.3	8.4
CD (0.05)	3.72	3.50	0.99

Treatments-

T_1 – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T_2 - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T_3 – HA $_3$ (fortified HA from soil + sand + vermicompost)

T_4 – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

The mean values ranged from 9.7 to 13.6 cm. The highest fruit length was recorded from T_6 (13.6 cm) which was on par with T_3 (13.3 cm), T_5 (12.8 cm) and T_4 (12.1 cm). The lowest value for fruit length was recorded from T_8 (9.7 cm) which received the extractant spray.

4.3.3.2. Fruit girth

Fruit girth was significantly influenced by the application of fortified HA's (Table 25). The mean values ranged from 4.1 to 5.8 cm. The highest fruit girth was recorded from T_3 (5.8 cm), which was on par with T_1 (5.5 cm), T_2 (5.5 cm), T_4 (5.4 cm), T_5 (5.7 cm) and T_6 (5.5 cm). The lowest value for fruit girth was noted from T_7 (4.1 cm) which received water spray.

4.3.3.3. Average fruit weight

Average fruit weight of crop was significantly influenced by the treatments (Table 25). The mean values ranged from 10.0 to 17.1 g. The highest value for average fruit weight was recoded from T_3 (17.1 g) which was on par with T_2 (15.1 g), T_4 (15.4 g), T_5 (15.3 g) and T_6 (16.4 g). The lowest value for average fruit weight was recorded from T_7 (10.0 g) which received water spray.

4.3.4. Effect of Fortified Humic Acids on Yield

4.3.4.1. Number of fruits per plant

Application of fortified humic acids showed significant effect on number of fruits per plant (Table 26). The mean values for number of fruits per plant ranged from 10.0 to 24.3. The highest value was recorded from T_3 (24.3) which received foliar application of vermicompost HA's fortified with multi nutrient mixture, followed by T_6 (18.3) which received fortified HA's from kitchen waste compost medium and was on par with T_4 (17.0) which was fortified HA's from desi cowdung

Table 25. Effect of Fortified humic acids on fruit characters

Treatments	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)
T_1 – HA $_1$	11.1	5.5	12.5
T_2 – HA $_2$	11.9	5.5	15.1
T_3 – HA $_3$	13.3	5.8	17.1
T_4 – HA $_4$	12.1	5.4	15.4
T_5 – HA $_5$	12.8	5.7	15.3
T_6 – HA $_6$	13.6	5.5	16.4
T_7 – Water	11.2	4.1	10.0
T_8 - Extractant	9.7	4.4	10.3
CD (0.05)	1.55	0.54	2.85

Treatments-

T $_1$ – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T $_2$ - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T $_3$ – HA $_3$ (fortified HA from soil + sand + vermicompost)

T $_4$ – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T $_5$ – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T $_6$ – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T $_7$ – Water (control)

T $_8$ – Extractant (0.5 N NaOH)

with farm waste medium. The lowest value was noted from T_7 (10.0) which was water spray.

4.3.4.2. Yield per plant

Treatments showed significant effect on yield per plant of okra (Table 26). The mean values of yield per plant ranged between 145.6 g and 415.4 g. The highest value was recorded from T_3 (415.4 g) which received foliar application of vermicompost HA's fortified with multi nutrient mixture. It was 271.4 g in T_4 which received a foliar spray of fortified HA's from desi cowdung mixed with farm waste medium and T_6 (261.5 g) which received fortified HA's from kitchen waste compost medium. Lowest value was noted from T_7 (145.6 g) with water spray.

4.3.5. Effect of Fortified Humic Acids on Pest and Disease Incidence

Incidence of fruit and shoot borer was recorded in crop study, incidence of jassids was nil. Yellow vein mosaic incidence was noticed from the crop and percentage of incidence was worked out (Table 27).

Incidence of fruit and shoot borer reported from T_1, T_2, T_7 and T_8 were 3.3, 6.7, 3.3 and 3.3 per cent respectively. YVM incidence was recorded from T_1 (3.3 %) and T_7 (3.3 %). Rest of the treatments did not show any symptom of pest and disease incidence.

4.3.6. Keeping quality of fruit.

Treatments showed a significant effect on keeping quality of fruits (Table 28). Keeping quality of fruits (firmness) was retained for 4.67 to 9.0 days among different treatments. Highest keeping quality was recorded from T_6 (9 days) that received fortified HA's from kitchen waste compost medium and was on par with

Table 26. Effect of Fortified humic acids on yield.

Treatments	No. of fruits per plant	Yield per plant (g)
T_1 – HA $_1$	13.3	168.5
T_2 – HA $_2$	12.0	171.1
T_3 – HA $_3$	24.3	415.4
T_4 – HA $_4$	17.0	271.4
T_5 – HA $_5$	16.3	254.1
T_6 – HA $_6$	18.3	261.5
T_7 – Water	10.0	145.6
T_8 - Extractant	12.0	183.2
CD (0.05)	1.73	1.65

Treatments-

T $_1$ – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T $_2$ - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T $_3$ – HA $_3$ (fortified HA from soil + sand + vermicompost)

T $_4$ – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T $_5$ – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T $_6$ – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T $_7$ – Water (control)

T $_8$ – Extractant (0.5 N NaOH)

Table 27. Effect of Fortified humic acids on Pest and Disease incidence

Treatments	Fruit and shoot borer (% incidence)	Yellow vein mosaic (% incidence)	Jassids (% incidence)
$T_1 - HA_1$	3.3	3.3	0
$T_2 - HA_2$	6.7	0.0	0
$T_3 - HA_3$	0.0	0.0	0
$T_4 - HA_4$	0.0	0.0	0
$T_5 - HA_5$	0.0	0.0	0
$T_6 - HA_6$	0.0	0.0	0
T_7 – Water	3.3	3.3	0
T_8 - Extractant	3.3	0.0	0
CD (0.05)	NS	NS	NS

Treatments-

$T_1 - HA_1$ (fortified HA from soil + sand + farm yard manure)

T_2 - HA_2 (fortified HA from soil + sand + coirpith compost)

$T_3 - HA_3$ (fortified HA from soil + sand + vermicompost)

$T_4 - HA_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

$T_5 - HA_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

$T_6 - HA_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

Table 28.Effect of fortified humic acids on keeping quality of fruits and B: C ratio of crop

Treatments	Keeping Quality (days)	B : C ratio
T_1 – HA 1	7.33	0.78
T_2 – HA 2	6.00	0.79
T_3 – HA 3	8.67	1.76
T_4 – HA 4	7.33	1.25
T_5 – HA 5	7.48	1.17
T_6 – HA 6	9.00	1.21
T_7 – Water	4.67	0.67
T_8 - Extractant	5.23	0.85
CD (0.05)	1.581	0.019

Treatments-

T_1 – HA_1 (fortified HA from soil + sand + farm yard manure)

T_2 - HA_2 (fortified HA from soil + sand + coirpith compost)

T_3 – HA_3 (fortified HA from soil + sand + vermicompost)

T_4 – HA_4 (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA_5 (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA_6 (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

T_3 (8.67 days) which received foliar application of vermicompost, the lowest keeping quality was recorded from T_7 (4.67 days).

4.3.7. B: C ratio

Significant difference among the treatments was noted in B: C ratio also (Table 28). B: C ratio of treatments ranged from 0.67 to 1.76. The highest value for B: C ratio was recorded from T_3 (1.76) which received foliar application of vermicompost HA's fortified with multi nutrient mixture, followed by T_4 (1.25). The lowest value for B: C ratio was noted from T_7 (0.67) which received water spray.

4.4 PLANT ANALYSIS

4.4.1. Content of nutrients in shoot

Plant shoot samples were analyzed for major and micronutrients at fifty per cent flowering and at final harvest stage. The data are shown in tables 29 to 32.

4.4.1.1. Nitrogen

Significant difference was observed in the nitrogen content of shoot at both stages of crop (Table 29). At 50 per cent flowering the highest value was recorded from T_3 (2.80 per cent), which was on par with T_6, T_4 and T_5. The lowest value was noted in T_8 (1.34 per cent). At final harvest stage the highest value was recorded from T_3 (2.49 per cent), which was on par with T_6 (2.16 per cent) and the lowest value was noted from T_8 (1.04 per cent).

4.4.1.2. Phosphorus

Effect of treatments on content of P was significant at both the stages of the crop (Table 29). At fifty per cent flowering the highest value was recorded from T_6 (0.66 per cent) which was on par with T_3 (0.64 per cent) and T_4 (0.53 per cent). The

Table 29. Contents of N, P and K in shoot portion at different growth stages, (per cent.)

Treatments	N		P		K	
	50 % Flowering	Final harvest	50 % Flowering	Final harvest	50 % Flowering	Final harvest
T_1 – HA_1	1.88	1.60	0.39	0.35	1.62	1.57
T_2 – HA_2	2.04	1.79	0.36	0.30	1.95	1.90
T_3 – HA_3	2.80	2.49	0.64	0.59	2.52	2.48
T_4 – HA_4	2.16	1.76	0.53	0.49	2.15	1.97
T_5 – HA_5	2.13	1.82	0.36	0.29	2.07	2.03
T_6 – HA_6	2.74	2.16	0.66	0.60	2.50	2.07
T_7 – Water	1.46	1.15	0.25	0.19	1.63	1.58
T_8-Extractant	1.34	1.04	0.34	0.25	1.60	1.52
CD (0.05)	0.678	0.447	0.185	0.128	0.664	0.534

Treatments-

T_1 – HA_1 (fortified HA from soil + sand + farm yard manure)

T_2 - HA_2 (fortified HA from soil + sand + coirpith compost)

T_3 – HA_3 (fortified HA from soil + sand + vermicompost)

T_4 – HA_4 (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA_5 (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA_6 (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

lowest value was reported from T_7 (0.25 per cent). At final harvest stage also T_6 recorded the highest P content (0.60 per cent) and was on par with T_3 (0.59 per cent) and T_4 (0.49 per cent). Lowest value was noted from T_7 (0.19 per cent).

4.4.1.3. Potassium

The data revealed significant difference among the treatments with respect to potassium content in shoot at both the stages of crop (Table 29). At 50 per cent flowering the highest K content was recorded from T_3 (2.52 per cent) which was on par with T_6, T_4, T_5 and T_2. Lowest value of 1.60 per cent was recoded from T_8. At final harvest stage also T_3 recorded the highest value 2.48 per cent, which was on par with T_6, T_5 and T_4. The lowest value was recorded from T_8 (1.52 per cent).

4.4.1.4. Calcium

At fifty per cent flowering application of fortified humic acids recorded significant difference among the treatments (Table 30). The highest value of 0.70 per cent was recorded from T_3, which was on par with T_6 (0.68 per cent), T_4 (0.58 per cent), T_2 (0.61 per cent), T_5 (0.47 per cent) and T_1 (0.54 per cent). The lowest value was recorded from T_7 (0.33 per cent). At final harvest stage the effect of treatments on Ca content was not significant.

4.4.1.5. Magnesium

Significant difference was noted with respect to Mg content of shoot at both the stages among the treatments (Table 30). At fifty percent flowering, the highest value was recorded from T_3 (0.37 per cent) which was on par with T_6 (0.35), T_4 (0.32 per cent), followed by T_2 (0.31 per cent). The lowest value was noted from T_7 (0.22 per cent). At final harvest stage the highest value was recorded from T_3 (0.23 per cent) followed by T_6 (0.20 per cent) and the lowest value was noted from T_7 (0.14 per cent).

Table 30. Contents of Ca, Mg and S in shoot portion at different growth stages, (per cent)

Treatments	Ca		Mg		S	
	50 % Flowering	Final harvest	50 % Flowering	Final harvest	50 % Flowering	Final harvest
T_1 – HA $_1$	0.54	0.12	0.27	0.16	0.15	0.29
T_2 – HA $_2$	0.61	0.13	0.31	0.17	0.17	0.28
T_3 – HA $_3$	0.70	0.14	0.37	0.23	0.25	0.32
T_4 – HA $_4$	0.58	0.13	0.32	0.17	0.19	0.20
T_5 – HA $_5$	0.47	0.12	0.30	0.17	0.19	0.28
T_6 – HA $_6$	0.68	0.13	0.35	0.20	0.20	0.31
T_7 – Water	0.33	0.12	0.22	0.14	0.11	0.21
T_8 - Extractant	0.34	0.11	0.23	0.18	0.12	0.18
CD (0.05)	0.541	NS	0.060	0.011	0.144	0.095

Treatments-

T_1 – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T_2 - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T_3 – HA $_3$ (fortified HA from soil + sand + vermicompost)

T_4 – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

4.4.1.6. Sulphur

Treatments showed significant difference with respect to S content in shoot at both the stages (Table 30).

At fifty percent flowering the highest value was recorded by T_3 (0.25 per cent) which was on par with T_6 (0.20 per cent), T_4 (0.19 per cent) and T_5 (0.19 per cent). The lowest value was noted from T_7 (0.11 per cent). At final harvest stage highest value was recorded from T_3 (0.32 per cent) which was on par with T_6 (0.31 per cent) and the lowest value was noted from T_8 (0.18 per cent).

4.4.1.7. Iron

Treatments imparted a significant difference in the iron content of the shoot portion at both the stages (Table 31). At fifty per cent flowering highest value was recorded in T_6 (113.3 mg kg^{-1}) which was on par with T_1, T_2, T_3, T_4 and T_5. The lowest value was recorded from T_8 (93.2 mg kg^{-1}). At final stage of harvest the highest value was recorded from T_6 (103.7 mg kg^{-1}) which was on par with T_2, T_3, T_4 and T_5. The lowest value was recorded from T_8 (80.6mg kg^{-1}).

4.4.1.8. Manganese

Data given in Table 31 revealed that the effect of treatments on Mn content of shoot portion at both stages of crop was significant.

At fifty percent flowering stage, the highest value was recorded by T_6 (26.2 mg kg^{-1}) which is on par with T_3 (25.5 mg kg^{-1}) and T_1 (23.9 mg kg^{-1}). The lowest value during fifty percent flowering was noted from T_7 (13.8 mg kg^{-1}). At final harvest stage highest value was recorded from T_6 (24.8 mg kg^{-1}) which was on par with T_3 (24.5 mg kg^{-1}) and followed by T_1 (22.4 mg kg^{-1}). The lowest value at final harvest stage was recorded by T_8 (9.8 mg kg^{-1}).

Table 31. Contents of Fe, Mn, and Zinc shoot portion at different growth stages, (mg kg^{-1})

Treatments	Fe		Mn		Zn	
	50% Flowering	Final harvest	50% Flowering	Final harvest	50% Flowering	Final harvest
T_1 – HA $_1$	104.2	84.3	23.9	22.4	19.2	18.5
T_2 – HA $_2$	105.7	97.1	15.3	13.5	15.3	16.7
T_3 – HA $_3$	111.5	100.9	25.5	24.5	27.1	24.5
T_4 – HA $_4$	106.7	95.1	15.4	14.5	18.4	18.4
T_5 – HA $_5$	110.5	98.9	13.8	11.9	22.8	23.2
T_6 – HA $_6$	113.3	103.7	26.2	24.8	27.0	26.8
T_7 – Water	97.5	87.9	13.8	13.5	13.8	11.0
T_8-Extractant	93.2	80.6	18.5	9.8	14.3	9.3
CD (0.05)	17.32	15.68	5.72	2.27	11.12	3.54

Treatments-

T $_1$ – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T $_2$ - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T $_3$ – HA $_3$ (fortified HA from soil + sand + vermicompost)

T $_4$ – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T $_5$ – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T $_6$ – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T $_7$ – Water (control)

T $_8$ – Extractant (0.5 N NaOH)

4.4.1.9. Zinc

Zinc content in plant was significantly influenced by different treatments (Table 31). The mean values ranged from 13.8 mg kg^{-1} to 27.1 mg kg^{-1}. At fifty per cent flowering stage the highest value was recorded from T_3 (27.1 mg kg^{-1}) which was on par with T_5, T_6, T_1, T_4 and T_2. At final harvest stage the mean values ranged from 9.3 mg kg^{-1} to 26.8 mg kg^{-1}. The highest value was recorded from T_6 (26.8 mg kg^{-1}) which was on par with T_3 (24.5 mg kg^{-1}), followed by T_5 (23.2 mg kg^{-1}). The lowest value was noted from T_8 (9.3 mg kg^{-1}).

4.4.1.10. Copper

Different treatments showed significant difference with respect the copper content in shoot portion at final harvest stage of crop (Table 32). At fifty per cent flowering stage highest Cu content was recorded by T_3 (21.1 mg kg^{-1}), followed by T_6 (16.7 mg kg^{-1}) and the lowest value was recorded from T_7 (8.8 mg kg^{-1}). At final harvest stage Cu content ranged from 7.5 mg kg^{-1} to 20.0 mg kg^{-1} and the highest value was recorded from T_3 (20.0 mg kg^{-1}), followed by T_6 (16.0 mg kg^{-1}) and the lowest value was recorded by T_7 (7.5 mg kg^{-1}).

4.4.1.11. Boron

Treatments showed a significant difference with respect to the boron content of shoot portion (Table 32). At fifty percent flowering stage B content ranged from 11.2 mg kg^{-1} to 27.6 mg kg^{-1}. The highest value was recorded from T_3 (27.6 mg kg^{-1}) which was on par with T_1, T_2 and T_6. The lowest value was noted from T_8 (11.2 mg kg^{-1}). At final harvest stage, B content ranged from 4.7 mg kg^{-1} to 19.6 mg kg^{-1}. The highest value was recorded from T_3 (19.6 mg kg^{-1}), which was on par with T_6 (19.4 mg kg^{-1}) and the lowest value was recorded from T_8 (4.9 mg kg^{-1}).

Table 32. Contents of Cu and B in shoot portion at different growth stages, (mg kg^{-1})

Treatments	Cu		B	
	50 % Flowering	Final harvest	50 % Flowering	Final harvest
T_1 – HA 1	13.9	13.1	22.4	15.9
T_2 – HA 2	15.3	14.6	19.3	17.3
T_3 – HA 3	21.1	20.0	27.6	19.6
T_4 – HA 4	14.0	13.2	15.0	12.6
T_5 – HA 5	15.8	14.8	16.4	16.1
T_6 – HA 6	16.7	16.0	27.0	19.4
T_7 – Water	8.8	7.5	11.2	4.7
T_8 - Extractant	12.3	9.7	12.9	4.9
CD (0.05)	1.65	1.56	8.12	5.35

Treatments-

T 1 – HA 1 (fortified HA from soil + sand + farm yard manure)

T 2 - HA 2 (fortified HA from soil + sand + coirpith compost)

T 3 – HA 3 (fortified HA from soil + sand + vermicompost)

T 4 – HA 4 (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T 5 – HA 5 (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T 6 – HA 6 (fortified HA from soil + sand + composted kitchen waste)

T 7 – Water (control)

T 8 – Extractant (0.5 N NaOH)

4.4.2. Contents of nutrients in fruit

4.4.2.1. Nitrogen

Nitrogen content in fruit portion was significantly influenced by the treatments (Table 33). At fifty per cent flowering stage, the N content ranged from 1.04 per cent to 2.46 per cent. The highest value was recorded from T_3 (2.46 per cent) which was on par with T_6 (2.27 per cent), followed by T_4 (1.82 per cent). The lowest value was recorded from T_8 (1.04 per cent). At final harvest stage N content ranged from 0.67 per cent to 2.07 per cent. The highest value was recorded from T_3 (2.07 per cent), which was followed by T_6 (1.68 per cent), and the lowest value was noticed in in T_8 (0.67 per cent).

