EXTRACTION AND CHARACTERIZATION OF HUMIC ACID FROM ORGANIC WASTES, EVALUATION OF THEIR IMPACT ON SOIL PROPERTIES, GROWTH AND YIELD OF CROPS

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BENGALURU – 560 065

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DOCTOR OF PHILOSOPHY

in

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

BENGALURU DECEMBER, 2016

Affectionately
Dedicated to
My Beloved Husband
Mr. Dayanand,
Children Samarth & Samanvi,
Parents, Brothers'
and
My guide
Dr. C.A. Srinivasamurthy

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
UNIVERSITY OF AGRICULTURAL SCIENCES
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CERTIFICATE

This is to certify that the thesis entitled **"EXTRACTION AND CHARACTERIZATION OF HUMIC ACID FROM ORGANIC WASTES, EVALUATION OF THEIR IMPACT ON SOIL PROPERTIES, GROWTH AND YIELD OF CROPS"** submitted by **Mrs. GAYATHRI, B., ID No. PALB 3087** for the degree of **DOCTOR OF PHILOSOPHY in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, GKVK, Bengaluru, is a record of research work done by her during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any other degree, diploma, associate ship, fellowship or similar other titles.

Bengaluru
December, 2016

(C. A. SRINIVASAMURTHY)
Major Advisor

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External Examiner

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December, 2016 **(Gayathri, B)**

EXTRACTION AND CHARACTERIZATION OF HUMIC ACID FROM ORGANIC WASTES, EVALUATION OF THEIR IMPACT ON SOIL PROPERTIES, GROWTH AND YIELD OF CROPS

GAYATHRI, B

THESIS ABSTRACT

A study on characterization and extraction of humic acid (HA) from ten different organic wastes viz., cocopeat, coffee pulp, pressmud, biofuel waste, distillery biocompost, sewage sludge, poultry manure, vermicompost, urban compost and farm yard manure (FYM) was carried out during 2014 and 2015. The impact of HA extracted from ten organic wastes @ 30, 60 and 90 kg ha^{-1} was assessed through greenhouse (maize and capsicum). Field experiment was conducted with three selected sources of HA (replicated thrice with 8 treatments) with capsicum as main crop and French bean as residual crop. Humic acid extracted from poultry manure had higher N (6.01 %) followed by pressmud and coffee pulp. Higher organic carbon (61.04 %) was recorded in biofuel waste. Total acidity and E_4/E_6 ratio was highest in poultry manure HA (8.02 meq g^{-1} and 5.21) followed by pressmud (7.84 meq g^{-1} and 5.12) and coffee pulp HA (7.68 meq g^{-1} and 5.10). Higher shoot and root dry weight 70.45 and 15.32 g pot^{-1}, respectively of maize with HA @ 60 kg ha^{-1} and 43.33 and 8.08 g pot^{-1} in capsicum with poultry manure HA @ 90 kg ha^{-1} followed by pressmud and coffee pulp. In field experiment higher capsicum fruit yield (55.41 t ha^{-1}), dry matter yield (3.66 t ha^{-1}) and nutrient content was recorded with application of poultry manure HA @ 90 kg ha^{-1} along with RDF. There was significant increase in nutrient status of post harvest soil with HA @ 90 kg ha^{-1}. Higher residual effect in pod yield (11.34 t ha^{-1}) and dry matter yield of (3.19 t ha^{-1}) was recorded in NPK+ FYM and was on par with HA extracted from different sources @ 90 kg ha^{-1}. Soil nutrient status declined after harvest of residual crop compared to main crop.

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(Dr. C. A. Srinivasamurthy)
Major Advisor

ಹ್ಯೂಮಿಕ್ ಆಮ್ಲವನ್ನು ಸಾವಯವ ತ್ಯಾಜ್ಯ ವಸ್ತುಗಳಿಂದ ಹೊರತೆಗೆದು ಅದರ ಗುಣಧರ್ಮಗಳ ಅಧ್ಯಯನ ಮತ್ತು ಅದರ ಬಳಕೆಯಿಂದ ಬೆಳೆಗಳ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಮಣ್ಣಿನ ಗುಣಧರ್ಮಗಳ ಮೇಲಾಗುವ ಪರಿಣಾಮದ ಮೌಲ್ಯಮಾಪನ

ಗಾಯತ್ರಿ, ಬಿ.

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಈ ಅಧ್ಯಯನವನ್ನು ೨೦೧೪ ಮತ್ತು ೨೦೧೫ ರಲ್ಲಿ ಹತ್ತು ವಿವಿಧ ಸಾವಯವ ತ್ಯಾಜ್ಯ ವಸ್ತುಗಳಾದ ಕೊಕೊ ಪೀಟ್, ಕಾಫಿ ತಿರುಳು, ಪ್ರೆಸ್‌ಮಡ್, ಜೈವಿಕ ಇಂಧನ ತ್ಯಾಜ್ಯ, ಡಿಸ್ಟಿಲರಿ ಬಯೋಕಾಂಪೋಸ್ಟ್, ಸೀವೇಜ್ ಸ್ಲಡ್ಜ್, ಕೋಳಿ ಗೊಬ್ಬರ, ಎರೆಹುಳು ಗೊಬ್ಬರ, ನಗರ ಘನ ತ್ಯಾಜ್ಯ ಮತ್ತು ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರಗಳಿಂದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲವನ್ನು ಭಟ್ಟಿಇಳಿಸಿ ಅದರ ಗುಣಧರ್ಮಗಳ ಬಗ್ಗೆ ಅಧ್ಯಯನ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಫಲಿತಾಂಶಗಳನ್ನಾಧರಿಸಿ ವಿವಿಧ ಸಾವಯವ ತ್ಯಾಜ್ಯ ವಸ್ತುಗಳಿಂದ ಪರಿಷ್ಕರಿಸಿದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲವನ್ನು ೩೦, ೬೦ ಮತ್ತು ೯೦ ಕಿ. ಗ್ರಾಂ/ಹೆ. ಪ್ರಮಾಣದಲ್ಲಿ ಬಳಸಿ ಹಸಿರು ಮನೆಯಲ್ಲಿ ಮೆಕ್ಕೆ ಜೋಳ ಮತ್ತು ದೊಣ್ಣೆಮೆಣಸಿನಕಾಯಿ ಬೆಳೆಯನ್ನು ಬೆಳೆಯಲಾಯಿತು. ಹಸಿರು ಮನೆ ಅಧ್ಯಯನದ ಫಲಿತಾಂಶವನ್ನಾಧರಿಸಿ ಮೂರು ಉತ್ತಮ ಮೂಲಗಳಿಂದ ಪರಿಷ್ಕರಿಸಿದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲವನ್ನು ಉಪಯೋಗಿಸಿ ಕ್ಷೇತ್ರ ಸಂಶೋಧನೆಯನ್ನು ದೊಣ್ಣೆಮೆಣಸಿನಕಾಯಿ ಮುಖ್ಯ ಬೆಳೆಯಾಗಿ ಹಾಗೂ ತಿಂಗಳ ಹುರುಳಿಯನ್ನು ನಂತರದ ಉಳಿಕೆ ಬೆಳೆಯಾಗಿ ಬೆಳೆಯಲಾಯಿತು. ವಿವಿಧ ಸಾವಯವ ವಸ್ತುಗಳ ಪೈಕಿ ಹೆಚ್ಚಿನ ಸಾರಜನಕವು ಕೋಳಿ ಗೊಬ್ಬರದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದಲ್ಲಿ (ಶೇ. ೬.೦೧) ನಂತರ ಪ್ರೆಸ್‌ಮಡ್ ಮತ್ತು ಕೊಕೊ ಪೀಟ್ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಹೆಚ್ಚು ಸಾವಯವ ಇಂಗಾಲವು (ಶೇ ೬೧.೦೪) ಜೈವಿಕ ಇಂಧನದ ತ್ಯಾಜ್ಯದಿಂದ ಪಡೆದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದಲ್ಲಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಒಟ್ಟು ಆಮ್ಲತೆ ಮತ್ತು $E_{೪}/E_{೬}$ ರ ಅನುಪಾತವು ಕೋಳಿ ಗೊಬ್ಬರದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದಲ್ಲಿ (೮.೦೨ ಮಿ. ಈ./ಗ್ರಾಂ. ಮತ್ತು ೫.೨೧) ನಂತರ ಪ್ರೆಸ್‌ಮಡ್ (೭.೮೪ ಮಿ.ಈ./ಗ್ರಾಂ. ಮತ್ತು ೫.೧೨) ಮತ್ತು ಕೊಕೊ ಪೀಟ್‌ನಿಂದ (೭.೬೮ ಮಿ.ಈ./ಗ್ರಾಂ. ಮತ್ತು ೫.