4.4.2.2. Phosphorus

Phosphorus content of fruit was significantly influenced by the treatments (Table 33). At fifty percent flowering stage it ranged from 0.22 per cent to 0.61 per cent. The highest value was recorded in T_6 (0.61 per cent) which was on par with T_3 (0.59 per cent) and the lowest value was recorded from T_7 (0.22 per cent). At final harvest stage the highest value was recorded from T_6 (0.58 per cent) and was on par with T_3 (0.57 per cent), and the lowest value was noted in T_7 (0.18 per cent).

4.4.2.3. Potassium

Potassium content of fruit was significantly influenced by the treatments only at final harvest stage (Table 33).

At final harvest stage K content ranged from 1.48 per cent to 2.42 per cent. Here the highest value was recorded from T_3 (2.42 per cent) which was on par with T_6 (2.03 per cent), followed by T_5 (1.93 per cent). The lowest value was recorded from T_8 (1.48 per cent).

Table 33. Contents of N, P and K in fruit portion at different growth stages (per cent.)

Treatments	N		P		K	
	50% Flowering	Final harvest	50% Flowering	Final harvest	50% Flowering	Final harvest
T_1 – HA $_1$	1.51	1.15	0.34	0.32	1.55	1.50
T_2 – HA $_2$	1.69	1.23	0.30	0.27	1.88	1.85
T_3 – HA $_3$	2.46	2.07	0.59	0.57	2.37	2.42
T_4 – HA $_4$	1.82	1.48	0.42	0.48	2.05	1.90
T_5 – HA $_5$	1.76	1.34	0.33	0.28	1.98	1.93
T_6 – HA $_6$	2.27	1.68	0.61	0.58	2.15	2.03
T_7 – Water	1.12	0.73	0.22	0.18	1.53	1.52
T_8 - Extractant	1.04	0.67	0.26	0.21	1.52	1.48
CD (0.05)	0.519	0.264	0.073	0.203	NS	0.438

Treatments-

T $_1$ – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T $_2$ - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T $_3$ – HA $_3$ (fortified HA from soil + sand + vermicompost)

T $_4$ – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T $_5$ – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T $_6$ – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T $_7$ – Water (control)

T $_8$ – Extractant (0.5 N NaOH)

4.4.2.4. Calcium

Data from the Table 34 shows the significant effect of treatments on Ca content of fruit at fifty per cent flowering. Here the Ca content ranged from 0.317 per cent to 0.696 per cent.

The highest value was recorded from T_6 (0.696 per cent), which was on par with T_2 (0.617 per cent), followed by T_5 (0.611 per cent). The lowest value was noted from T_7 (0.317 per cent). At final harvest stage the treatments were found to be non-significant.

4.4.2.5. Magnesium

Magnesium content of fruit was significantly influenced by the treatments at both stages of crop (Table 34). At fifty per cent flowering stage the Mg content ranged from 0.044 per cent to 0.086 per cent. The highest value was noted from T_4 (0.086 per cent) which was on par with T_3 (0.083 per cent) and T_6 (0.081 per cent). The lowest was recorded from T_7 (0.044 per cent). At final harvest stage Mg content ranged from 0.025 per cent to 0.038 per cent, here the highest value was recorded from T_5 (0.038 per cent) which was on par with T_6, T_1, T_4 and T_3, and the lowest value was noted from T_7 (0.025 per cent) and T_8 (0.025 per cent).

4.4.2.6. Sulphur

The effect of treatments on Sulphur content of the fruit samples were found to be non-significant at fifty per cent flowering and at final harvest stage (Table 34).

4.4.2.7. Iron

Iron content of fruit was significantly influence by the treatments only at the final harvest stage of crop (Table 35), and the iron content of fruit ranged between 36.3 mg kg^{-1} to 46.8 mg kg^{-1}. The highest value was recorded from T_3 (46.8 mg kg^{-1}),

Table 34. Contents of Ca, Mg and S in fruit portion at different growth stages (per cent.)

Treatments	Ca		Mg		S	
	50 % Flowering	Final harvest	50 % Flowering	Final harvest	50 % Flowering	Final harvest
T_1 – HA $_1$	0.501	0.056	0.079	0.031	0.243	0.279
T_2 – HA $_2$	0.617	0.049	0.068	0.027	0.282	0.265
T_3 – HA $_3$	0.519	0.056	0.083	0.030	0.292	0.300
T_4 – HA $_4$	0.596	0.061	0.086	0.030	0.326	0.263
T_5 – HA $_5$	0.611	0.054	0.055	0.038	0.263	0.282
T_6 – HA $_6$	0.696	0.054	0.081	0.033	0.291	0.361
T_7 – Water	0.317	0.048	0.044	0.025	0.161	0.249
T_8- Extractant	0.350	0.048	0.064	0.025	0.152	0.257
CD (0.05)	0.227	NS	0.028	0.009	NS	NS

Treatments-

T_1 – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T_2 - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T_3 – HA $_3$ (fortified HA from soil + sand + vermicompost)

T_4 – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

which was on par with T_5 (44.2 mg kg^{-1}), followed by T_3 (43.9 mg kg^{-1}). The lowest value was noted by T_7 (36.3 mg kg^{-1}).

4.4.2.8. Manganese

Treatments showed significant difference with respect to the Mn content in fruit at both the stages (Table 35). At fifty per cent flowering stage Mn content ranged from 9.8 mg kg^{-1} to 18.0 mg kg^{-1}. The highest value was recorded from T_3 (18.0 mg kg^{-1}), which was on par with T_6 (17.3 mg kg^{-1}) and the lowest value was recorded from T_2 (9.8 mg kg^{-1}). At final harvest stage Mn content varied from 6.4 mg kg^{-1} to 16.8 mg kg^{-1}. Here the higher value was recorded from T_3 (16.8 mg kg^{-1}) and was on par with T_6 (15.8 mg kg^{-1}), and the lowest value was noted from T_7 (6.4 mg kg^{-1}).

4.4.2.9. Zinc

Zinc content of fruit was significantly influenced by the treatments (Table 35). Treatments showed significant difference in Zn content, only at the final harvest stage. At final harvest stage the Zn content of fruit ranged from 10.3 mg kg^{-1} to 45.2 mg kg^{-1}. Here the highest values were recorded from T_6 (45.2 mg kg^{-1}), followed by T_3 (40.4 mg kg^{-1}), and the lowest mean value was recorded from T_1 (10.3 mg kg^{-1}).

4.4.2.10. Copper

Copper content of fruit was significantly influenced by the treatments (Table 36). At fifty per cent flowering the Cu content ranged from 9.13 mg kg^{-1}to 15.43 mg kg^{-1}. The highest value was recorded from T_3 (15.43 mg kg^{-1}), which was on par with T_6, T_5, T_4 and T_2. Here the lowest value was noted from T_7 (9.13 mg kg^{-1}). At final harvest stage Zn content varied from 6.30 mg kg^{-1} to 14.27 mg kg^{-1}, here the highest value was recorded from T_3 (14.27 mg kg^{-1}), followed by T_6 (12.30 mg kg^{-1}) and the lowest value was recorded from T_7 (6.30 mg kg^{-1}).

Table 35. Contents of Fe, Mn and Zn in fruit portion at different growth stages (mg kg^{-1})

Treatments	Fe		Mn		Zn	
	50% Flowering	Final harvest	50 % Flowering	Final harvest	50 % Flowering	Final harvest
T_1 – HA $_1$	48.5	41.6	14.4	13.1	12.3	10.3
T_2 – HA $_2$	50.3	42.1	9.8	7.7	36.6	34.1
T_3 – HA $_3$	47.1	46.8	18.0	16.8	41.3	40.4
T_4 – HA $_4$	31.5	40.9	12.4	10.5	34.5	32.6
T_5 – HA $_5$	49.9	44.2	13.5	11.7	37.4	35.9
T_6 – HA $_6$	49.7	43.9	17.3	15.8	49.9	45.2
T_7 – Water	30.4	36.3	10.9	6.4	16.0	14.2
T_8-Extractant	31.4	39.2	11.3	6.7	14.0	12.3
CD (0.05)	NS	2.88	2.41	1.20	NS	2.42

Treatments-

T_1 – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T_2 - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T_3 – HA $_3$ (fortified HA from soil + sand + vermicompost)

T_4 – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

Table 36. Contents of Cu and B in fruit portion at different growth stages (mg kg^{-1})

Treatments	Cu		B	
	50 % Flowering	Final harvest	50 % Flowering	Final harvest
T_1 – HA $_1$	9.25	8.27	16.52	8.65
T_2 – HA $_2$	11.64	9.77	14.18	7.71
T_3 – HA $_3$	15.43	14.27	26.65	17.06
T_4 – HA $_4$	11.97	10.76	14.03	8.65
T_5 – HA $_5$	12.07	11.81	15.43	13.56
T_6 – HA $_6$	13.68	12.30	26.80	14.49
T_7 – Water	9.13	6.30	7.01	3.74
T_8 - Extractant	9.45	7.23	6.23	2.81
CD (0.05)	4.03	1.15	9.971	3.061

Treatments-

T_1 – HA $_1$ (fortified HA from soil + sand + farm yard manure)

T_2 - HA $_2$ (fortified HA from soil + sand + coirpith compost)

T_3 – HA $_3$ (fortified HA from soil + sand + vermicompost)

T_4 – HA $_4$ (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA $_5$ (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA $_6$ (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

4.4.2.11. Boron

Boron content of fruit samples was significantly influenced by the treatments (Table 36). At fifty percent flowering stage the B content ranged from 6.23 mg kg^{-1} to 26.80 mg kg^{-1}. The highest value was recorded from T_6 (26.80 mg kg^{-1}) which was on par with T_3 (26.65 mg kg^{-1}) and the lowest value was noted from T_8 (6.23 mg kg^{-1}). At final harvest stage, the B content ranged from 2.81 mg kg^{-1} to 17.06 mg kg^{-1}. The highest value was recorded from T_3 (17.06 mg kg^{-1}), which was on par with T_6 (14.49 mg kg^{-1}) and the lowest value was recorded from T_8 (2.81 mg kg^{-1}) which received the extractant spray.

4.4.2.12. Crude protein content of fruit

Crude protein content of fruits at fifty percent flowering and at final harvest are presented in Table 37. At fifty percent flowering the protein content ranged from 6.48 per cent to 15.40 per cent, here the highest value was recorded from T_3 (15.40 per cent) which was on par with T_6 (14.18 per cent) and the lowest value was recorded from T_8 (6.48 per cent). At final harvest the protein content ranged from 4.55 per cent to 12.95 per cent, here the highest value was recorded from T_3 (12.95 per cent) followed by T_6 (10.50 per cent), and the lowest value was noted from T_7 (4.55 per cent).

4.4.3 Correlation analysis between yield and plant nutrient content at fifty percent flowering stage.

Correlation analysis was carried out between yield and plant nutrient content at fifty percent flowering stage (Table 38). The results of the correlation study indicated that N, S and Cu recorded r the values 0.824, 0.919 and 0.879, and were significantly correlated to yield at 0.05 % level. Whereas, nutrient content of P, K and Zn were positively correlated to yield at 0.01 % level. At fifty per cent flowering stage all the nutrients were found to be positively correlated with Yield.

Table 37. Crude Protein content in fruit portion at different growth stages (per cent.)

Treatments	At 50 % Flowering	At final harvest
T_1 – HA 1	9.45	7.18
T_2 – HA 2	10.59	7.70
T_3 – HA 3	15.40	12.95
T_4 – HA 4	11.38	9.28
T_5 – HA 5	11.03	8.40
T_6 – HA 6	14.18	10.50
T_7 – Water	7.00	4.55
T_8 - Extractant	6.48	4.20
CD (0.05)	3.245	1.651

Treatments-

T_1 – HA_1 (fortified HA from soil + sand + farm yard manure)

T_2 - HA_2 (fortified HA from soil + sand + coirpith compost)

T_3 – HA_3 (fortified HA from soil + sand + vermicompost)

T_4 – HA_4 (fortified HA from soil + sand + desi cowdung with assorted farm waste)

T_5 – HA_5 (fortified HA from soil + sand + desi cowdung with straw and Gliricidia)

T_6 – HA_6 (fortified HA from soil + sand + composted kitchen waste)

T_7 – Water (control)

T_8 – Extractant (0.5 N NaOH)

Table 38. Correlation analysis between yield and plant nutrient content (shoot) at fifty percent flowering stage.

Variables	Yield	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Yield	1.000											
N	0.824**	1.000										
P	0.801*	0.901	1.000									
K	0.703*	0.758	0.508	1.000								
Ca	0.656	0.923	0.853	0.764	1.000							
Mg	0.624	0.818	0.764	0.789	0.956	1.000						
S	0.919**	0.945	0.843	0.843	0.862	0.808	1.000					
Fe	0.664	0.929	0.741	0.735	0.854	0.727	0.875	1.000				
Mn	0.468	0.602	0.725	0.368	0.615	0.564	0.482	0.405	1.000			
Cu	0.879**	0.906	0.817	0.801	0.781	0.705	0.911	0.794	0.725	1.000		
Zn	0.808*	0.902	0.843	0.623	0.727	0.575	0.856	0.844	0.693	0.944	1.000	
B	0.611	0.864	0.800	0.716	0.881	0.804	0.756	0.755	0.865	0.880	0.828	1.000

• = Significant at 0.01 % level ** = Significant at 0.05 % level

Discussion

5. DISCUSSION

The important results of the experiments conducted for the evaluation of fortified humic acids from grow bag mixtures as phytotonic in Okra. [*Abelmoschus esculentus* (L.) Moench] which consisted of an incubation study, to evaluate different grow bag media, extraction, characterisation and fortification of humic acids from the media, and crop study in grow bags to evaluate the efficacy of multinutrient fortified HA's presented in the preceding chapter are discussed below.

Part – I

5.1 INCUBATION STUDY

Different grow bag media was prepared by altering the composition and was evaluated for soil fertility parameters and microbial count.

5.1.1 **Soil Fertility Parameters and Microbial Enumeration**

Different soil fertility parameters of the incubated growth media *viz*. pH, electrical conductivity, available N, P and K, Ca, Mg, available micronutrients *viz.* Fe, Cu, Zn, Mn and B, and microbial enumeration of bacteria, fungi and actinomycetes were observed for a period of three months at fortnightly interval are (given in Fig.1-8) are discussed below.

pH of the incubated growth media ranged between 5.4- 10.4 (Table 6). The highest value was recorded from T_6 at 6^{th} fortnight of incubation, which contained composted kitchen waste and throughout the incubation pH was in an alkaline range in T_6. The lowest pH (5.4) was noted from T_2, containing coir pith compost, and the pH ranged from moderately acidic to neutral. (Fig 1). During the first three fortnights of T_1, T_2, T_3, T_4 and T_5, pH of growth media followed an increasing trend in general.

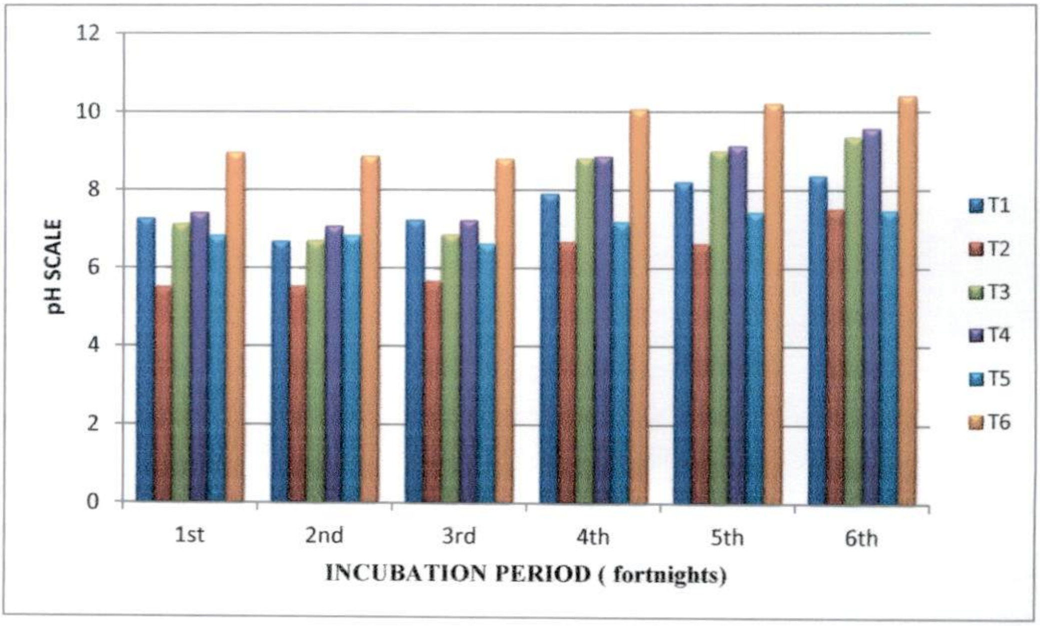

Fig 1. pH of different growth media at fortnightly intervals (during incubation)

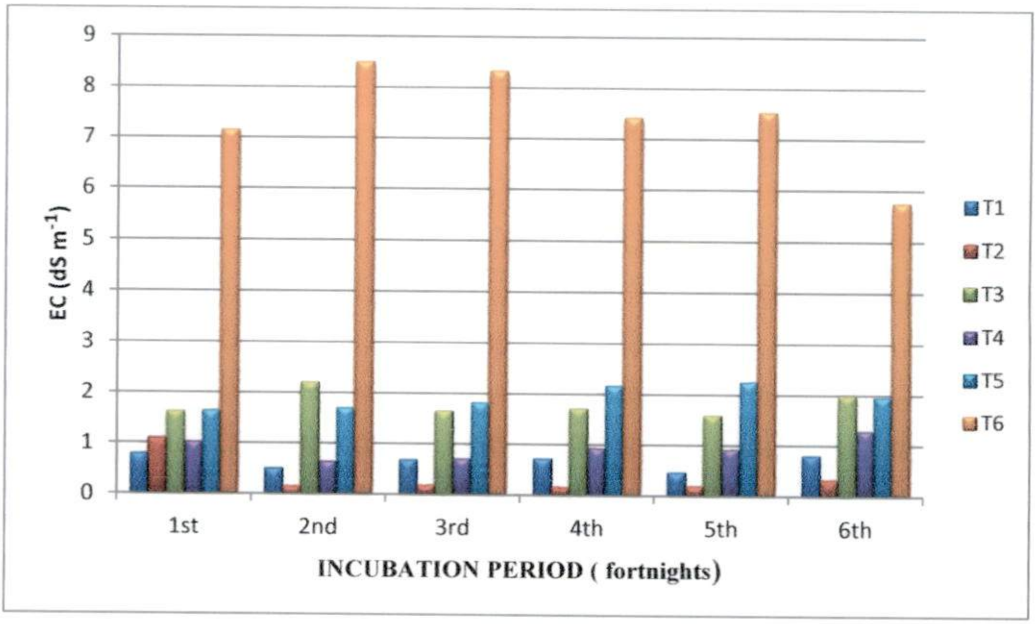

Fig 2. EC of different growth media at fortnightly intervals during incubation (dS m^{-1})

The possible factors that act on pH may be NH_4^+ excretion from the calciferous glands of earthworms in the case of vermicompost medium (Lee, 1985). It can also be due to release of bases and organic components as part of the mineralization enhanced by the action of humic substance (Schnitzer, 2000). The alkaline pH of T_6 media can be due to the presence of alkaline carrier substance used in preparation composting inoculum and the amount of kitchen waste compost was used in equal quantity that of soil, therefore considering the high nutrient availability of T_6, it can be utilized by reducing the quantity taken in growth media preparation. Alkaline range of pH of the compost, especially vermicompost was reported by Zachariah (1995).