೧೦) ಪರಿಷ್ಕರಿಸಿದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದಲ್ಲಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಮೆಕ್ಕೆ ಜೋಳದಲ್ಲಿ ಅತ್ಯಂತ ಹೆಚ್ಚಿನ ಕಾಂಡ ಹಾಗೂ ಬೇರಿನ ಇಳುವರಿಯು (೭೦.೪೫ ಮತ್ತು ೧೫.೩೨ ಗ್ರಾಂ./ಕುಂಡ) ಕೋಳಿಗೊಬ್ಬರದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲವನ್ನು ೬೦ ಕಿ. ಗ್ರಾಂ./ಹೆ. ಪ್ರಮಾಣದಲ್ಲಿ ಉಪಚರಿಸಿದ ಕುಂಡದಲ್ಲಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಅದೇ ರೀತಿ ದೊಣ್ಣಮೆಣಸಿನಕಾಯಿಯಲ್ಲಿ (ಕಾಂಡ ೪೩.೩೩ ಮತ್ತು ಬೇರಿನ ೮.೦೮ ಗ್ರಾಂ./ಕುಂಡ) ಇಳುವರಿಯು ೯೦ ಕಿ. ಗ್ರಾಂ./ಹೆ. ಕೋಳಿಗೊಬ್ಬರದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದಿಂದ ಉಪಚರಿಸಿದ ಕುಂಡದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಕ್ಷೇತ್ರ ಅಧ್ಯಯನದಲ್ಲಿ ಅತ್ಯಂತ ಹೆಚ್ಚಿನ ದೊಣ್ಣಮೆಣಸಿನಕಾಯಿ ಇಳುವರಿ (೫೫.೪೧ ಟ./ಹೆ.), ಒಣ ದಂಟಿನ ಇಳುವರಿ (೩.೬೬ ಟ./ಹೆ.) ಮತ್ತು ಹೆಚ್ಚು ಪೋಷಕಾಂಶಗಳ ಹೀರುವಿಕೆಯು ಕೋಳಿ ಗೊಬ್ಬರದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದ ಜೊತೆಗೆ ಶಿಫಾರಸ್ಸಿತ ಪ್ರಮಾಣದಲ್ಲಿ ರಸಗೊಬ್ಬರ ಮತ್ತು ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ಹಾಕಿದ ತಾಕುಗಳಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಹ್ಯೂಮಿಕ್ ಆಮ್ಲದ ಉಳಿಕೆ ಪ್ರಮಾಣದ ಪರಿಣಾಮವು ತಿಂಗಳ ಹುರುಳಿ ಬೆಳೆಯಲ್ಲಿ ಹೆಚ್ಚಿನ ಇಳುವರಿ (೧೧.೮೪ ಟ./ಹೆ.) ಮತ್ತು ಒಣ ದಂಟಿನ ಇಳುವರಿ (೩.೧೯ ಟ./ಹೆ.), ಸಾ.ರಂ.ಪೊ. ರಸಗೊಬ್ಬರದ ಜೊತೆಗೆ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಈ ಫಲಿತಾಂಶವು ವಿವಿಧ ಮೂಲಗಳಿಂದ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲವನ್ನು ಪರಿಷ್ಕರಿಸಿ ೯೦ ಕಿ. ಗ್ರಾಂ./ಹೆ. ಪ್ರಮಾಣದಲ್ಲಿ ಉಪಚರಿಸಿದ ತಾಕುಗಳಿಗೆ ಸಮನಾಗಿದೆ. ಈ ಸಾವಯವ ಅಧ್ಯಯನದಿಂದ ಮುಖ್ಯವಾಗಿ ತಿಳಿದುಬಂದ ಅಂಶವೇನೆಂದರೆ ಹ್ಯೂಮಿಕ್ ಆಮ್ಲ ಬಳಸುವುದರಿಂದ ಮುಖ್ಯ ಹಾಗೂ ನಂತರದ ಬೆಳೆಯು ಚೆನ್ನಾಗಿ ಬೆಳೆಯುವುದು ಹಾಗೂ ಪೋಷಕಾಂಶಗಳ ಸಮರ್ಪಕ ಬಳಕೆಯಾಗುವುದು. ಉಳಿಕೆ ಬೆಳೆಯನ್ನು ಬೆಳೆದ ನಂತರ ಮಣ್ಣಿನಲ್ಲಿ ಎಲ್ಲಾ ಪೋಷಕಾಂಶಗಳ ಲಭ್ಯತೆಯು ಸ್ವಲ್ಪ ಕಡಿಮೆಯಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ.

ಡಿಸೆಂಬರ್, ೨೦೧೬

ಮಣ್ಣು ವಿಜ್ಞಾನ ಮತ್ತು ಕೃಷಿ ರಸಾಯನಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
ಗಾಂಧಿ ಕೃಷಿ ವಿಜ್ಞಾನಕೇಂದ್ರ, ಬೆಂಗಳೂರು–೫೬೦೦೬೫

(ಸಿ.ಎ. ಶ್ರೀನಿವಾಸಮೂರ್ತಿ)
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

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I INTRODUCTION

Healthy soil is the foundation of a healthy food system, helps produce healthy crops which in turn nourishes people. Maintainance and improvement of soil quality is critical to sustain agricultural productivity and environmental quality. Increased inputs and modern technologies in agricultural production systems can often compensate for and mask losses in productivity associated with reductions in soil quality. However, an increased and unjustified agricultural input not only reduces economic sustainability but also increases the potential for negative impact on environmental quality (National Research Council, 1993). Thus, the wide spread adoption of unsustainable production techniques in agricultural systems has resulted in extensive deterioration of soil quality by reducing soil organic matter and thereby crop production (Verhulst *et al*., 2010).

The results generated from various long term fertilizer experiments revealed that continuous use of high analysis chemical fertilizers has not only increased the crop yield but also has adversely affected the sustainability (Viramani, 1994). The decrease in stability and sustainability in production was observed as a result of unscientific method of fertilizer management such as application of imbalanced fertilizer through sub-optimal or super- optimal doses leading to mining of nutrients from soil and depletion of soil organic matter (Kanwar and Katyal, 1997).

The increase in human population has threatened soil quality by intensive management of cultivable land and also through urbanization leading to soil degradation. Urbanization has resulted in generation of huge quantities of wastes which pose problems of disposal but also may enrich the soils around peri urban areas. Industrialization, in an unscientific way also has damaged our soil and water resources.

Organic matter is considered as the “Life of soil” due to its importance in maintaining fertility of the soil, the depletion of the same will become a major threat to food security in the years to come. Hence, there is a need to improve the soil fertility in a sustainable manner by utilizing the locally available agroindustrial and other organic wastes because these wastes contains substantial amount of nutrients which are necessary for the plant growth in addition to maintaining of soil health. Utilization of these agro industrial wastes and other organic wastes as a source of nutrients reduces the reliance on chemical fertilizers and these organic wastes provides substantial quantity of nutrient elements as well as humus which helps in improving the physical, chemical and biological properties of soil. However, to improve the organic matter content of soils many management techniques have been adopted such as crop rotation, plough techniques, green manuring and application of animal residues, application of humic acids and humates (Doran, 2003).

Use of bulky organic manures has been considered as a burden by the farmers as it requires large number of labourer for transportation and application. Also, use of bulky organic manures results in spreading of weed seeds in crop land and control of weeds would also be a major problem. In this context, extraction of humic substances from bulky organic manures and their use may help solve many problems associated with use of bulky organic manures.

Many of the agroindustrial units viz., sugar mills distilleries etc., generate large quanties of organic wastes which pose problems of disposal and transport. In this context extraction of humic acid from these agro industrial wastes would be a very valuable alternative. The industry would benefit in overcoming disposal and transportation.

The urban centers generate huge quantities of sewage sludge. Bangalore city generates about 1100 tons of sewage sludge per day which poses problems of disposal. This sewage sludge can be a used as raw material for extraction of humic acid and thus the extracted humic acid can be used as an amendment to improve the physical, chemical and biological properties of soil.