Electrical conductivity (EC) of the growth media ranged between 0.20 dS m^{-1} to 8.50 dS m^{-1} during incubation (Table 7). The EC of growth media in T_1, T_2, T_3, and T_4 was in the safe limit for crop growth throughout the period of incubation (Fig 2). Generally EC was high in T_6 throughout incubation, and highest EC of 8.50 dS m^{-1} was recorded from T_6 at second fortnight of incubation, followed by T_5 during fifth fortnight of incubation. Similar results were reported by Thompson and Pownall (1989), which concluded that organic constituents having high ionic concentration can enhance ionic mobility and finally result in higher electrical conductivity values. Carrier of the composting inoculum might also have contributed to high EC in the medium containing kitchen waste inoculum compost. High pH and very high EC was considered as a common character of vermicompost (Tringovska *et al.*, 2014).

Available N content was low to medium range in all treatments except T_6 (Fig 3), in which it was high in the first four fortnights of incubation (Table 8). The highest value of 703.0 kg ha^{-1} was recorded at 6^{th} fortnight of T_6 which was growth medium with composted kitchen waste.

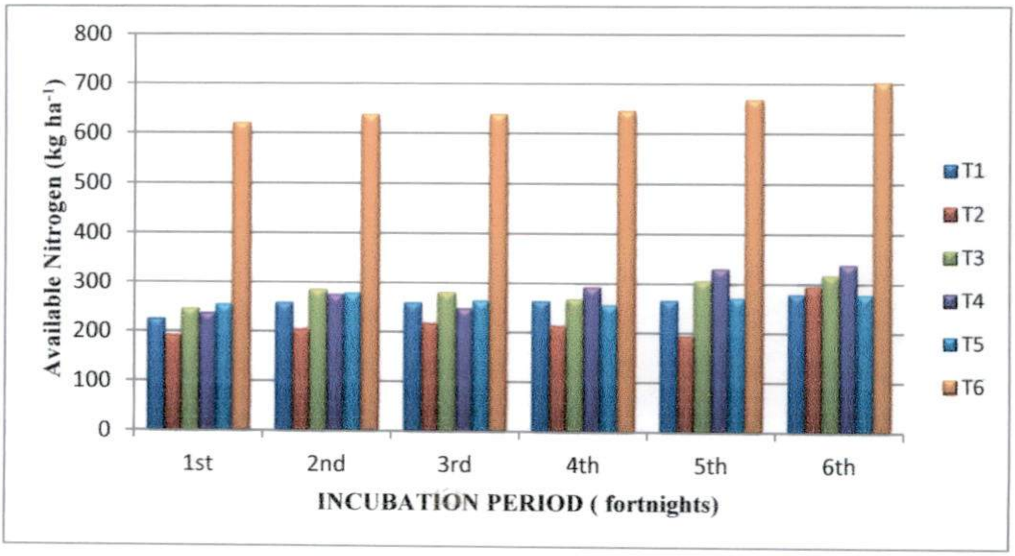

Fig 3. Available Nitrogen content of different growth media at fortnightly intervals during incubation (kg ha^{-1})

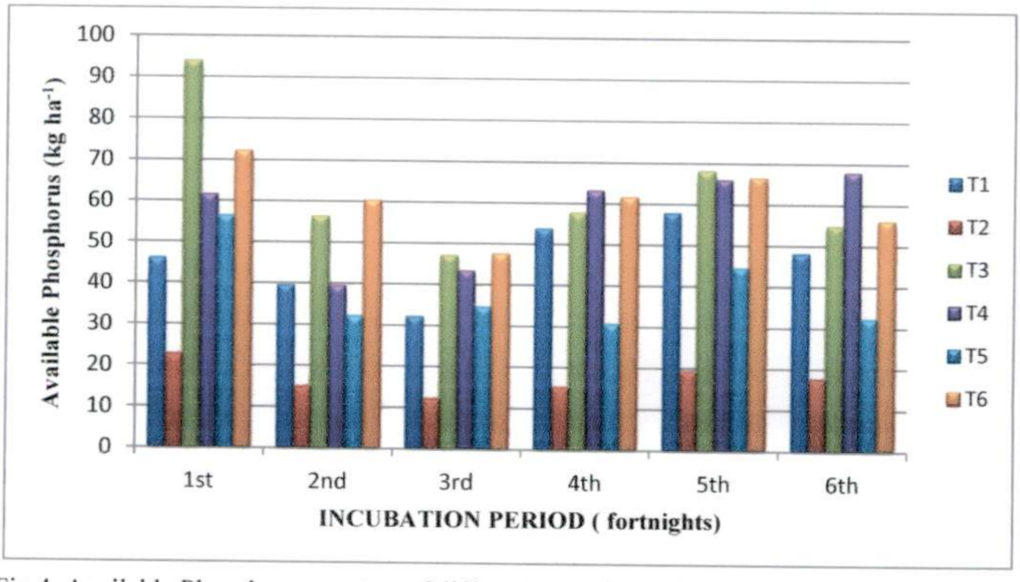

Fig 4. Available Phosphorus content of different growth media at fortnightly intervals during incubation (kg ha^{-1})

The release pattern of available N varied among the different treatments, and in general the N content showed an increasing trend up to fourth fortnight period. This can be due to mineralization of the organic substrates by high microbial (bacterial) activity noted up to fourth fortnight of incubation. T_6 was followed by T_3 (vermicompost media), the high degree of decomposition in vermicompost might be one of the reasons for the high nitrogen content (Shuxin *et al.*, 1991).

Available P content of growth media showed high fluctuations during the incubation, (Fig 4) and the mean values ranged from 12.3- 93.9 kg ha^{-1} among the different treatments (Table 9). Except T_2 (coir pith medium) all other treatments showed high levels of available P with the highest value for vermicompost growth medium T_3 during the first fortnight of incubation. Available P status of the coir pith containing growth medium was only at medium level owing to the inherent low content of P in coir pith.

The higher P content of T_3 might be due to the higher P content of vermicompost might have reflected in higher soil available P, this may be due to greater mineralization of organic matter with the aid of micro flora associated with earthworms. The presence of P solubilizing organisms in the vermicompost may enhance the biological solublization of P and thereby the soil available P (Gaur, 1990). Dissolution of native P of the soil in the media by the composted organic substances in it, enhanced the availability of P (Reza *et al.*, 2012).

The fluctuations in P content can be due to difference in microbial activity and phosphatase activity. There was a decline in the available P content on increase of incubation period, similar results were reported by Kaloi *et al.* (2011), who conducted an incubation study to evaluate the phosphate release in soils of Hyderabad. The study reported that nutrient release pattern of phosphorus, tends to decline, with increase in the period of incubation.

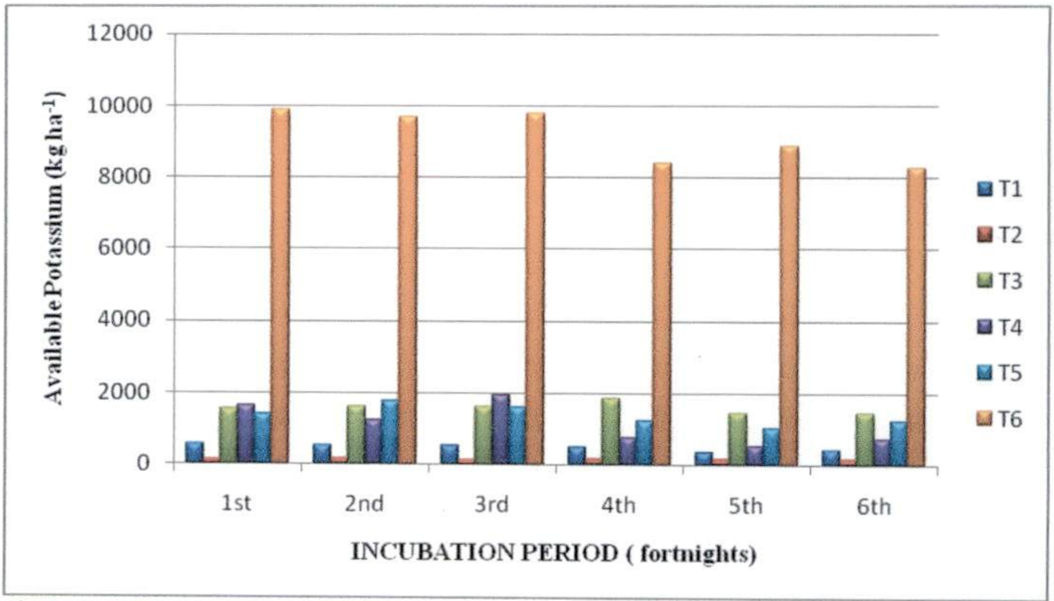

Fig 5. Available Potassium content of different growth media at fortnightly intervals during incubation (kg ha^{-1})

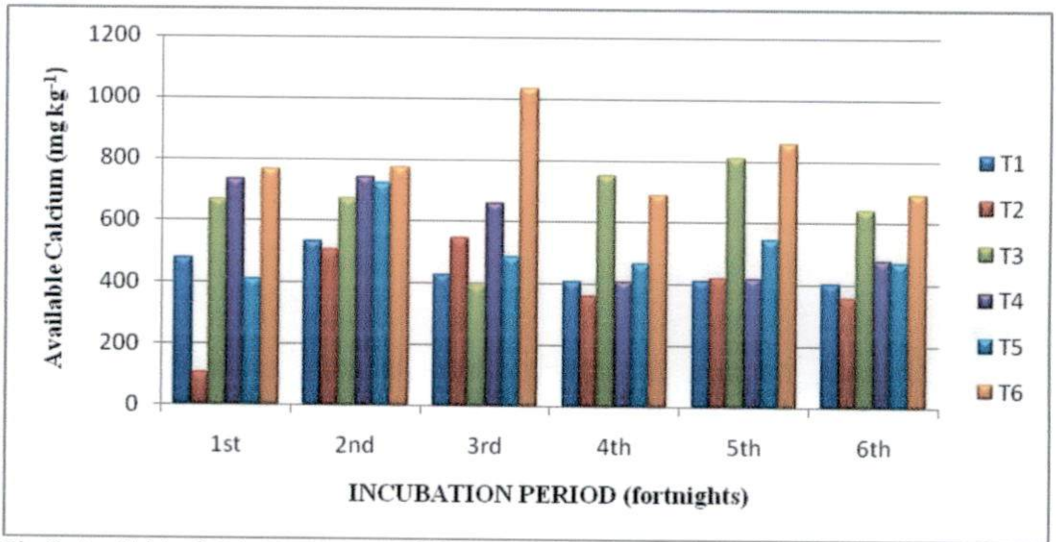

Fig 6. Available Calcium content of different growth media at fortnightly intervals during incubation (mg kg^{-1})

The available K content was high in all media and it was very high in T_6 the kitchen waste compost and value recorded was 9893.3 kg ha^{-1} at 1^{st} fortnight (Table 10). Throughout the period of incubation the highest value of available K was noted in T_6 (Fig 5). Availability of K showed a decreasing trend towards the later periods of incubation. However the status of available K was high in all growth media during the incubation period. As microbial enzyme activity is reported to be more in vermicompost and compost from K rich materials, the K buildup in soil solution is more (Basker *et al.*, 1992). Faster degradation of organic substances leading to better mineralization pattern consequent to high microbial activity resulted in enhanced release of basic cations like K^+ (Ammal and Muthiah, 1994). The high content of K in the materials used in compost making might also have contributed to high status of available K in the growth media during incubation.

During the course of incubation kitchen waste inoculum compost (T6) recorded the highest calcium content of 1032.6 mg kg^{-1} in the 3^{rd} fortnight (Table 11). The increased availability of Ca in kitchen waste might be due to rapid degradation of organic complexes (substrates used in kitchen waste compost includes fish, chicken bone) by the microbial activity (Fig 6). T_6 was followed by T_3 (vermicompost medium) and similar results were reported by Kale and Krishnamurthy (1980), they found that earthworms were of relatively feeding on calcium rich materials, thereby increasing the total Ca availability. As per the report of Pierce (1972) the active calciferous glands of earthworms can absorb excess Ca from their diet and excreted via the digestive tract. In general available status of the growth media throughout the period of incubation was sufficient in all the treatments (>300 ppm except in T_2 during first fortnight.

Available Mg was sufficient (> 120 ppm) in T_1 and T_5 throughout the period of incubation (Table 12). The highest Mg content (184.3 mg kg^{-1}) was recorded for medium with desi cow dung (500g) with straw and *Gliricidia* (Fig 7). This can be due to the presence of green leaf manure *Gliricidia*, which eventually releases the Mg on

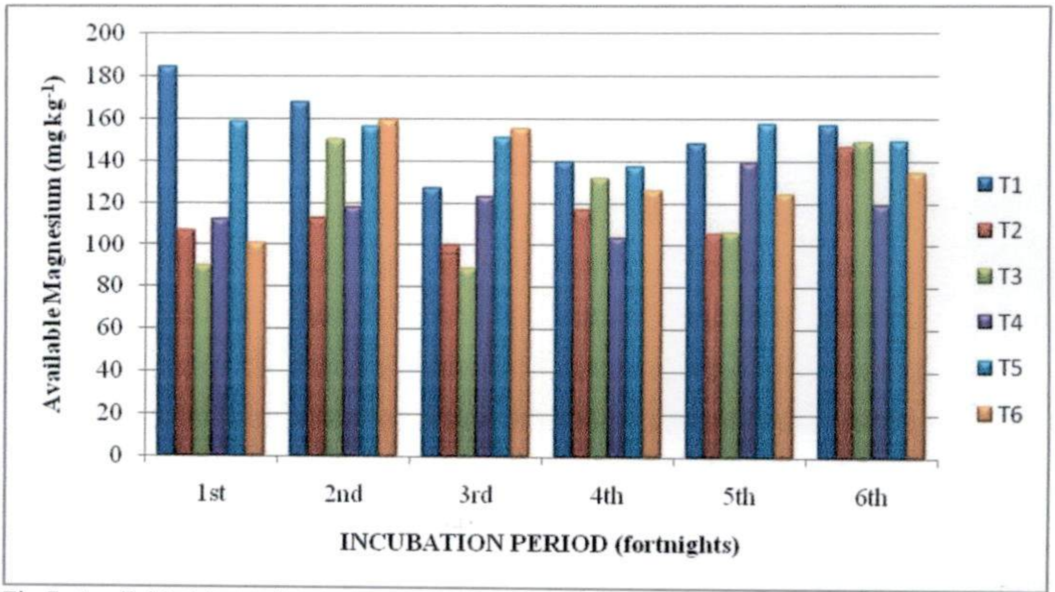

Fig 7. Available Magnesium content of different growth media at fortnightly intervals during incubation (mg kg^{-1})

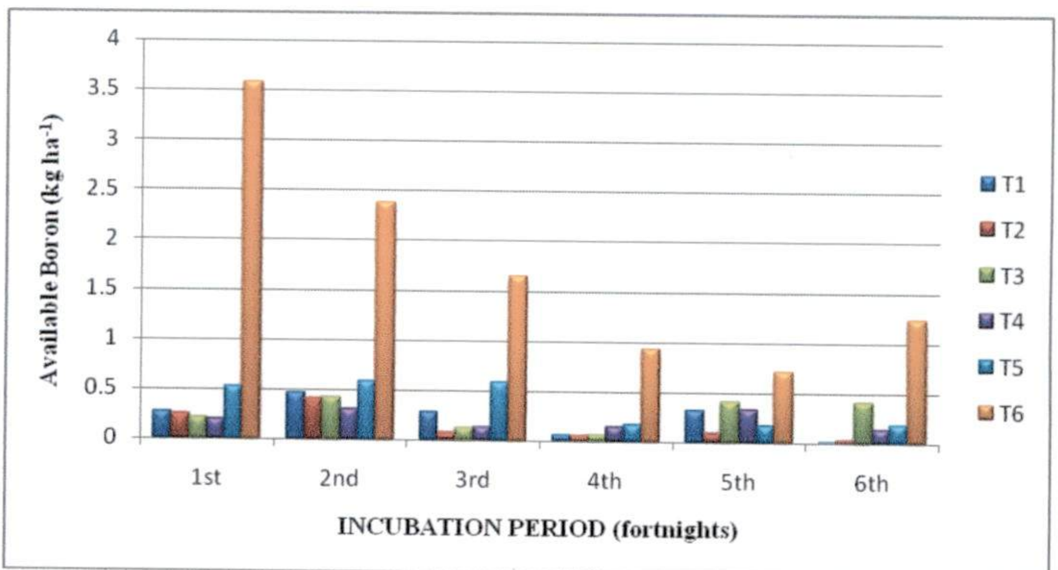

Fig 8. Available Boron content of different growth media at fortnightly intervals during incubation (mg kg^{-1})

decomposition. Mg content was found deficient in various treatments during initial phase, and towards the end of incubation it was in the sufficient range, this can be due to increased microbial activity and thereby release of Mg from organic substances of plant leaf origin.

Available micronutrient content showed wide fluctuations during the course of incubation. Among the micronutrients available Boron was found to be low in FYM (T_1), coir pith compost (T_2) and desi cowdung + FW media (T_4). Highest B content was recorded from T_6 3.58 mg kg^{-1} during 1^{st} fortnight (Fig 8), and later it was reduced (Table 13).

Available iron content was significant only at the sixth fortnight of incubation (Table 14), and the highest content was recorded from vermicompost medium (103.3 mg kg^{-1}) Available Mn content was significant only at 1^{st} fortnight and Mn content were deficient in T_2 containing coirpith, Highest Mn content was recorded from T_3 (18.63 mg kg^{-1}).

During incubation the available Fe, Mn, Cu and Zn were in general found to be not significantly influenced by the treatment composition of different growth media (Tables 14 to 17) indicating that availability of micronutrients was not in any way influenced by changing the organic substrates if in the growth media. Ravichandran (2011) has reported that humic acids in combination with trace elements as foliar spray could improve plant growth.

Fig. 9 represents that bacterial population was found to be significant only after 3^{rd} fortnight of incubation, (Table 18) and the highest bacterial count was recorded in vermicompost 8.88 log cfu g^{-1} soil. Similar results were reported by Edwards and Fletcher (1988), who reported that there is increased number of bacteria and actinomycetes in the earthworm gut, compared to those in soil. Indira *et al.* (1996) reported that population of beneficial organisms like phosphorus solubilizing bacteria was in the range of 10^5 to 10^6.

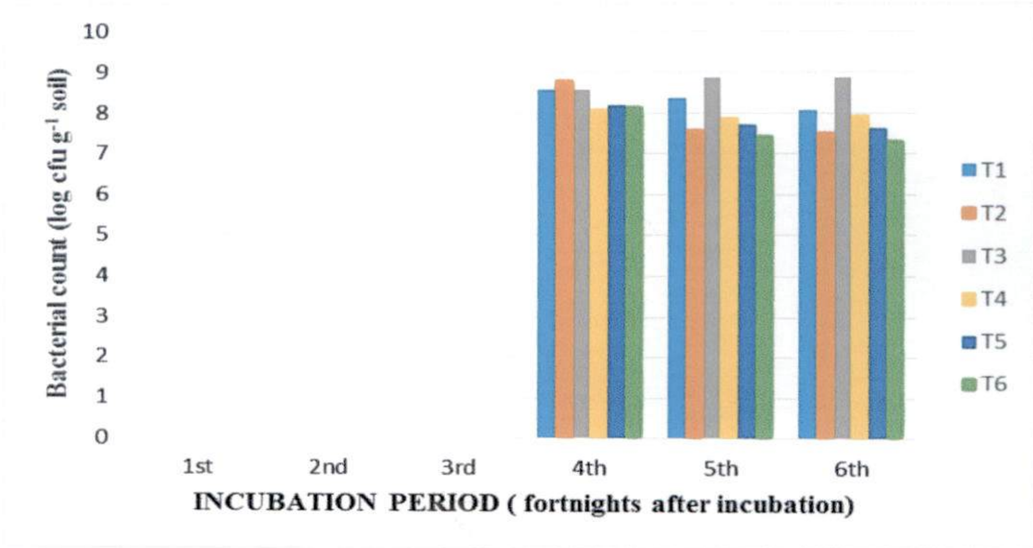

Fig. 9 Bacterial population in different growth media at fortnightly intervals during incubation (log cfu g^{-1} soil)

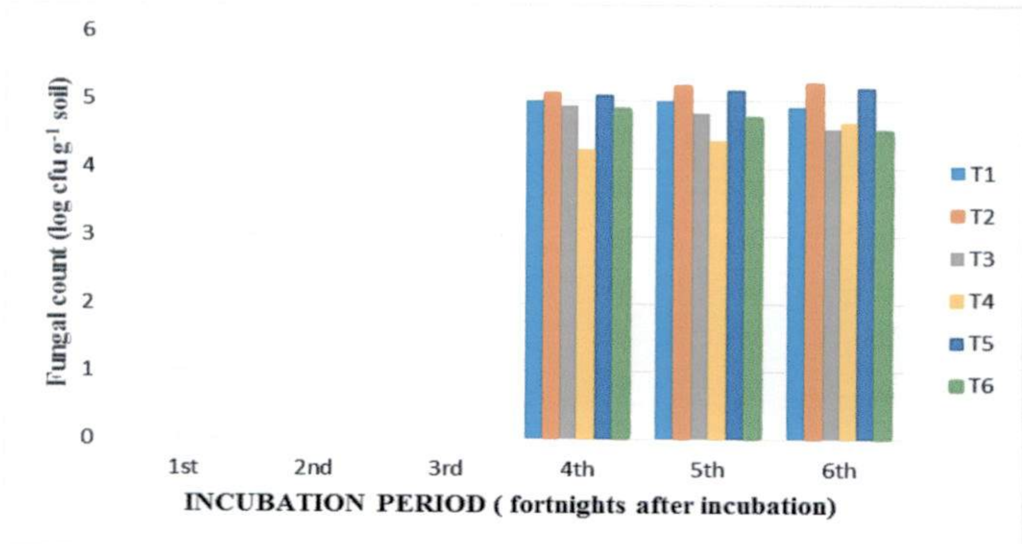

Fig.10 Fungal population in different growth media at fortnightly intervals during incubation (log cfu g^{-1} soil)

Fungal population was found to be significant only after 3rd fortnight (Fig. 10) of incubation (Table 19). The highest value for fungal population was recorded from T_2 (coirpith containing media) 5.39 log cfu g^{-1} soil (Fig 10), this might be due to the increased lignin content of the coir pith compost, which is essential for the mycelial growth of fungus. Decline in fungal population towards the end of the incubation period can be attributed to increase in pH of the growth media (Table 3) as fungi prefers acidic pH for its growth and activity (Alexander, 1978).

Actinomycetes population found to be significant only after 4th fortnight (Fig. 11) of incubation (Table 20). T_4 recorded the maximum population for actinomycetes (5.61 log cfu g^{-1} soil), which was medium comprising of desi cowdung with assorted farm waste. The results shows some critical relation between the desi cowdung and actinomycetes population, this can be due to the presence of natural growth promoting factors in the desi cowdung.

Characteristics of humic acids like total acidity, humic acid content and time taken for pH stabilization were monitored (Table 21). T3 (vermicompost humic acid) recorded highest value for total acidity (12.0 meq g^{-1} of humic material) and humic acids content (25.7 % of organic matter). Time taken for stabilization pH was maximum for T4 (70 hrs) which was humic acids from desi cowdung mixes with assorted farm waste. The increase in total acidity might be due increased amount of fulvic acid fractions in T3. Increased amount of humic acid content in T3 can be due to innate nature of vermicompost for better degradation and mineralization of organic matter to plant available form. Similar results were reported by Canellas *et al.* (2000) while studying the size composition and biostimulative properties of vermicompost humic acid. Use of multi-micronutrient fortified humic acids as foliar spray in the present crop study could elucidate the significant effect of source of humic acids on crop yield quality over and above the effect of multinutrient which was uniformly used in all the six types of humic acids.

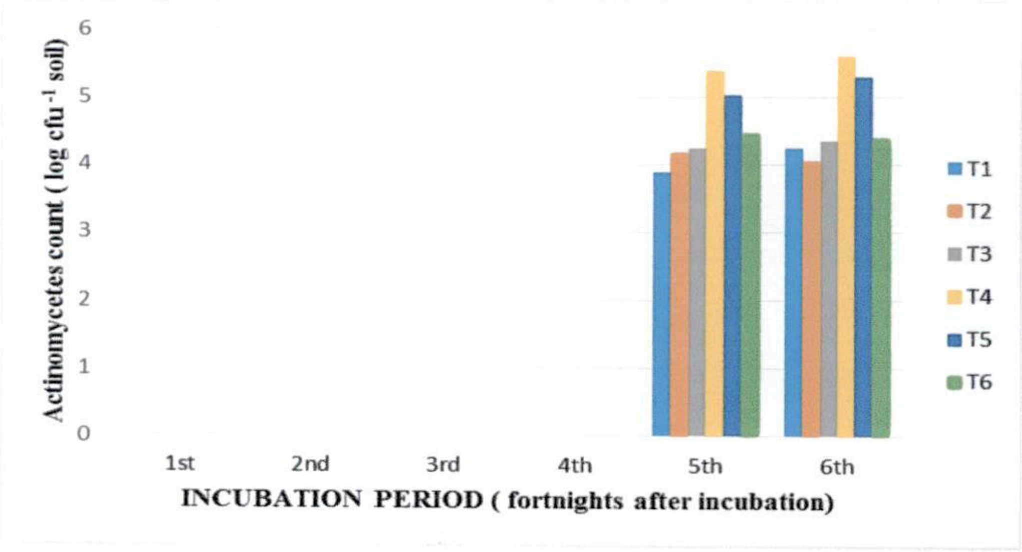

Fig. 11 Actinomycetes population in different growth media at fortnightly intervals during incubation (log cfu g^{-1} soil)

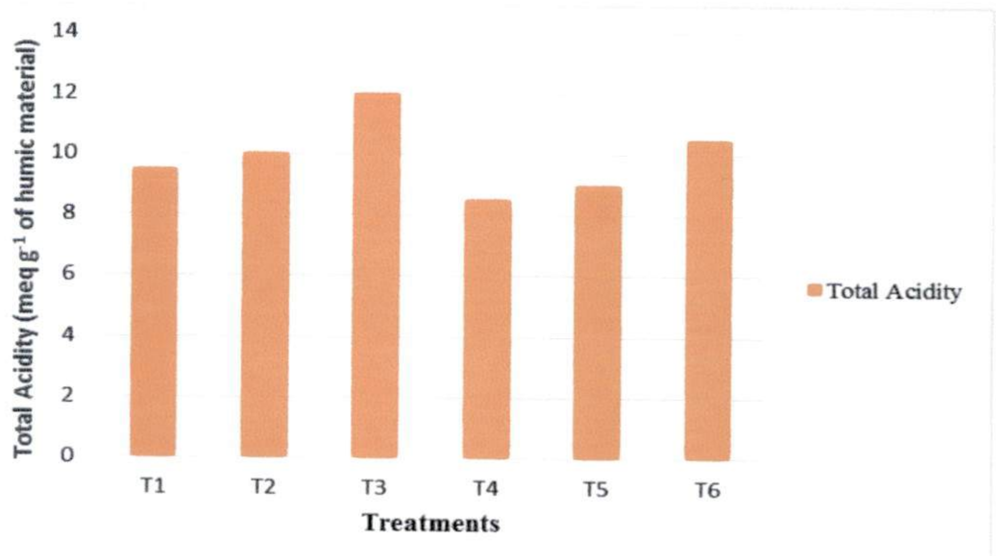

Fig. 12 Total acidity of humic acids extracted from different growth media (meq g^{-1} of humic material)

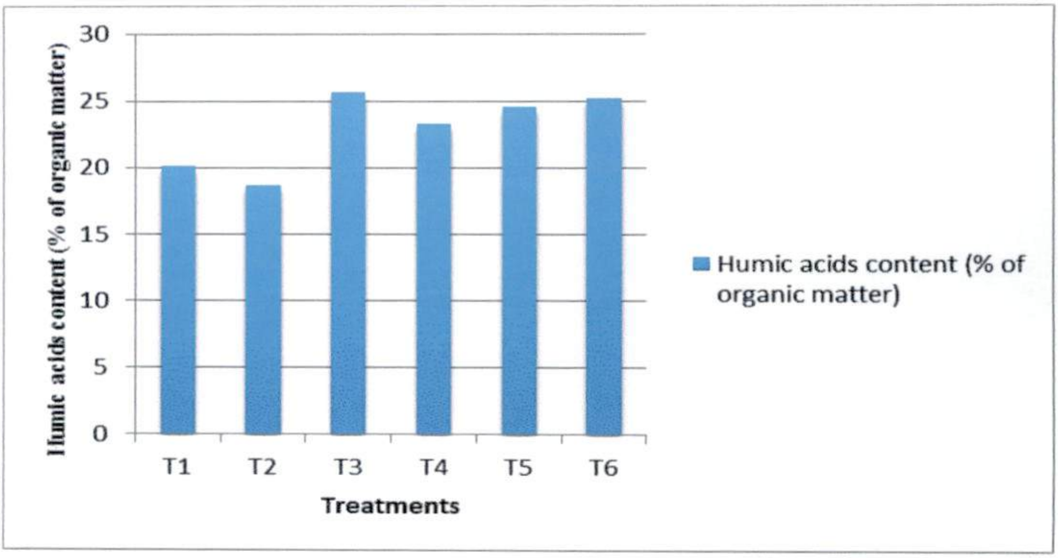

Fig. 13 Humic acid content obtained from different growth media expressed as per cent of organic matter

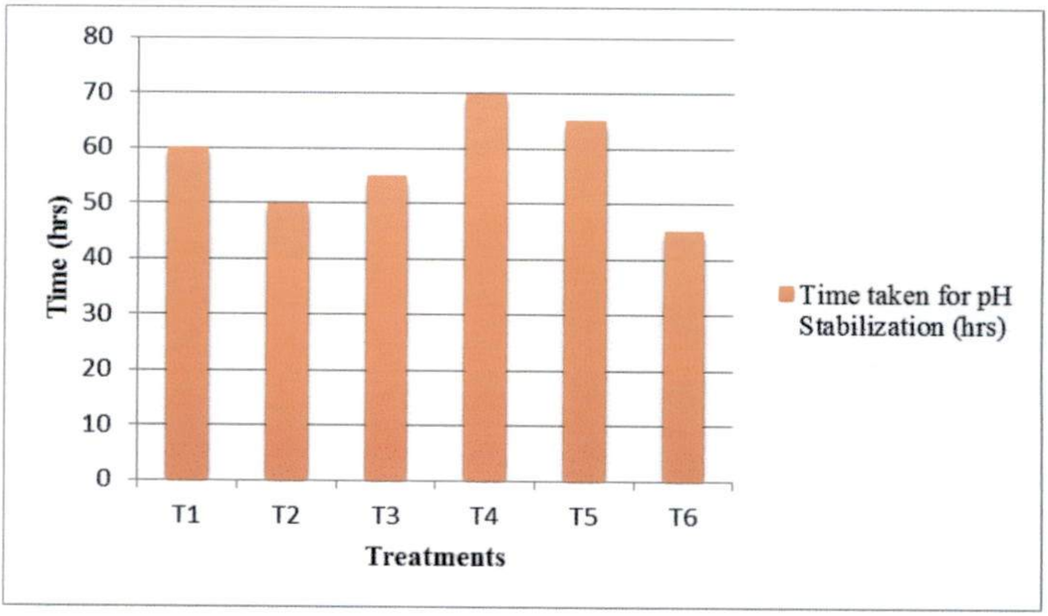

Fig. 14 Time taken for pH stabilization of humic material extracted from different growth media (hrs)

PART II

5.2 CROP STUDY IN GROWBAGS

Humic acids in organic matter has direct physiological effect on crop growth and yield. It has an effect on the increase in the uptake of nutrients, nucleic acid activity, protein synthesis, membrane permeability, rate of respiration and photosynthesis (Serenella *et al.*, 2002). Effect of multinutrient fortified humic acids was evaluated in okra (variety Varsha uphar) by growbag cultivation during January – April 2017, and the salient results obtained in the study are discussed in this chapter.

5.2.1 Effect of fortified humic acids on biometric characters of okra

5.2.1.1 Shoot Characters

Shoot characters recorded at first flowering, first harvest and final harvest (Table 22). Fig. 15 indicated that T_6 (foliar application of kitchen waste compost humic acids fortified with multinutrient mixture @ 0.5 % concentration at weekly intervals) recorded the highest mean value for plant height, at first harvest (74.17 cm) and final harvest (127.70 cm). The enhancement of N uptake and hormonal like action of humic acids contributed to the increased shoot length in T_6. Kitchen waste compost recoded highest available N content (703.0 kg ha^{-1}) during the incubation study and HA's extracted from this compost might have also possessed this inherent N content. Studies conducted by Nardi *et al.* (2002) also reported the plant hormone (auxin) like behavior of humic acids and stimulatory effect on plant growth vary depending on source of humic acids.

The stimulatory effect of humic acids was attributed to the influence of concentration and molecular weight of humic substance Nardi *et al.* (2002). It was

T_3 (Fortified Vermicompost humic acid) T_7 (Water spray)

Plate 4. Crop at first flowering stage

T_3 (Fortified Vermicompost humic acid) T_7 (Water spray)

Plate 4. Crop at first harvest stage

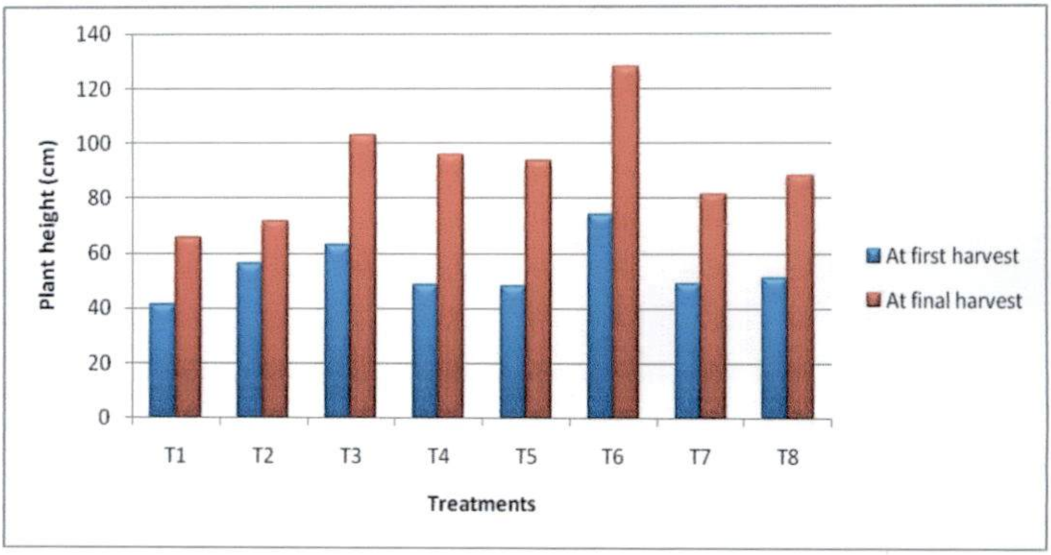

Fig. 15 Effect of multinutrient fortified humic acid on plant height (cm)

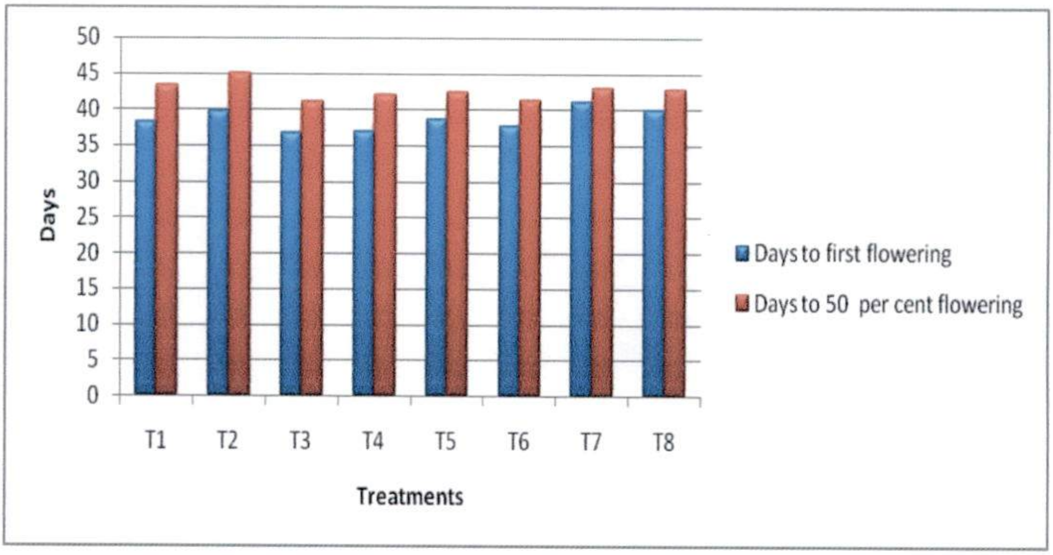

Fig. 16 Effect of multinutrient fortified humic acids on flowering (days)

indicated that low molecular size (LMS <300 Da) can easily reach the plasmalemma of the cells, and as the molecular size increases, the rate of interaction decreases. This might be the reason for difference in performance of humic acids from different sources.

Application of humic acids in combination with plant nutrients as foliar spray can improve the growth of plant foliage, roots and overall plant growth process (Ravichandran, 2011). This is in confirmation with the effect of multinutrient fortified humic acids obtained in the present study.

5.2.1.2 Flowering and Duration of Crop

Fig. 16 indicates that number of days to first flowering and 50 % flowering was the least in T_3, vermicompost containing growth media (36.7 days and 41 days respectively) compared to all other treatments (Table 23 and 24). Significant role of humic substance in acceleration of flower initiation in maize plants by stimulation of metabolic activities was reported by Eyheraguibel (2008). Early flowering in tomato was noted when vermicompost was used and it was due to the role played by phytohormones, enzymes, antibiotics and vitamins in vermicompost (Pushpa, 1996)

The highest productive duration was recorded in T_3 (71 days), and it was followed by T_6 (66.6 days), which was fortified HA's from kitchen waste compost containing medium (Fig. 17).The highest crop duration was recorded from T_3 (114.0 days), which received foliar application of vermicompost HA's fortified with multinutrient mixture, followed by T_6 (105.3 days). This can be due to the plant growth promoting nature of humic substance, the auxin like nature of HA's can delay senescence.