Humic substances influence many soil properties irrespective of the quantities present. Thus humic acid derived from organic wastes like cocopeat, pressmud, coffee pulp, sewage sludge, poultry manure, urban compost etc. which have substantial quantities of humic materials are of great importance in maintaining soil organic matter levels especially in semi-arid tropics of India.

The most active fraction of humus is the humic substances. Hayes *et al.* (1989) described them as a group of naturally occurring, biogenic, heterogeneous organic substances that can generally be characterized as yellow to black coloured high molecular weight material. This group of organic substances can be fractionated in terms of their solubility in acid and alkali into (i) yellowish fulvic acid that is soluble in acid and alkali; (ii) blackish humic acid that is insoluble in acid but soluble in alkali, and (iii) humin that is insoluble both in acid and alkali (Stevenson and Cole, 1999).

Humic acids are heterogeneous, which include macromolecule, hydrophilic acidic functional groups and hydrophobic groups. Humic acid hydrophilic groups promotes hydration and thus increases the water retention capacity in soils. Humic acid (HA) is the main fractions of humic substance (HS) and the most active components of soil and compost.

Application of humic acids stimulates plant growth and consequently yield by acting on various mechanisms such as cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, enzyme activities (Concheri *et al*., 1994; Nardi *et al*., 2000; Chen *et al*., 2004). It is the active constituent of humus, which can play a very important role in soil conditioning and plant growth. Donnell (1973) observed that humic acid obtained from leonardite (a naturally occurring, highly compressed and decomposed, soft brown coal-like organic material, usually found in conjunction with deposit of lignite) exhibits auxin-like effects. Physically, it promotes good soil structure and increases the water holding capacity of the soil, biologically it enhances the growth of useful soil organisms, and chemically it serves as an effective adsorption and retention complex for inorganic plant nutrients and thereby enhances nutrient uptake and yield by improving the quality and production of crops.

Keeping all these factors in view the present investigation entitled “Extraction and characterization of humic acid from organic wastes, evaluation of their impact on soil properties, growth and yield of crops” was carried out with the following objectives:

1. Extraction and characterization of humic acid from different organic wastes.
2. To study the effect of varied levels of humic acid from different organic wastes on growth and dry matter yield of maize and capsicum
3. To study the direct effect of selected humic acid levels and sources on growth, yield and quality of capsicum.
4. To study the residual effect of selected humic acid levels and sources on growth and yield of French bean.

II REVIEW OF LITERATURE

Recycling of renewable organic wastes and industrial by-products as a nutrient source for maintenance of soil health is vital for increasing crop production. Disposal of organic wastes is a major problem faced by many industries as dumping of these wastes in the vicinity of industrial areas causes environmental hazards. Hence, recycling is one of the best options of managing wastes. India has a vast scope for reutilizing renewable organic wastes like poultry manure, pressmud, coirpith, sewage sludge, coffee pulp, urban solid waste etc. Value addition and utilization of the above wastes as raw materials for crop production with suitable technologies is the need of the day. Thus, organic wastes can be used as such or can be used for extraction of humic acid and effectively used for maintaining soil health and fertility.

Information pertaining to the role of humic acid in maintaining soil fertility and in turn enhancing the yield and quality of crops are detailed in this chapter.

2.1 Characterization of organic wastes from different sources

2.2 Structure and chemistry of humic substances

2.3 Extraction of humic acid from different organic wastes/sources

2.4 Characterization of humic acid extracted from different organic wastes

 2.4.1 Spectroscopic characterization of humic acid

 2.4.2 Elemental composition of humic acid extracted

 2.4.3 Functional groups of humic acid

2.5 Effect of humic acid application on growth, yield and quality of crops.

2.6 Effect of humic acid on nutrients uptake by different crops

2.7 Effect of humic acid application on physical, chemical and biological properties of soil.

2.1 Characterization of organic wastes from different sources

The composition of the organic waste varies due to many factors. The composition mainly depends on the type of waste, which is dependent on the raw materials used in the industry or the human population and how often waste is collected and how it is disposed.