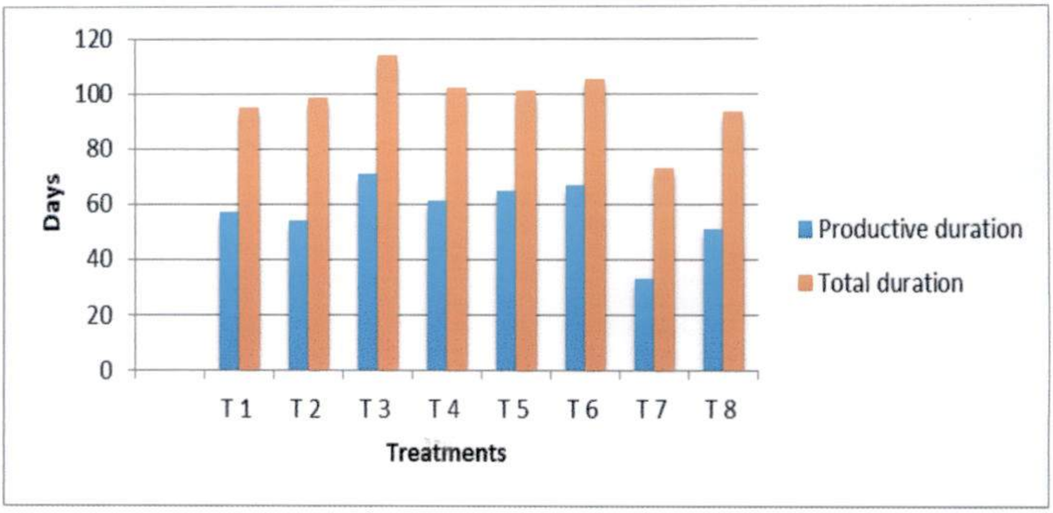

Fig. 17 Effect of multinutrient fortified humic acids on duration of crop (days)

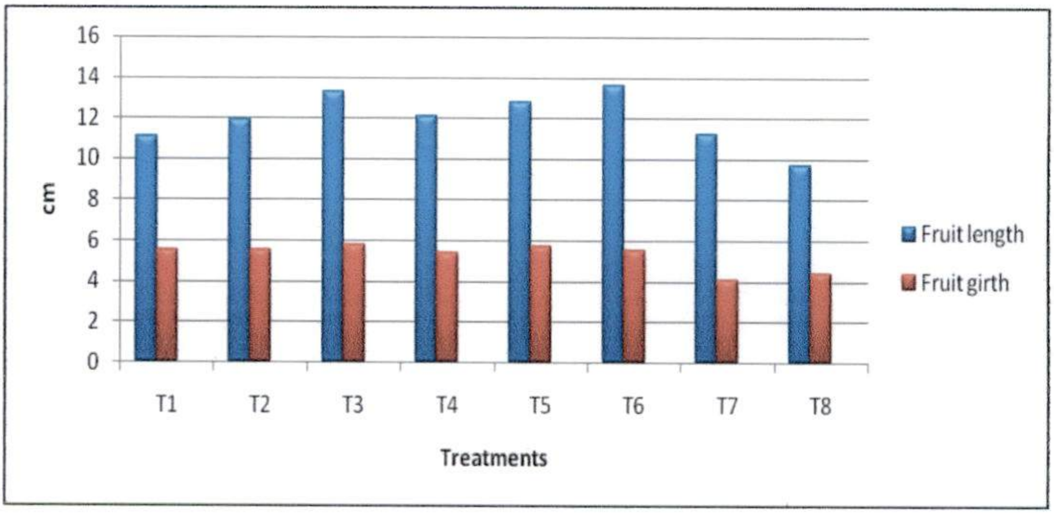

Fig. 18 Effect of fortified humic acids in fruit characters

5.2.1.3 Number of Harvests and Fruit Characters

T_3 (foliar application of vermicompost HA's fortified with multi nutrient mixture) recorded the highest value (Fig. 19) for total number of harvests (15.6). Regarding the fruit characters (Fig. 18) and yield (Fig. 20), T_3 recorded the highest value. The highest average fruit weight (17.1 g) was noted from T_3 (Table 24 and 25). Regarding the number of fruits per plant and yield per plant, highest values were recorded from T_3 (24.3 and 415.4g plant^{-1} respectively). The results of the fruit characters matches with the findings published by Arancon *et al.* (2006), which reported the effect of humic acid derived from cattle, food and paper waste vermicornpost on growth of green house plants. The findings of the study concluded that vermicompost humic acids has a stimulative and growth enhancing effect on the plant heights, leaf areas, shoot dry weights of peppers, tomatoes and marigolds and numbers of fruits of strawberries were superior.

Canellas *et al.* (2000) reported that exchangeable auxin were found from macrostructure of humic acids extracted from vermicompost using GC-MS and such complexes can stimulate the increase shoot length, root length, increased number of lateral roots, and enhance the activity of membrane H^+ ATPase.

5.2.2 Influence of Fortified Humic Acids on Yield and Yield Attributes

Results on fruit characters (Fig. 18) and yield (Fig. 20) revealed that, fortified humic acids from vermicompost (T_3) was best performer among the different treatments (Table 26). The mean values for number of fruits per plant ranged from 10.0 to 24.3. The highest value was recorded from T_3 (24.3), and followed by T_6 (18.3) which received fortified HA's from kitchen waste compost medium.

Similar results was reported by Azarpour *et al.* (2012), while studying the effect of nitrogen fertilizer and foliar application of humic acids of vermicompost origin on yield and yield components of eggplant had noticed that the foliar humic

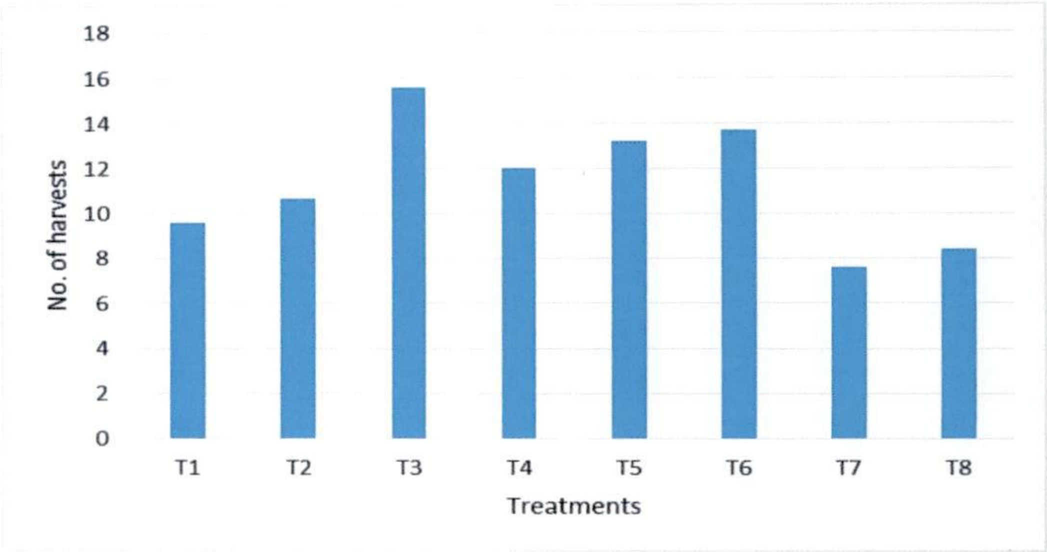

Fig. 19 Effect of multinutrient fortified humic acids on number of harvest

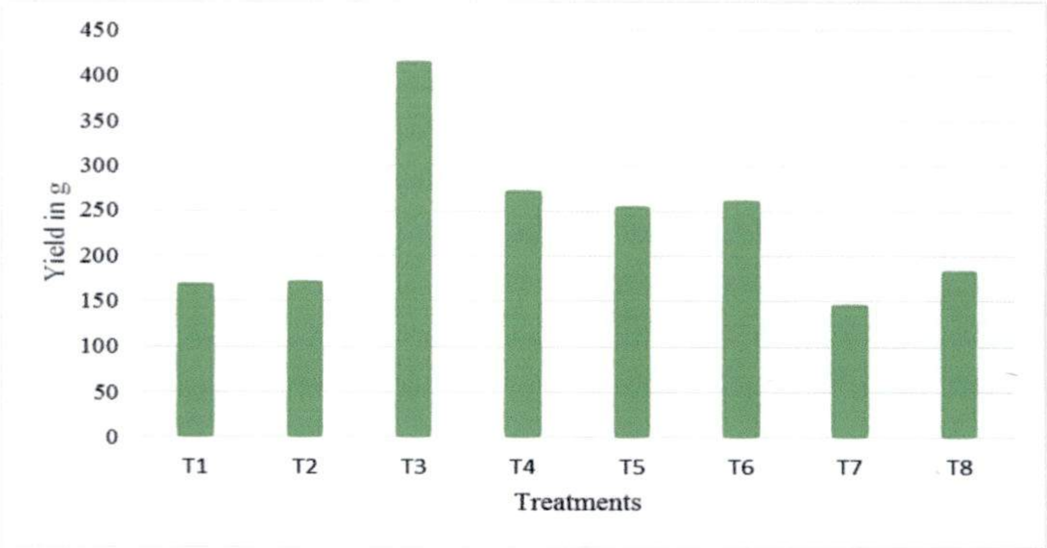

Fig. 20 Effect of multinutrient fortified humic acids on yield (g $plant^{-1}$)

acids spraying had significant effect on yield improvement. The highest fruit yield was obtained from use of 50 mg L^{-1} humic acids spraying and also from 80 kg ha^{-1} nitrogen fertilizer. Similar results on crop yield were reported by Atiyeh *et al.* (2002) who studied the influence of humic acids derived from earthworm processed organic wastes on growth and yield of tomato and cucumber. Characters like plant height, leaf area, root and shoot dry weight, and yield were significantly increased due to humic acids application. Irrespective of the type of humic acids used, the treatments T_1 to T_6 performed significantly superior to the T_7 (water spray) and T_8 (extractant spray). This highlights the role of multinutrient fortified humic acids on yield and yield attributes. Similar results were reported by Hazra *et al.* (1987), which the reported foliar effect of micronutrients was on growth and yield of okra. In which Zn, Fe and Cu were applied in two concentrations (0.1 % and 0.2 %) singly and in their respective concentration combinations. The experiment recorded an increase in plant height (114.96 cm) with Zn at 0.2 % concentration. The results also revealed marked increase in fruit number per plant, fruit length, fruit weight and fruit yield with the application of Zn and Cu at both concentrations singly and also at their respective concentration. Significant differences observed in yield between T_1 and T_6 also substantiate the role of humic acids from different sources as reported by Nardi *et al.* (2002).

5.2.3 Pest and Disease Incidence

Incidence of fruit and shoot borer reported from T_1, T_2, T_7, and T_8 and YVM incidence was recorded from T_1 and T_7 (Table 27). Rest of the treatments did not show any symptom of pest and disease incidence. This indicates the reduced incidence of pest and disease in humic acids applied plants. Similar results were reported by Edwards *et al.* (2004) in which he studied the effect of vermicompost on suppression of pathogens like *Pythium, Rhizoctonia* and *Verticilium*. The study also noted that use of vermicompost in soil less media under protected cultivation can reduce the feeding damage caused by sucking and chewing pests.

5.2.4 Keeping Quality

Fig. 21 indicates that keeping quality of fruits (firmness) was retained for 4.67 to 9.0 days (Table 28). Dhanasekaran *et al.* (2007a) reported that combined foliar application of 0.5 % humic acids with nutrient mixture has recorded higher fruit quality in okra. Highest keeping quality was recorded from T_6 (9 days) that received fortified HA's from kitchen waste compost medium and was on par with T_3 (8.37 days), which received foliar application of vermicompost humic acid. Increase in the fruit quality, early yield and nutrient uptake as humic acids effect has been reported by Adani *et al.*, 1998.

5.2.5 B: C Ratio

B: C ratio of treatments ranged from 0.67 to 1.76 (Table 28). The highest value for B: C ratio was recorded from T_3 (1.76) (Fig. 22), which received foliar application of vermicompost HA's fortified with multi nutrient mixture, and followed by T_4 (1.25).

Increase in yield obtained in the present study for the highest B: C ratio was 185 % over control treatment (T_7) Dhannasekaran *et al.* (2007b) recorded 46.5 % higher fruit yield in okra through foliar application of 0.3 % humic acids. The lowest value for B : C ratio was noted from T_7 (0.67), which received water spray. Dhanasekaran *et al.* (2007a) reported that combined foliar application of 0.5 % humic acids with nutrient mixture has recorded higher yield and fruit quality in okra.

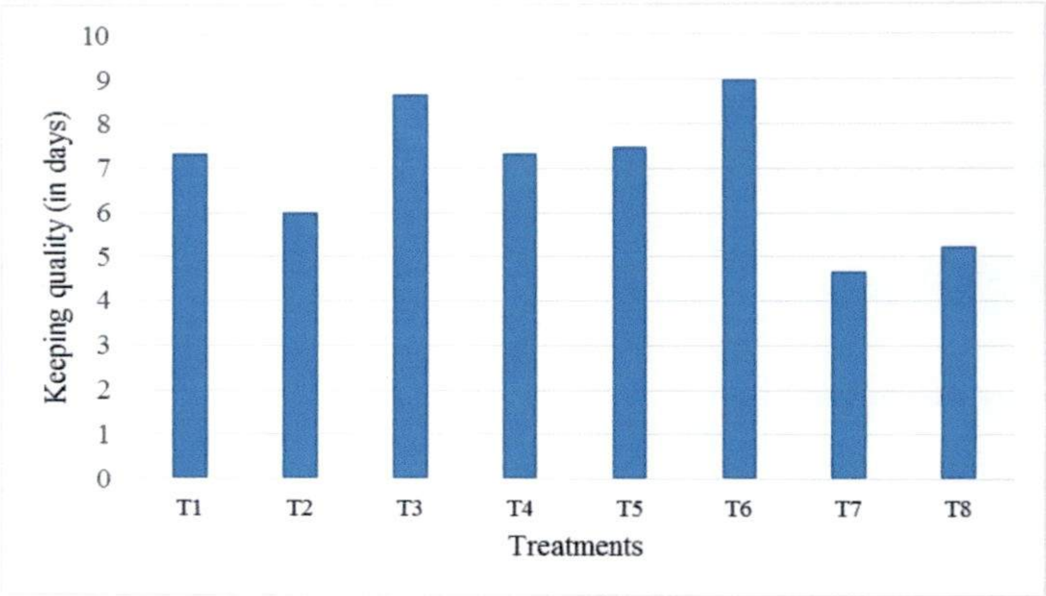

Fig. 21 Effect of multinutrient fortified humic acids on keeping quality (days)

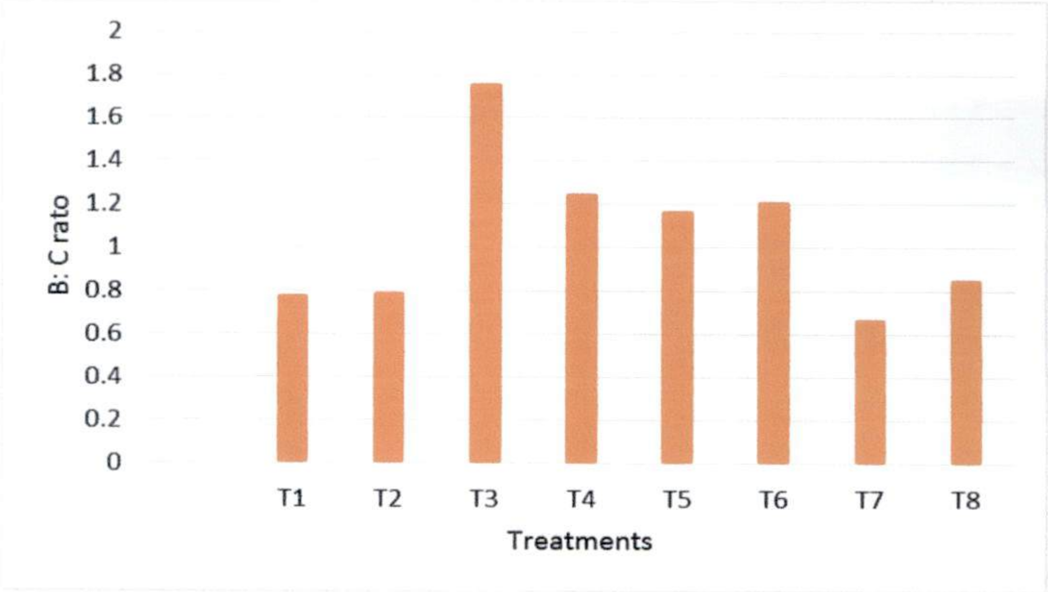

Fig. 22 Effect of multinutrient fortified humic acids on B: C ratio of the crop.

5.2.6 Nutrient Analysis of Shoot and Fruit

5.2.6.1 Nitrogen, Phosphorus and Potassium

Significant difference was observed in the content of nitrogen in shoot and fruit fifty percent flowering and final harvest (Table 29 and 33) (Fig. 23 and 24).

At 50 per cent flowering the highest shoot N content was recorded from T_3. At final harvest stage also the highest shoot N content was recorded from T_3 (Fig. 23). Though the available N in vermicompost growth media in the incubation study is only medium, the humic acids extracted from it which was used in the crop study for foliar spray might have contained more nitrogen and contributed to the high N content shoot and fruit in T_3.

N content in fruit (Fig. 24) was also the highest in T_3 at fifty per cent flowering and at final harvest. Similar results were recorded by Khattak and Dost (2010), who reported that application of humic acids @ 1 kg ha^{-1} along with N, P and K resulted in 19 % increase in seed cotton yield and nutrient content.

Regarding P content of shoot (Table 29 and 33) at fifty per cent flowering the highest value was recorded from T_6 (kitchen waste compost humic acid). At final harvest stage also T_6 recorded the highest shoot P content (Fig.23). At 50 per cent flowering fruit P content was highest in T_6 and at final harvest stage the highest value was recorded from T_6. Similar results were recorded by Erdal *et al.* (2000) reported that humic acids combined with P fertilization has increased the dry weight and P uptake in maize and also Babu *et al.* (1989) reported that humic acids application in calcareous soil has increased N, P and K content in groundnut.

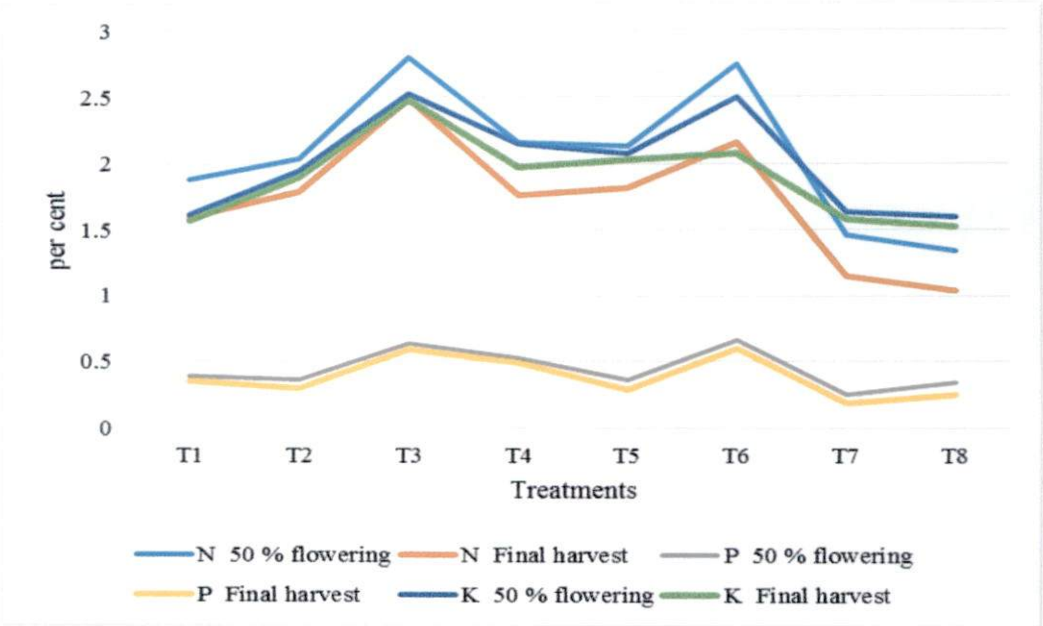

Fig. 23 Contents of N, P and K in shoot portion at different growth stages (per cent.)

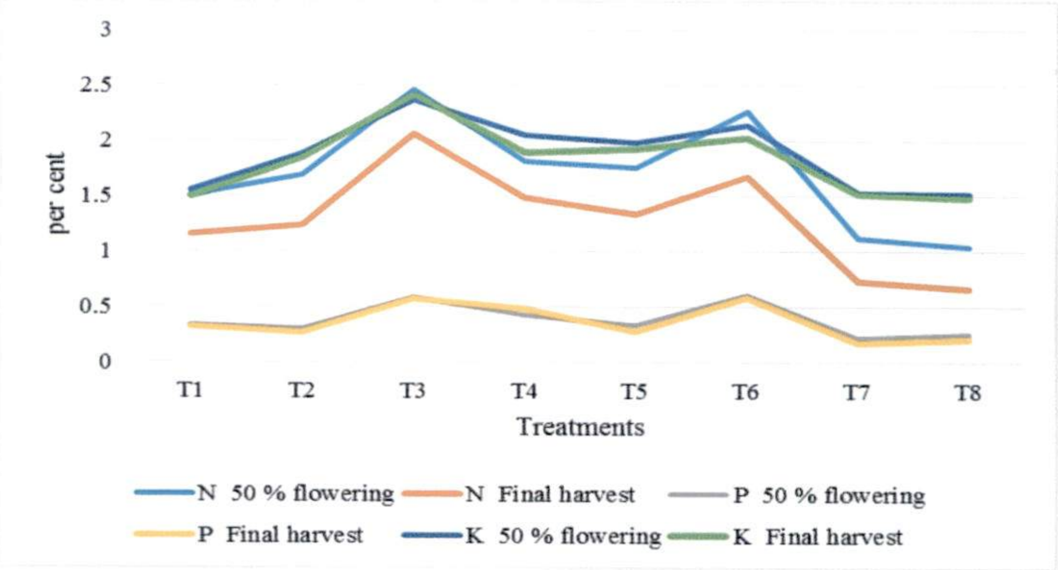

Fig. 24 Contents of N, P and K in fruit portion at different growth stages (per cent)

The data revealed significant difference among the treatments with respect to potassium content in shoot at shoot and fruit at both the stages of crop (Table. 29 and 33). At 50 per cent flowering the highest shoot K content was recorded from T_3. At final harvest stage also T_3 recorded the highest value. Regarding the fruit K content, the treatments were significant only at final harvest stage. Highest value for fruit K was recorded from T_3. Similar results were reported by Katkat *et al.* (2009) who recorded that foliar application of humic acids raised the dry weight and uptake of N, P and K.

5.2.6.2 Calcium, Magnesium and Sulphur

At fifty per cent flowering highest Ca content was recorded from T_3 (Table 30) in shoot (Fig. 25) and fruit (fortified vermicompost humic acid). Similar results were reported by Nikbakth *et al.* (2008) who noted that humic acids application has increased the nutrient content, Ca, Mg, Fe and Zn in gerbera and its flowers also possessed extended shelf life. The postharvest qualities are attributed to Ca accumulation in the scapes and hormonal activity of humic acids. Fruit Ca content at fifty percent flowering was highest in T_6 (Table 31) (Fig. 26). This might be due to inherent high Ca content of kitchen waste compost (Table 8), from which humic acids were extracted.

Shoot Mg content at fifty percent flowering and at final harvest was maximum in T_3 (Table 30) (Fig. 25). Mg content in fruit (Fig. 26) was highest for T_4 and T_5 at fifty per cent flowering and at final harvest respectively. Similar results were reported by Katkat *et al.* (2009), who observed that increased dry weight and uptake of Ca and Mg due to application of humic acids. Sulphur content in shoot was the highest for T_3 at fifty per cent flowering and at final harvest (Table 30). Similar works were reported by Liu *et al.* (1998), who reported that foliar application of 400 mg L^{-1} humic acids showed increased photosynthetic rate and tissue concentration of Mg, Mn and S.

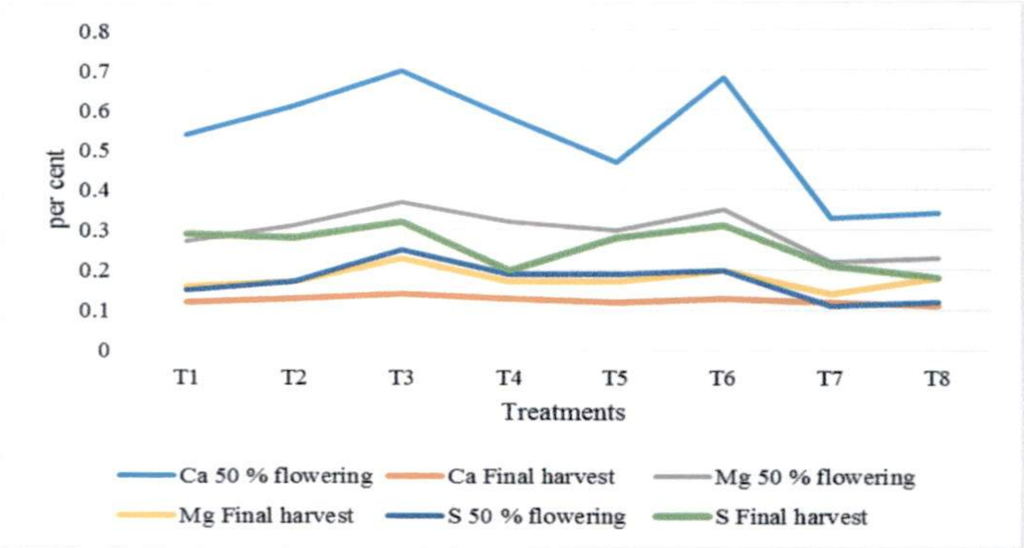

Fig. 25 Contents of Ca, Mg and S in shoot portion at different growth stages (per cent)

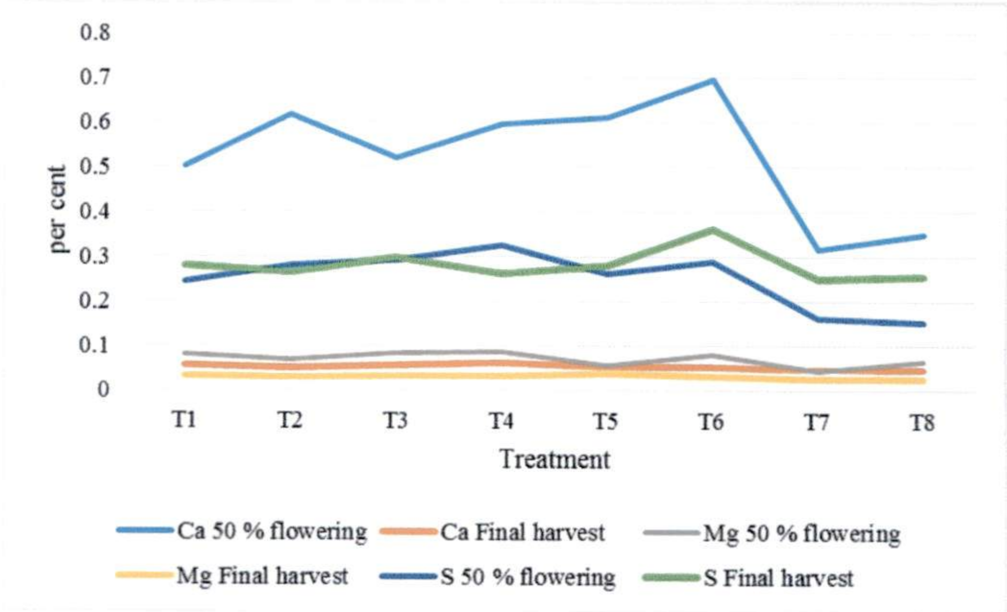

Fig. 26 Contents of Ca, Mg and S in fruit portion at different growth stages (per cent.)

5.2.6.3 Iron, Manganese and Zinc

The iron content of shoot was highest in T_6 (Fig. 27) at both stages of crop, which received foliar application fortified humic acids from kitchen waste inoculum compost (Table 31). The Fe content in fruits (Fig. 31) were significant only at final harvest and highest value was noted from T_6.

Mn content in shoot was highest in T_6 at fifty per cent flowering (Fig. 27) and at final harvest, however the fruit Mn content (Table 32) (Fig. 31) was highest for T_3 (fortified vermicompost humic acid) at both stages of the crop. Similar results were reported by Katkat *et al.* (2009) who reported the increased uptake of Fe and Zn through foliar application of humic acids.

Highest Zn content in shoot portion was shown by different treatments at fifty percent flowering and at final harvest stage of crop (Fig. 27) (Table 31). Regarding the Zn content of shoot portion, the highest content was recorded from T_3 and T_6, at fifty percent flowering and at final harvest respectively. Similar results were reported by Kar *et al.* (2007) reported the foliar application of micronutrient fortified humic acids showed increased Zn uptake. Mn content in fruit was highest in T_3 at fifty percent flowering and at final harvest respectively (Fig. 28). The highest Zn content of fruit was recorded from T_6 at final harvest stage of crop (Table 35). Similar results were reported by Khaled and Fawy (2011) reported that soil and foliar application of humic acids increased the uptake of nutrients. Similar results were reported by Pushpa (1996) who reported that vermicompost application in tomato has shown increased uptake of Zn, Cu and Mn.

5.2.6.4 Copper and Boron

Fig. 29 and 30 indicates that Copper and Boron content in shoot and fruit were significantly influenced by the treatments. T_3, the multinutrient fortified humic acids from vermicompost recorded highest content of Cu and B from shoot and fruit

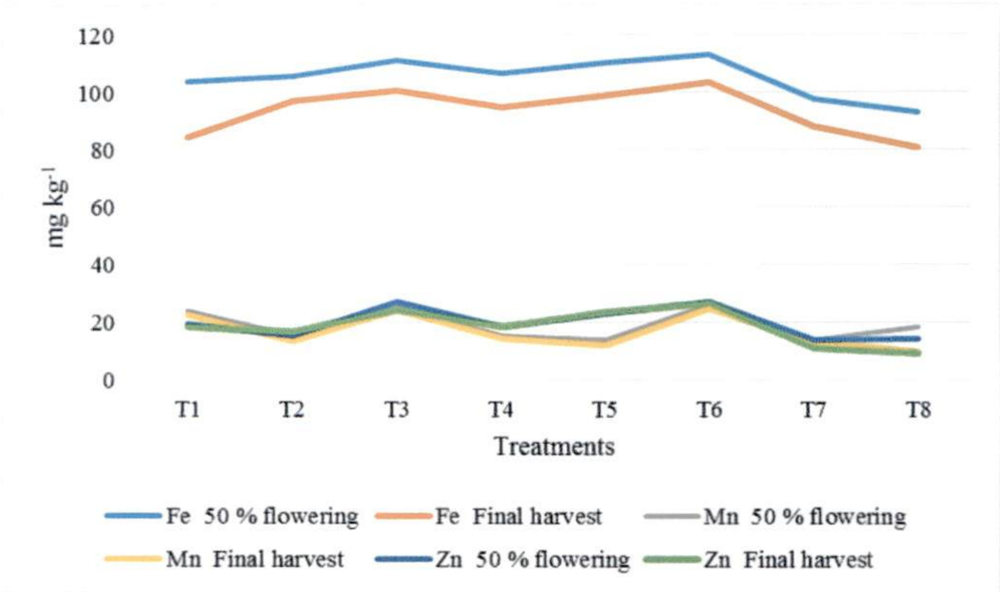

Fig. 27 Contents of Fe, Mn, and Zinc shoot portion at different growth stages (mg kg^{-1})

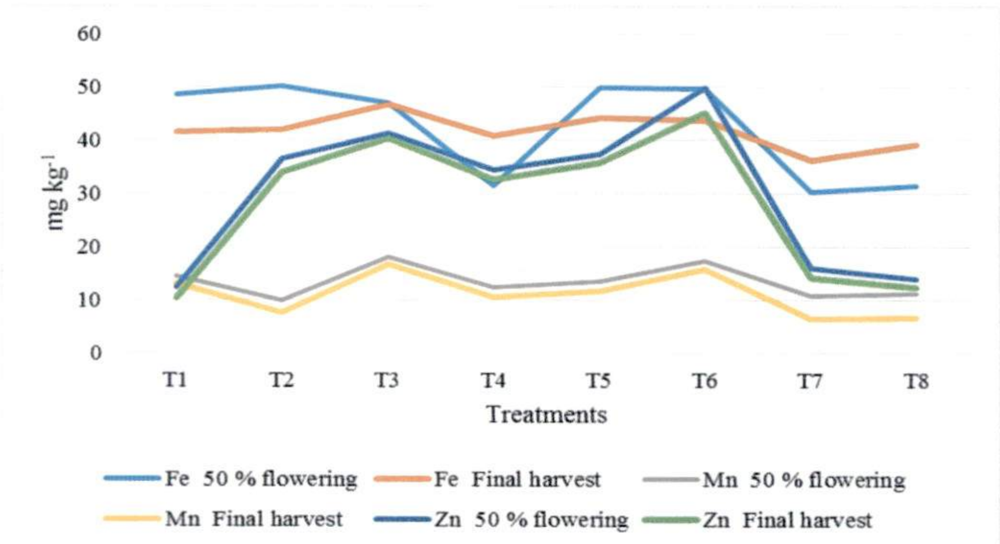

Fig. 28 Contents of Fe, Mn and Zn in fruit portion at different growth stages (mg kg^{-1})

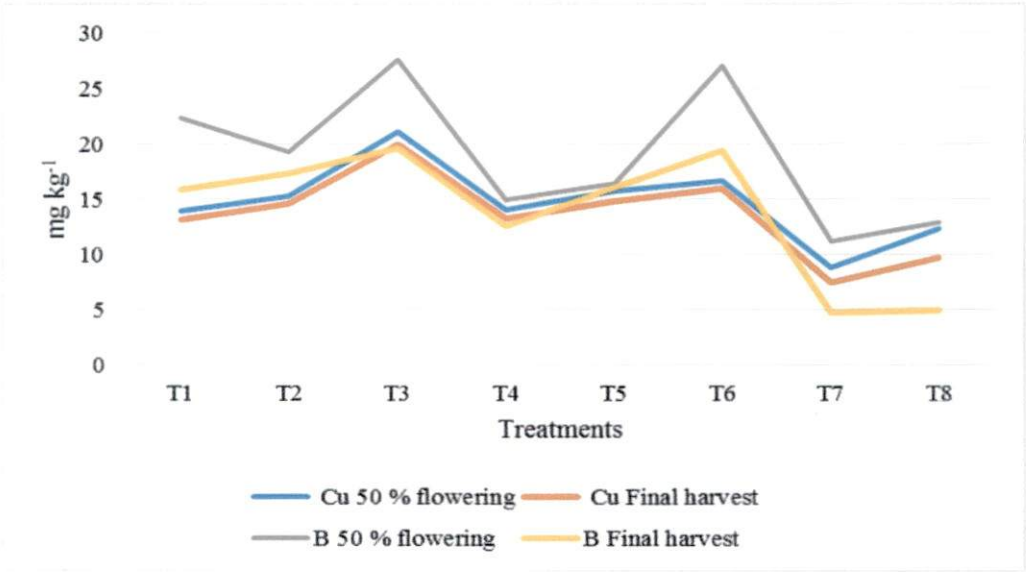

Fig. 29 Contents of Cu and B in shoot portion at different growth stages (mg kg^{-1})

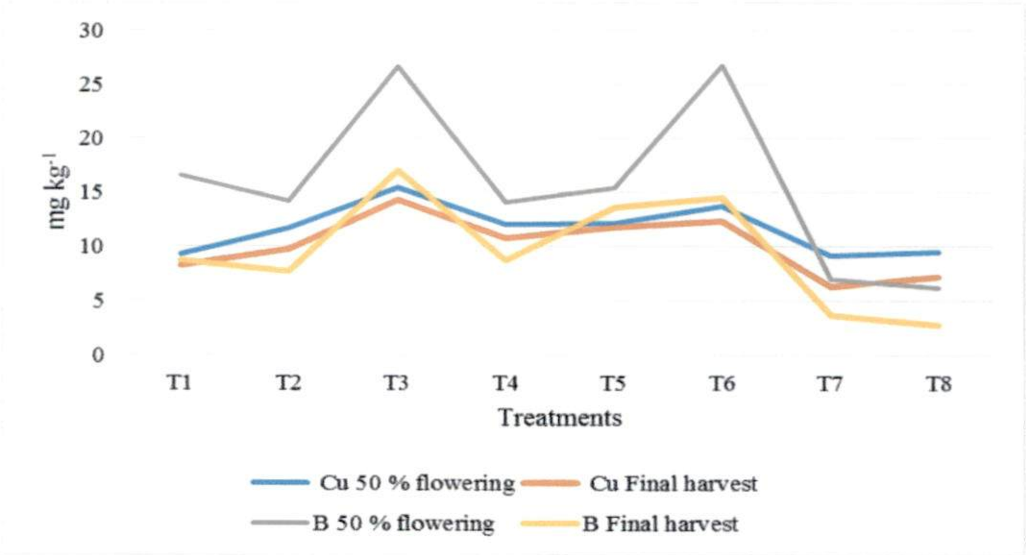

Fig. 30 Contents of Cu and B in fruit portion at different growth stages (mg kg^{-1})

analysis at fifty percent flowering and at final harvest stage of crop (Table 32 and 36). Similar results were noted by Jasmin (1999) which recorded that application of vermicompost extracts resulted in higher content of Cu in plants.

5.2.6.4 Crude Protein Content of Fruit

T_3 (multinutrient fortified humic acids from vermicompost) recorded highest Crude protein content of fruit samples at fifty percent flowering and at final harvest stage(Table 37). Similar results were reported by Babu *et al.* (1989) who reported that humic acids application in calcareous soil has increased the number of pods, haulm yield and crude protein content of groundnut.

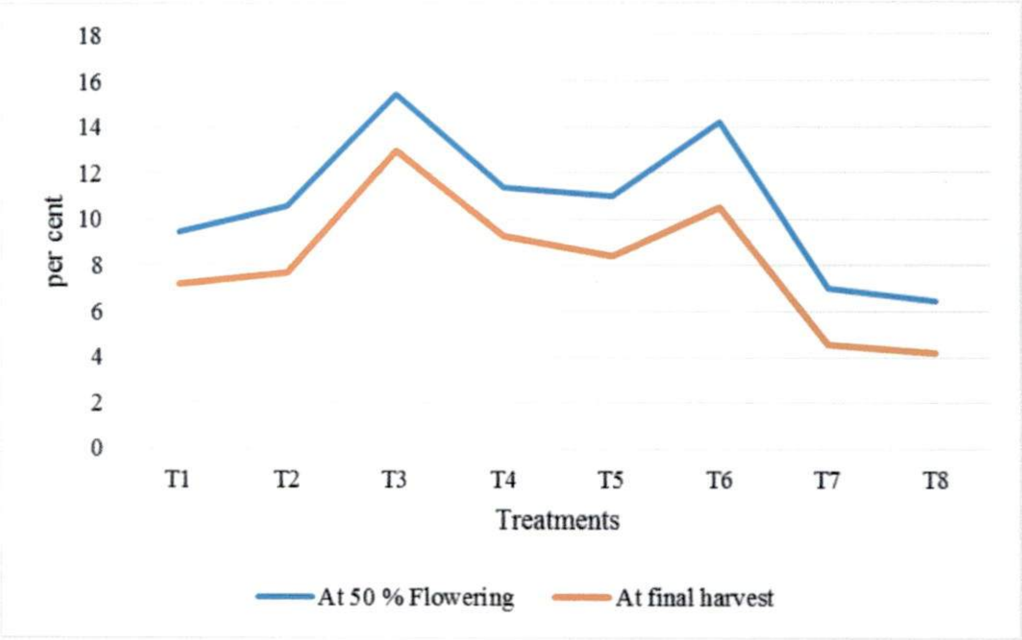

Fig. 31 Crude Protein content in fruit portion at different growth stages (per cent)

Summary

6. SUMMARY

The study entitled "Evaluation of fortified humic acids from growbag mixtures as phytotonic in Okra. [*Abelmoschus esculentus* (L.) Moench]" was undertaken with objectives to study the physicochemical characteristics and microbial enumeration of growbag mixtures and the effect of their humic acids fortified with multi nutrient mixture as foliar spray on growth, yield and quality of okra. The study consisted of two parts, an incubation study and a crop study in grow bags. Incubation study was carried out with different growth media as treatments of which the first treatment was conventional composition of growbag medium ie. soil + sand + FYM. The third component FYM was replaced by various organic substrates, the third component of other the other treatments of incubation study were coir pith compost, vermicompost, desi cowdung mixed with assorted farm waste, desi cow dung mixed with straw and *Gliricidia* and kitchen/ food waste compost prepared using composting inoculum respectively. Incubated growth mixtures were sampled 6 times at fortnightly intervals and analysed for physicochemical properties and microbial load. Humic acids were extracted from growth mixtures after two months of incubation and were characterised and fortified with multinutrient mixture.