Gomez *et al*. (1993) characterized sewage sludge and reported that it was acidic in reaction, EC (6.35 mS cm^{-1}), OM (56.6 %), N (29.9 g kg^{-1}), P (17.9 g kg^{-1}), K(2.6 g kg^{-1}), Na (0.66 g kg^{-1}), Ca (49.4 g kg^{-1}), Mg (5.6 g kg^{-1}), Fe (9700 ppm), Mn (115 ppm), Cu (272 ppm), Zn (905 ppm), B (79 ppm), Cd (4 ppm), Cr (12 ppm), Hg (1 ppm), Ni (18 ppm) and Pb (2 ppm).

Negro *et al*. (1995) analyzed sewage sludge and reported that it contained 39. 5 per cent C, 6.15 per cent N, with C: N ratio of 6.5, 0.65 per cent P, 0.69 per cent K, 2.6 g

kg^{-1} Ca, 9.8 g kg^{-1} Mg and 14.9 g kg^{-1} Fe. Other micronutrients like Cu, Zn, and Mn were also present in minor quantities.

According to Devegowda (1997) poultry excreta and other wastes are good source of organic manure. He reported that poultry manure was rich in major nutrient sources as well as secondary and micronutrients with average values of 4 per cent N, 3 per cent P, 2.5 per cent K, 2.4 per cent Ca, 0.67 per cent Mg, and 0.5 per cent S. Among micronutrients it was rich in Zn (463 ppm), Fe (451 ppm), Mn (406 ppm) and Cu (150 ppm).

Kadalli (1999) reported that coir dust had pH of 6.25, EC 1.54 dS m^{-1} and it contained 48.72 per cent OC, 0.47 per cent N, 0.02 per cent P, 0.62 per cent K, 0.46 per cent Ca, 0.31 per cent Mg, 0.07 per cent S, with respect to micronutrients it contained (53, 15, 1264 and 58 ppm) of Zn, Cu, Fe and Mn respectively.

According to Surya Rao (2000), pressmud had a pH of 7.5, EC 1.22 dS m^{-1}, 23.28 per cent OC, 1.84 per cent N, 1.64 per cent P, 0.38 per cent K, 2.22 per cent Ca, 2.08 per cent Mg, 0.72 per cent S, 180 ppm Zn, 82.56 ppm Cu, 2524.66 ppm Fe, 568.66 ppm Mn. The lignin and cellulose content was 22.94 and 13.24 per cent, respectively and had total phenols to an extent of (61.42 mg $100g^{-1}$).

Muneshwar Singh *et al*. (2001) reported that farm yard manure contained 0.62 per cent of nitrogen, 0.52 per cent of phosphorus and 0.71 per cent of potassium.

Bhanu Prakash *et al*. (2007) characterized urban solid wastes for the presence of vegetable matter and other decomposables which are the predominant constituents present to an extent of 77 per cent. Plastic, metals, glass and paper totally constituted about 23 per cent. They reported that the initial composition of urban waste indicated an organic carbon status of 42.46 per cent with the C: N ratio of 52.86 and was fairly low in N (0.76 %), P (0.04 %) and medium in K (0.54 %).

Preethu *et al*. (2007) reported that the pH of the coffee pulp was slightly acidic in reaction pH (6.8) and EC was 2.5 dS m^{-1}. The organic carbon content was (38.2 %) with high amount of nitrogen (2.05 %). The C: N ratio was 18.5. It also had high percentage of lignin (38.6%), cellulose (29.4%) and total phenol (110.5 mg $100g^{-1}$).

Ravi Kumar (2009) characterized the FYM collected at farmer's field and found the organic carbon (10.86 %), N (0.62 %), P (0.3 %), K (0.4 %), Ca (2.3 %), Mg (0.92 %), S (0.44 %) and micronutrients (40, 91, 1169 and 698 ppm Cu, Zn, Fe and Mn, respectively).

Mohamed Amanollah *et al*. (2010) analysed the nutrient content of poultry cage manure and reported that it has 5.8-7.6, 3.63-5.30 per cent, 1.54-2.90 per cent, 2.5-2.9 per cent, 970-1450 ppm, 80-172 ppm, 370- 590 ppm, 290-460 ppm, 0.8-1.02 per cent and 0.4-0.50 per cent of C:N ratio, N, P, K, Fe, Cu, Mn, Zn, Ca and Mg, respectively.