The effect of multinutrient fortified humic acids were assessed in the growbag containing routine potting mixture using okra variety Varsha Uphar as the test crop during January 2017- April 2017 as per POP recommendations. The study consisted of eight treatments in which HA_1 to HA_6, were humic acids extracted from the incubated growbag media of different composition and fortified with multinutrient mixture as T_1 to T_6 respectively, T_7- water spray and T_8- extractant spray (0.5 N NaOH). Foliar application of treatments at 0.5 % concentration were given at fortnightly intervals throughout the crop period. The plant samples were analysed at fifty percent flowering and at final harvest for nutrient composition and fruit quality.

The incubation was carried out for a period of three months maintaining the moisture @ 60 per cent water holding capacity.

- Incubation study recorded neutral to alkaline pH in all media except coir pith medium in which it was acidic to neutral (5.4-7.5) and kitchen waste inoculum compost it was in the alkaline range throughout the incubation period (8.8-10.4) indicating the ameliorative capacity of organic substances in acid soils.

- EC of the growth media was non saline in all media except in medium containing kitchen waste inoculum compost (7.15-8.50 dS m^{-1}) which can be overcome by reducing the quantity of inoculum compost while making the growth media.

- Available N content was highest in kitchen waste inoculum compost (703.0 kg ha^{-1}) and all in other media it was in low to medium status.

- Available P content was high in all media except in coirpith compost containing medium in which it was in medium status only. Highest P content was recorded from vermicompost medium (93.9 kg ha^{-1}).

- Available K was high in all media except coir pith medium, where it was low to medium and the highest K content was recorded in kitchen waste inoculum compost (9893.3 kg ha^{-1}).

- Ca content was sufficient (>300 mg kg^{-1}) throughout in all media except in coirpith containing medium. Lowest available Ca (103.3 mg kg^{-1}) was observed in coirpith containing medium in the first fortnight only.

- Available Mg showed variations during the period of incubation. In general it was sufficient (>120 mg kg^{-1}) in all the media, and the nutrient release pattern showed an increasing trend.

- Available B was highest in kitchen waste compost (0.71-3.58 mg kg^{-1}). Generally, the availability of other micronutrients (Fe, Mn, Cu and Zn) were not significantly influenced by the composition of the growth media.

- Microbial enumeration of incubated samples showed highest bacterial count from vermicompost (8.88 log cfu g^{-1} soil).

- Fungal population was found to be maximum in coir pith compost (5.39 log cfu g^{-1} soil) in which pH was more conducive for fungi than in other media.

- Highest count of actinomycetes was noted in growth medium with desi cow dung and farm waste. It is noteworthy that quantity of desi cowdung used in the growth medium was only one-fourth quantity of FYM/ compost in other media, which is in confirmation with the reports of natural farming.

- Humic acids extracted from the vermicompost growth media showed a higher total acidity of 12 meq g^{-1} of humic material. Content of humic acids was also highest in vermicompost media indicating that, of total humic acids, fulvic acid is more than humic acid component.

- Time taken for pH stabilization of humic acids was highest for desi cow dung mixed with assorted farm waste medium. Indicating that it contains more humic acid than fulvic acid.

- Crop study in growbag revealed that different humic acids fortified with multinutrient mixture have significant effect on growth and yield of bhindi. Application of vermicompost humic acids (T_3) recorded the best biometric characters and yield characters *viz*., days to flowering (36.7 days), number of fruits per plant (24.3), average fruit weight (17.1 g) and a highest yield of (415.4 g plant^{-1}). T_3 also recorded the highest crude protein content (15.40 %) and B: C ratio (1.76).

- All biometric characters except internodal length at first harvest was found to be positively correlated with yield.

- The results of plant nutrient analysis in shoot indicated that T_3 (fortified vermi compost humic acids) has the highest content of total N (2.80 %) and K (2.52 %), while T_6 recorded highest content of P (0.66 %). The N, P, K status of T_3 was found to be positively correlated with yield. Content of secondary nutrients was also the highest in T_3.

- T_6 (fortified kitchen waste humic acids) recorded the highest amount of P, Fe, Mn and Zn in shoot portion and highest content of P, Fe and Cu in fruit

- The multinutrient fortified humic acids from vermicompost (T_3) recorded the highest content of Cu and B in shoot and fruit at fifty percent flowering and at final harvest stage of crop

- The highest Crude protein content of fruit samples at fifty percent flowering and at final harvest stage was noted in T_3 which received multinutrient fortified humic acids from vermicompost.

- Correlation analysis was carried out between yield and plant nutrient content at fifty percent flowering stage. The results of the correlation study indicated that N, S and Cu recorded r the values 0.824, 0.919 and 0.879, and were significantly correlated to yield at 0.05 level. Whereas, nutrient content of P, K and Zn were positively correlated to yield at 0.01 level.

Conclusion

The study concluded that composition of growth media has significantly influenced quantity and quality of humic acids. In the incubation study T_6 (kitchen waste compost) recorded the highest nutrient content followed by T_3 (vermicompost). However, the highest humic acids content was noted in the medium containing vermicompost comparing the effects of fortified humic acids, best results in crop study were shown by the vermicompost HA (T_3), followed by the treatment which received HA extracted from medium containing desi cowdung mixed with assorted farm waste (T_4). Hence humic acids extracted from growth media containing vermicompost, fortified with multinutrient mixture can be recommended as a phytotonic.

In the incubation study kitchen waste compost (T_6) reported highest nutrient content followed by vermi compost. Even though the nutrient content was high in T_6, the pH and EC were beyond the safe limit, this makes it undesirable as a growbag media when used in equal proportion with sand and soil by weight. Composition of growth media significantly influenced quantity and quality of humic acids. Comparing the effects of fortified humic acids, best results in crop study was recorded in vermi compost HA (T_3). Indicating that the quality of humic acids from vermicompost was superior.

Future line of work

- Effect of soil application of fortified humic acids on soil health and productivity need to be validated.
- Evaluation of kitchen waste inoculum compost need to be attempted by reducing its quantity in growth media as it is rich in nutrients.

References

7. REFERENCES

Adani, F., Genevini, P., Zaccheo, P., and Zocchi, G. 1998. The effect of commercial humic acid on tomato plant growth and mineral nutrition. *J. Plant Nutr.* 21 (3): 561-575.

Alexander, M. 1978. Introduction to soil microbiology. *Soil Sci.* 125 (5): 127-331.

Ammal, B. U. and Muthiah, D. N. 1994. Potassium release characteristics in soil as influenced by inorganic and organic manuring. *J. Pot. Res.* 10 (3): 223-228.

Arancon, N. Q., Edwards, C. A., Lee, S., and Byrne, R. 2006. Effects of humic acids from vermicomposts on plant growth. *Eur. J. Soil Biol.* 42: 65-69.

Asli, S. and Neumann, P. M. 2010. Rhizosphere humic acid interacts with root cell walls to reduce hydraulic conductivity and plant development. *Plant Soil* 336: 313-322.

Aswath, C. and Pillai, P. 2004. Effect of coco peat medium and electrical conductivity on production of gerbera. *J. Ornam. Hortic.* 7 (1): 15-22.

Atiyeh, R. M., Lee, S., Edwards, C. A., Arancon, N. Q., and Metzger, J. D. 2002. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresource Technol.* 84 (1): 7-14.

Atlas, R. M. and Parks, L. C. 1993. *Handbook of Microbiological Media.* CRC Press Inc., London, 529p.

Awang, Y., Isamil, M. R., and Roeber, R. U. 1997. The growth and flowering of some annual ornamentals on coconut dust. *Acta Hortic.* 450: 31-38.

Azarmi, R., Giglou, M. T., and Taleshmikail, R. D. 2008. Influence of vermicompost on soil chemical and physical properties in tomato (*Lycopersicum esculentum*) field. *Afr. J. Biotechnol.* 7 (14): 2397-2401.

Azarpour, E., Moradi, M., and Bozorgi, H. R. 2012. Effects of vermicompost application and seed inoculation with biological nitrogen fertilizer under different plant densities in soybean [*Glycine max* (L.) cultivar, Williams]. *Afr. J. Agric. Res.* 7 (10): 1534-1541.

Babu, M., Govindasamy, R., and Chandrasekaran, S. 1989. Effect of humic acid on the yield and composition of peanut (*Arachis hypogea* L.) in calcareous soil. In: *Humus Acids in Agriculture.* Proceedings of the national seminar, Chidambaram, Annamalai University, Tamil Nadu, pp. 131-138.

Bachman, G. R. and Metzger, J. D. 2007. Physical and chemical characteristics of a commercial potting substrate amended with vermicompost produced from two different manure sources. *Hortic. Technol.* 17 (3): 336-340.

Bama, K. S., Selvakumari, G., and Mani, P. J. 2005. Role of humic acid and fertilizers on soil enzymes. *J. Ecobiol.* 17: 109-112.

Barche, S., Singh, P., Mahasagar, H., and Singh, D. B. 2011. Response of foliar application of micronutrients on tomato variety Rashmi. *Indian J. Hortic.* 68 (2): 278-279.

Basker, A., Macgregor, A. N., and Kirkman, J. H. 1992. Influence of soil ingestion by earthworms on the availability of potassium in soil - An inoculation experiment. *Biol. Fertil. Soils* 14: 300-303.

Bhatt, L. and Srivastava, B. K. 2005. Effect of foliar application of micronutrients on physical characteristics and quality attributes of tomato (*Lycopersicon esculentum*) fruits. *Indian J. Agric. Sci.* 75 (9): 591-592.

Bray, R. H. and Kurtz, L. T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* 59: 39-45.

Canellas, L. P., Olivares, F. L., Okorokova-Façanha, A. L., and Façanha, A. R, 2000. Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence, and plasma membrane H^+-ATPase activity in maize roots. *Plant Physiol.* 130 (4): 1951-1957.

Cappuccino and Sheman. 1996. *Microbiology - A Laboratory Manual* (4^{th} Ed.). The Benjamin/ Cummings Publishing Company Inc., 213p.

Chen, Y. and Aviad, T. 1990. Effects of humic substances on plant growth. In: *Humic Substances in Soil and Crop Sciences: Selected Readings*. Soil Science Society of America, Guilford, pp.161-186.

Cochran, W. G. and Cox, G. M. 1965. *Experimental Designs*. John Willey and Sons Inc., New York, 182p.

Cuckoorani, M. 2013. Organic nutrients scheduling in soilless vegetative cultivation. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 101 p.

Deiana, S., Gessa, C., Manunza, B., Rausa, R., and Seeber, R. 1990. Analytical and spectroscopic characterization of humic acids extracted from sewage sludge, manure, and worm compost. *Soil Sci.* 150 (1): 419-424.

Delfine, S., Tognetti, R., Desiderio, E., and Alvino, A. 2005. Effect of foliar application of N and humic acids on growth and yield of durum wheat. *Agron. Sustain. Dev.* 25 (2): 183-191.

Dhanasekaran, K. and Bhuvaneswari, R. 2005. Effect of nutrient-enriched humic acid on the growth and yield of tomato. *Int. J. Agric. Sci.* 1 (1): 80-83.

Dhanasekaran, K., Bhuvaneswari, R., and Umadevi, M. 2007a. Effect of foliar feeding of energized lignite humic acid on bhindi (*Abelmoschus esculentum* L.). *Annamali Univ. Agric. J.* 25: 871- 876.

Dhanasekaran, K., Bhuvaneswari, R., Sathyamurthi. S., and Sivakumar, K. 2007b. Response of foliar application of humic acid on growth and yield of bhindi. *Inter. J. Trop. Agric.* 25: 871-876.

Dhanasekaran, K., Sivakumar, K., Bhuvanesewari, R., and Sathiyamurthi, S. 2009. Effect of soil application of lignite humic acid on the growth and yield of tomato. *Int. J. Trop. Agric.* 27: 15-16.

DOA [Department of Agriculture]. 2013. Manual on soil plant and water analysis. Venugopal, V. K., Nair, K. M., Vijayan, M. R., John, K. S., Suresh kumar, P., and Ramesh, C. R. (eds), Government of Kerala, 157p.

Edwards, C. A. and Fletcher, K. E. 1988. Interactions between earthworms and microorganisms in organic-matter breakdown. *Agric. Ecosyst. Environ.* 24 (1-3): 235-247.

Edwards, C. A., Dominguez, J., and Arancon, N. Q. 2004. The influence of vermicompost on plant growth and pest incidence. *Soil Zoology for Sustainable Development in the 21st Century, Cairo*, pp.397-420.

Elayaraja, D., Vetriselvan, R., and Dhanasekaran, K. 2010. Effect of NPK levels and different humic acid formulations on the growth, yield and nutrients uptake by ladies finger. *Int. Res. J. Chem.* 38: 19-28.

Erdal, I., Turkmen, O., and Yildiz, M. 2000. Effect of potassium fertilizer on the development of cucumber (*Cucumis sativus* L.) fidelities grown under salt stress and changes in the content of certain nutrients. *Yuzuncu Yıl Univ. J. Agric. Sci.* 12 (2): 108-112.

Erro, J., Urrutia, O., Baigorri, R., Aparicio-Tejo, P., Irigoyen, I., Storino, F., Mandado, M., Yvin, J. C., and Garcia-Mina, J. M. 2012. Organic complexed superphosphates (CSP): physicochemical characterization and agronomical properties. *J. Agric. Food Chem.* 60 (8): 2008-2017.

Eyheraguibel, B., Silvestre, J., and Morard, P. 2008. Effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of maize. *Bioresource Technol.* 99 (10): 4206-4212.

Fuleky, G. and Czinkota, I. 1993. Hot water percolation (HWP): A new rapid soil extraction method. *Plant Soil* 157: 131-135.

Gaur, A. C. 1990. *Phosphate Solubilizing Microorganisms as Bio Fertilizers.* Omega publications, New Delhi, 176p.

Giuffrida, F., Leonardi, C., and Marfa, O. 2008. Substrate reuse in tomato soilless cultivation. *Acta Hortic.* 801: 1577-1582.

Glaser, B., Lehmann, J., and Zech, W. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal - a review. *Biol. Fertil. Soils* 35 (4): 219-230.

Govindasamy, R., Chandrasekaran, S., and Natarajan, K. 1989. Influence of (lignite) humic acid on ammonia volatilization from urea. In: *Humus Acids in Agriculture.* Proceedings of the national seminar, Chidambaram, Annamalai University, Tamil Nadu. pp. 151-164

Govindasmy, R. and Chandrasekaran, S. 1992. Effect of humic acids on the growth, yield and nutrient content of sugarcane. *Sci. Total Environ.* 117: 575-581.

Gupta, U. C. 1967. A simplified method for determining hot-water soluble form of boron in Podzol soils. *Soil Sci.* 103: 424-428.

Gutierrez-Miceli, F. A., Santiago-Borraz, J., Molina, J. A. M., Nafate, C. C., Abud-Archila, M., Llaven, M. A. O., Rincon-Rosales, R., and Dendooven, L. 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). *Bioresource Techno.* 98 (15): 2781-2786.

Haghighi, M., Kafi, M., and Fang, P. 2012. Photosynthetic activity and N metabolism of lettuce as affected by humic acid. *Int. J. Veg. Sci.* 18 (2): 182-189.

Hayes, M. H. 2006. Solvent systems for the isolation of organic components from soils. *Soil Sci. Soc. Am. J.* 70 (3): 986-994.

Hazra, P., Maity, T. K., and Mandal, A. R. 1987. Effect of foliar application of micronutrients on growth and yield of okra (*Abelmoschus esculentus* L). *Prog. Hortic.* 19 (3): 219-222.

Ikram, S., Habib, U., and Khalid, N. 2012. Effect of different potting media combinations on growth and vase life of Tuberose (*Polianthes tuberosa* Linn.). *Pak. J. Agri. Sci.* 49 (2): 121-125.

Indira, B. N., Rao, J. C. B., Senappa, C., and Kale, R. D. 1996. Microflora of vermicompost. In: Veeresh, C. K. (ed.), *Proceedings of National Seminar on Organic Farming and Sustainable Agriculture,* 9-11 October 1996, Banglore. Association of Promotion of Organic Farming, Banglore, pp.51-52.

Jackson, M. L. 1973. Soil Chemical Analysis (2nd Edition). Prentice Hall of India, New Delhi, 498p.

Jariene, E., Danilcenko, H., Kulaitiene, J., and Gajewski, M. 2007. Effect of fertilizers on oil pumpkin seeds crude fat, fibre and protein quantity. *Agron. Res.* 5 (1): 43-49.

Jasmin, R. 1999. Effect of soil and foliar application of vermiwash on growth yield and quality of tomato (*Lycopersicon esculentum* Mill.) M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 126p.

Jiji, T., Dale, D., and Padmaja, P. 1996. Vermicompost reduces the requirement of chemical fertilizers in cowpea and bittergourd. In: Veeresh, C. K. (ed.), *Proceedings of National Seminar on Organic Farming and Sustainable Agriculture,* 9-11 October 1996. Banglore. Association of Promotion of Organic Farming, Banglore, pp.87-88.

Kale, R. D. and Krishnamurthy, R. V. 1980. The calcium content of the body tissues and castings of the earthworm *Pontoscolex corethrurus* (Anelida, Oligocheta). *Pedobiologia* 20: 309-315.

Kaloi, G. M., Bhughio, N., Panhwar, R. N., Junejo, S., Mari, A. H., and Bhutto, M. A. 2011. Influence of incubation period on phosphate release in two soils of district Hyderabad. *J. Anim. Plant Sci.* 21: 665-670.

Kar, D., Ghosh, D., and Srivastava, P. C. 2007. Efficacy evaluation of different zinc-organo complexes in supplying zinc to maize (*Zea mays* L.) plant. *J. Indian Soc. Soil Sci.* 55 (1): 67-72.

Katkat, A. V., Celik, H., Murat Ali, Turan and Ashik, B. B. 2009. Effects of soil and foliar application of humic substance on dry weight and mineral nutrient uptake of wheat under calcareous soil conditions. *Aust. J. Basics App. Sci.* 3: 1266-1273.

Khalate, S. P., Sanghavi, K. U., and Kadam, J. R. 1990. Effect of some micronutrients on seed yield and seed quality of onion. *South Indian Hortic.* 50 (1-3): 248-250.

Khaled, H. and Fawy, H. A. 2011. Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil Water Res.* 6 (1): 21-29.

Khattak, R. A. and Dost, M. 2010. Seed cotton yield and nutrient concentrations as influenced by lignitic coal derived humic acid in salt-affected soils. *Sarhad J. Agric.* 26 (1): 43-49.

Kirn, A., Kashif, S. R., and Yaseen, M. 2010. Using indigenous humic acid from lignite to increase growth and yield of okra (*Abelmoschus esculentus* L.). *Soil Environ.* 29 (2):187-191.

Lee, K. E. 1985. *Earthworms: their ecology and relationships with soils and land use.* Academic Press Inc., Cambridge, 123p.

Levesque, M. and Schnitzer, M. 1966. Effects of NaOH concentration on the extraction of organic matter and of major inorganic constituents from a soil. *Can. J. Soil Sci.* 46 (1): 7-12.

Liu, C., Cooper, R. J., and Bowman, D. C. 1998. Humic acid application affects photosynthesis, root development, and nutrient content of creeping bentgrass. *Hortic. Sci.* 33 (6): 1023-1025.

Lokesh, R., Mahishi, D. M., and Shivashankar, G. 1988. Studies on use of coconut coirdust as rooting medium. *Curr. Res.* 17: 157- 158.

Lopez-Mosquera, M. E., Moirón, C., and Seoane, S. 2002. Changes in chemical properties of an acid soil after application of dairy sludge. *Invest. Agric. Prod. Prot. Veg.* 17 (1): 78-86.

Madhumathi, G. 1991. Effect of humic acids and zinc on growth and yield of hybrid sorghum (CSH-9). *J. Res.* 16: 36-43.

Makarov, M., Haumaier, L., and Zech, W. 2002. The nature and origins of diester phosphates in soils: a 31P-NMR study. *Biol. Fertile. Soils* 35(2): 136-146.

Martin, J. P. 1950. Use of acid, rose bengal, and streptomycin in the plate method for estimation soil fungi. *Soil Sci.* 69: 215-232.

McBride, M. B. 1994. *Environmental Chemistry of Soils*. Oxford University Press, New York, 286p.

Medhi, G. and Kakati, R. N. 1994. Effect of micronutrients in increasing the growth and yield of bhendi (Abelmoschus esculentus L.). *Hortic. J.* 7 (2): 155-158.

Mini, V. 2015. Assessment and management of micronutrient deficiencies in Onattukara. Ph.D. thesis, Kerala Agricultural University, Thrissur, 242 p.

Nardi, S., Pizzeghello, D., Muscolo, A., and Vianello, A. 2002. Physiological effects of humic substances on higher plants. *Soil Biol. Biochem.* 34 (11): 1527-1536.

Narimani, H., Rahimi, M. M., Ahmadikhah, A., and Vaezi, B. 2010. Study on the effects of foliar spray of micronutrient on yield and yield components of durum wheat. *Arch. Appl. Sci. Res*. 2 (6): 168-176.

Naruka, I. S., Gujar, K. D., and Gopal, L. 2000. Effect of foliar application of zinc and molybdenum on growth and yield of okra (*Abelmoschus esculentus* L. Moench) cv. Pusa Sawani. *Haryana J. Hortic. Sci.* 29 (3): 266-267.

Nash, V. E. and Laiche Jr, A. J. 1981. Changes in the characteristics of potting media with time. *Commun. Soil Sci. Plant Anal.* 12 (10): 1011-1020.

Newman, S. E. and Follett, M. 1989. Comparison of the effects of Super-start+ to a standard soluble fertilizer on geraniums. *Res. Report Mississippi Agric. Forestry Exp. Stn*. 14: 1-4.

Nikbakht, A., Kafi, M., Babalar, M., Xia, Y. P., Luo, A., and Etemadi, N. A. 2008. Effect of humic acid on plant growth, nutrient uptake, and postharvest life of gerbera. *J. Plant Nutr.* 31 (12): 2155-2167.

O'Donnell, R. W. 1973. The auxin-like effects of humic preparations from leonardite. *Soil Sci.* 116 (2): 106-112.

Padem, H., Ocal, A., and Alan, R. 1997. Effect of humic acid added to foliar fertilizer on quality and nutrient content of eggplant and pepper seedlings. *In: Greenhouse Management for Better Yield & Quality in Mild Winter Climates.* Proceedings of an international symposium, Turkey. ISHS, pp. 241-246.

Paksoy, M., Türkmen, O., and Dursun, A. 2010. Effects of potassium and humic acid on emergence, growth and nutrient contents of okra (*Abelmoschus esculentus* L.) seedling under saline soil conditions. *Afr. J. Biotechnol.* 9 (33): 5343-5346.

Patil, P. V., Chalwade, P. B., Solanke, A. S., and Kulkarni, V. K. 2003. Effect of fly ash and FYM on physicochemical properties of vertisols. *J. Soils* Crops 13 (1): 59-64.

Pettit, R. E. 2004. Organic matter, humus, humate, humic acid, fulvic acid and humin: their importance in soil fertility and plant health. *CTI Res.* 1-14.

Peyvast, G. H., Olfati, J. A., Madeni, S., and Forghani, A. 2008. Effect of vermicompost on the growth and yield of spinach (*Spinacia oleracea* L.). *J. Food Agric. Environ.* 6 (1): 110-113.

Piccolo, A., 2002. The supramolecular structure of humic substances: a novel understanding of humus chemistry and implications in soil science. *Adv. Agron.* 75: 57-134.

Piccolo, A., Pietramellara, G., and Mbagwu, J. S. C. 1996. Effects of coal derived humic substances on water retention and structural stability of Mediterranean soils. *Soil Use Manag.* 12 (4): 209-213.

Pierce, J. G. 1972. The calcium relations of selected lumbricidae. *J. Anim. Ecol.* 41: 167-188.

Ping, Z. P., Xue, S. C., Shun, Z. M., Men, M. X., and Zhao, H. X. 2001. Study the effect of humic acid (HA) compound fertilizer on the quality and physiologic index of rape seed. *J. Agric. Res.* 21: 14-23.

Piper, C. S. 1966. *Soil and plant analysis*. Hans Publishers, Bombay, 487p.

Pushpa, S. 1996. Effect of vermicompost on the yield and quality of tomato (*Lycopersicon esculentum* Mill.). M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 90p.

Rahim, N. A. 2015. *Effect of Planting Density and Growing Media on Growth and Fruit Production of Okra* (*Abelmuschus esculentus* (L.) Moench. Project Report (B.Sc.), University Malaysia, Sarawak, 24p.

Rathod, V. E., Sagare, B. N., Ravanika, H. N., Sarp, P. A., and Hadole, S, S. 2003. Efficacy of amendmens for improvement in soil properties and yield of cotton grown in sodic vertisols of Vidharba using alkali water. *J. Soils and Crops* 13 (1): 176-178.

Ravichandran, M. 2011. Humic acids: A mystique substance in sustainable crop production. *J. Indian Soc. Soil Sci.* 59: 49-57.

Reza, S. K., Pal, S., and Singh, S. 2012. Rock phosphate-enriched pressmud compost: Direct effect in pearl millet (*Pennisetum glaucum* L.) and residual effect in mustard (*Brassica juncea*) in a Typic Haplustept. *J. Indian Soc. Soil Sci.* 60 (2): 134-138.

Sangeetha, M., Singaram, P., and Devi, R. D. 2006. Effect of lignite humic acid and fertilizers on the yield of onion and nutrient availability. *Proceedings of the Eighteenth World Congress of Soil Science,* 29-31 July 2006, pp. 9-15.

Sangwan, P., Garg, V. K., and Kaushik, C. P. 2010 a. Growth and yield response of marigold to potting media containing vermicompost produced from different wastes. *Environ.* 30 (2): 123-130.

Sangwan, P., Kaushik, C. P., and Garg, V. K. 2010 b. Vermicomposting of sugar industry waste (press mud) mixed with cow dung employing an epigeic earthworm *Eisenia fetida. Waste Manag. Res.* 28 (1): 71-75.

Sao, Y., Bhatt, V. R., and Swarnkar, P. K. 2010. Characterization of humic acids derived from lignite coal and FYM and effect of lignite, humic acid and FYM on yield of fodder maize. *J. Curr. Trends Sci. Technol.* 1 (2): 20-26.

Savithri, P. and Khan H. H. 1994. Characteristics of coconut coir pith and its utilization in agriculture. *J. Plant Crops* 22: 1-18.

Schnitzer, M. 2000. A lifetime perspective on the chemistry of soil organic matter. *Adv. Agron.* 68: 1-58.

Schnitzer, M. and Gupta, U. C. 1964. Some chemical characteristics of the organic matter extracted from the O and B2 horizons of a gray wooded soil. *Soil Sci. Soc. Am. J.* 28 (3): 374-377.

Schnitzer, M. and Khan, S. U. 1978. *Soil Organic Matter*. Elsevier Science Ltd, New York, 365p.

Searle, S. R. 1961. Phenotypic, genotypic and environmental correlations. *Biometrics* 17: 474-780.

Sellamuthu, K. M. and Govindaswamy, M. 2003. Effect of fertilizer and humic acid on rhizosphere microorganisms and soil enzymes at an early stage of sugarcane growth. *Sugar Tech.* 5 (4): 273-277.

Serenella, N., Pizzeghelloa, D., Muscolb, A., and Vianello, A. 2002. Physiological effects of humic substances on higher plants. *Soil Biol. Biochem.* 34: 1527-1536.

Sharif, M., Khattak, R. A., and Sarir, M. S. 2002. Effect of different levels of lignitic coal derived humic acid on growth of maize plants. *Commun. Soil Sci. Plant Anal.* 33: 3567-3580.

Shuxin, L., Xiong, D. and Debning, W. 1991. Studies on the effect of earthworms on the fertility of red arid soil. In: Veeresh, G. K., Rajagopal, D., and Vikranth, C. A. (eds), *Advances in Management and Conversion of Soil Fauna.* Oxford and IBH publishing Co., New Delhi, pp. 543-545.

Simpson, J. E., Adair, C. R., Kohler, G. D., Dawson, E. N., Debald, H. A. and Klick, J. T. 1965. Quality evaluation of foreign-domestic rice. Tech. Bull. No. 1331, USDA, pp. 1- 86.

Sims. J. R. and Johnson, G. 1991. Micronutrient soil tests. In: Mortvedt, J. J., Cox, F. R., Shuman, L. M. and Welch, R. M. (eds), *Micronutrient in Agriculture* (2nd Ed.). SSSA, Madison, USA, pp. 427- 476.

Smith, D. G. and Lorimer, J. W. 1964. An examination of the humic acids of Sphagnum peat. *Can. J. Soil Sci.* 44 (1): 76-87.

Soumya, A. 2015. Performance evaluation of tomato in soilless culture. M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 116 p.

Sparling, G. P., Schipper, L. A., and Russell, J. M. 2001. Changes in soil properties after application of dairy factory effluent to New Zealand volcanic ash and pumice soils. *Soil Res.* 39 (3): 505-518.

Subbaiah, B. V. and Asija, G. L. A. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci.* 25: 259-360.

Tabatabai, M. A. and Bremner, J. M. 1970. An alkaline oxidation method for determination of total Sulphur in soils. *Soil Sci. Soc. Am. Proc.* 34: 62-65.

Takacs, M. and Fuleky, G. 2010. Characterization of dissolved organic matter (DOM) extracted from soils by hot water percolation (HWP). *Agrokemiaes Talajtan* 59: 99-108.

Theunissen, J., Ndakidemi, P. A., and Laubscher, C. P. 2010. Potential of vermicompost produced from plant waste on the growth and nutrient status in vegetable production. *Int. J. Phys. Sci.* 5 (13): 1964-1973.

Thompson, D. W. and Pownall, P. G. 1989. Surface electrical properties of calcite. *J. colloid interface sci.* 131 (1): 74-82.

Timonin, M. J. 1940. The interaction of higher plants and soil microorganisms-microbial population of rhizosphere of seedlings of certain cultivated plants. *Can. J. Res.* 181: 307-317.

Treder, J. 2008. The effects of cocopeat and fertilization on the growth and flowering of oriental lily 'star gazer'. *J. Fruit Ornam. Plant Res.* 16: 361-370.

Trevisan, S., Francioso, O., Quaggiotti, S., and Nardi, S. 2010. Humic substances biological activity at the plant-soil interface: from environmental aspects to molecular factors. *Plant Signaling Behav.* 5 (6): 635-643.

Tringovska, I., Dincheva, T., and Ivanova, I. 2014. Effect of the genotype, vermicompost type and dosage on tomato growth and nutrient uptake at nursery stage. *Int. J. Agric. Innovations Res.* 3 (3): 761-769.

Ushashree, N. N., Govindasamy, R., Karunakaran, C., and Chandrasekharan, S. 1989. In: Proceedings of the National Seminar on acids in agriculture". Annamalai University, Tamil Nadu. pp. 65-70.

Vasuki, N. 2010. Micronutrient management for enhancing crop production-Future strategy and requirement. *J. Indian Soc. Soil Sci.* 58 (1): 32-36.

Walkley, A. J. and Black, I. A. 1934. Estimation of soil Organic carbon by chromic acid titration method. *Soil Sci.* 31: 29- 38.

Warman, P. R. and Anglopez, M. J. 2010. Vermicompost derived from different feed stocks as a plant growth medium. *Bioresource Technol.* 101 (12): 4479-4483.

Warrier, K. C. S., Kumar, K. G. A., and Venkalaramanu, K. 1998. A low cost rooting media for macro propagation of eucalyptus. *Sylva Plus.* 6: 13-17.

Wolf, B. 1971. The determination of boron in soil extracts, plant materials, compost, manure, water and nutrient solutions. *Commun. Soil Sci. Plant Anal.* 2: 363-374.

Wright, J. R. and Schnitzer, M., 1959. Oxygen-containing functional groups in the organic matter of a podzol soil. *Nat*, 184: 1462-1463.

Ying Du, H., Xue-Shi, C., and Sun-Zhong, F. 2007. Effects of different application rates of humic acid compound fertilizer on leave nutrient accumulation and physiological mechanism of grape. *Chinese J. Eco-Agric.*15: 49-51.

Zaller, J. G. 2007. Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. *Sci. Hortic.* 112 (2): 191-199.

Zientara, M. 1983. Effect of sodium humate on membrane potential in internodal cells of *Nitellopsis obtusa*. *Acta Societatis Botanicorum Poloniae*. 52 (3): 271-277.

Zachariah, A. A. 1995. Vermicomposting of vegetable garbage. M. Sc. thesis. Kerala Agricultural University. 157p.

EVALUATION OF FORTIFIED HUMIC ACIDS FROM GROW BAG MIXTURES AS PHYTOTONIC IN OKRA

[*Abelmoschus esculentus* (L.) Moench.]

by

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ABSTRACT

The research entitled "Evaluation of fortified humic acids from growbag mixtures as phytotonic in Okra [*Abelmoschus esculentus* (L.) Moench]" was undertaken with an objective to study the physicochemical characteristics and microbial enumeration of different growbag mixtures and the effect of their humic acids fortified with multinutrient mixture on growth, yield and quality of okra. The study consisted of two parts, an incubation study and a crop study in grow bags. Incubation study was carried out for a period of three months maintaining 60% of water holding capacity. Conventional composition of growbag media, soil + sand + FYM. The third component FYM was replaced by various composts to form 6 treatments. T_1- soil + sand + FYM, T_2 -soil + sand + coirpith compost, T_3- soil + sand + vermicompost, T_4- soil + sand + desi cowdung with assorted farm waste soil, T_5- sand + soil+ desi cowdung mixed with straw and G*liricidia*, T_6- soil + sand + composted kitchen waste using composting inoculum. Incubated mixtures were sampled 6 times and analysed for physicochemical properties and microbial load at fortnightly intervals. Humic acids were extracted from incubation mixtures and were characterised and fortified with multinutrient mixture.

The effect of multinutrient fortified humic acids were assessed in the growbag containing routine potting mixture using okra variety Varsha Uphar as the test crop during January 2017- April 2017 as per POP recommendations. The study consisted of eight treatments in which HA_1 to HA_6, were humic acids extracted from the incubated growbag media of different composition and fortified with multinutrient mixture as T_1 to T_6 respectively, T_7- water spray and T_8- extractant spray (0.5 N NaOH). Foliar application of treatments at 0.5 % concentration were given at fortnightly intervals throughout the crop period. The plant samples were analysed at fifty percent flowering and at final harvest.

Incubation study recorded neutral to alkaline pH in all media except coirpith medium (5.49 - 7.5) and kitchen waste inoculum compost (8.75-10.4). EC of the growing media was non saline in all media except kitchen waste inoculum compost (7.15 - 8.50 d Sm^{-1}). Available N content was highest in kitchen waste inoculum compost (703.0 kg ha^{-1}) and all other media were in low to medium range. Available P content was highest in vermicompost medium (93.9 kg ha^{-1}). Available K was high in all media except coirpith medium where it was low to medium and the highest K content was recorded in kitchen waste inoculum compost (9893 kg ha^{-1}). Ca content was sufficient throughout the incubation in all media except coirpith during the first fortnight (103.3 mg kg^{-1}). Available Mg was found to be deficient in coirpith, vermicompost and kitchen waste during the first fortnight. Available B was highest in kitchen waste compost (6.71 – 3.50 mg kg^{-1}). Generally, the availability of other micronutrients (Fe, Mn, Cu and Zn) were not significantly influenced by the composition of the growth media.

Microbial enumeration of incubated samples showed highest bacterial count from vermicompost (8.88 log cfu /g soil). Fungal population was found to be maximum in coirpith compost (5.39 log cfu/g soil) and highest count of actinomycetes was noted in medium with desi cowdung and farm waste. Humic acids extracted from the vermicompost growth media showed a higher total acidity of 12 meq g^{-1} of humic material. Content of humic acids was the highest in vermicompost media. Time taken for pH stabilization of humic acids was highest for desi cowdung + farm waste medium.

Crop study in growbag revealed that different humic acids fortified with multinutrient mixture have significant effect on growth and yield of bhindi. Application of vermicompost HA (T_3) recorded best biometric characters and yield characters *viz.*, days to flowering (36 days), number of fruits per plant (24 no.), average fruit weight (17.1 g) and a highest yield of (573.15 g $plant^{-1}$). T_3 also showed maximum keeping quality (9 days) and highest crude protein content (15.40 %) in fruit. B: C ratio (1.76) was also highest in T_3.

The results of plant nutrient analysis indicated that T_3 (vermicompost HA) has the highest content of total N (2.80%) and K (2.52 %), while T_6 recorded highest content of P (0.66%) which was on par with T3. The N, P, K status of T_3 was found to be positively correlated with yield. Content of secondary nutrients was also the highest in T_3.

Hence it may be concluded that composition of growth media has significantly influenced quantity and quality of humic acids. In the incubation study T6 (kitchen waste compost) recorded the highest nutrient content followed by T_3 (Vermicompost). However, the highest humic acids content was noted in the medium containing vermicompost comparing the effects of fortified humic acids, best results in crop study were shown by the vermicompost HA (T_3), followed by the treatment which received HA extracted from medium containing desi cowdung + assorted farm waste (T_4). Hence humic acids extracted from growing media containing vermicompost, fortified with multinutrient mixture can be recommended as a phytotonic.

Appendices

Appendix 1

Composition of media used for the isolation of micro organisms

1. Bacteria - Nutrient Agar

Beef extract	-	3g
Peptone	-	5g
NaCl	-	5g
Agar	-	20g
Distilled water	-	1000 ml

2. Fungi- Martins Rose Bengal Agar

Dextrose	-	10g
Peptone	-	5g
KH_2PO_4	-	1g
$MgSO_4 . 2H_2O$	-	0.5g

3. Actinomycetes - Kenknight's Medium

Glucose	-	1g
K_2HPO_4	-	0.1g
$NaNO_3$	-	0.1g
KCl	-	0.1g
$MgSO_4 . 7H_2O$	-	0.1g
Agar	-	15g

Appendix 2

Nutrient content of fertilizers used for experiment

Fertilizer	Nutrient content (%)
Urea	46 % N
Rajphos	20 % P_2O_5
Muriate of potash	60 % K_2O
Magnesium Sulphate	10 % Mg
Zinc sulphate	21 % Zn
Copper sulphate	24 % Cu
Borax	10.5 % B