Coffee waste an alternative organic source with soil improving properties for sandy soils in humid tropical environment was found to have pH (8.0), with moisture (17.7 %), Ca (0.37 %), Mg (0.14 %), K (2.49 %), Na (0.04 %), N (1.69 %), P (0.18 %), Mn (0.01 %), Al (0.29 %), Fe (0.29 %) and C:N ratio of 27 (Kasongo *et al*. 2011).

Sathisha and Devarajan (2011) studied the characteristics of the pressmud and found that it was alkaline in reaction with pH (7.18), EC (2.96 dS m^{-1}), OC (32.60 %), total nitrogen (1.2 %) and C:N ratio of 27.17, phosphorus 1.15 per cent. potassium 0.62 per cent, Ca and Mg (4.14 and 1.10 %) and higher amount of total phenols (23.30 mg 100 g^{-1}) lignin (16.40 mg 100 g^{-1}) and cellulose (13.52 %).

Barik *et al.* (2011) analyzed and characterized FYM and vermicompost for nutrient status and found that FYM contained 0.52, 0.18 and 0.23 per cent of N, P and K, respectively. Whereas, vermicompost had 1.56, 0.54 and 0.61 per cent of N, P and K, respectively.

Sunita Devi *et al*. (2012) reported that poultry manure contains ash (24.5 %), OM (75.5 %), OC (43.8 %), total N (3.5 %) and had C : N ratio of 12.5.

Manju *et al.* (2013) characterized municipal solid waste compost (MSWC) of selected Indian cities and found that the MSWC from Bangalore recorded pH of 8.19, EC 0.58 dS m^{-1}, 26.61 per cent organic C, 1.13 per cent N, 2.92 per cent P with C : N ratio of 23.55. They also reported heavy metal concentration with average values of 34.43, 7.28, 2.18, 6.58 and 2.32 mg kg^{-1} of Cu, Cr, Ni, Pb and Cd, respectively.

2.2 Structure and chemistry of humic substances

In the late 17th century, Archard first isolated the humic substances by extracting the peat with alkali and obtained a dark amorphous precipitate upon acidification. Theodore De Saussure introduced the term ‘humus’ later to the dark matter. Comprehensive and extensive study on the origin and chemical nature of humic substances was carried out by Sphrengel. Later, Berzellius extended the work on understanding the chemical properties of humic substances (Stevenson, 1994).

Humic acid molecules are created through hydrocarbon bonds forming chains that roll into a ball in their natural state, these balls form larger aggregates that constitute the organic part of soil that is the humus (Levinsky, 1996). When humic acids are treated with alkaline agents it gets charged and transform into water-soluble salts-sodium and potassium humate. This allows the humic acid molecules to pass into solution and become biologically active.

The structure of humic substances is not completely understood and over the last few decades nuclear magnetic resonance spectroscopy has provided key insight into structural details of humic substances (Avena *et al*., 1998).

Butuzova *et al*. (1998) reported that the physico-chemical properties of humic acids and their physiological activity are mostly determined by the qualitative and quantitative composition of oxygen-containing functional groups that varies during coalification, pyrolysis and oxidation.

A typical humic acid molecule polymer structure consists of six carbon aromatic ring of the basis of di- or trihydroxylphenols linked by -O-, -NH-, -N-, - S-, and contain group-OH and quinone (O- C_6H_4-O-) (Tan, 1998).

According to Myneni *et al*. (1999) humic substances had a great deal of structural variety that included sheets and globular configurations, thread and net like shaped and small uniform aggregates. The changes in microstructure modify the exposed surface area and alter the functional group chemistry affecting protonation and cation complexation.

Humic acids have a highly heterogenous structure, functionalities and varied elemental composition (Li *et al*., 2003). Humic substances are major component of organic colloids and ubiquitous in natural groundwater. Thus, they constitute a large portion of the total organic carbon pool in terrestrial and aquatic environments (Fan *et al*., 2003).

Humic acids are made up of complicated mixtures which are linked together in no specific order, the result of this is extraordinary complex materials wherein no two molecules are exactly the same (Mikkelsen, 2005).

More specifically, humic acids are widely spread in nature and occur mainly in heavy degraded peat but also in all natural environments in which organic materials and microorganisms can be found (Pena-Mendez *et al*., 2005). According to Kulikova *et al*. (2005) humic acids comprises 50 - 90 per cent of the organic matter from these products. Not only can humic acids be found in soil, natural water, rivers, sea sediments, peat and other chemically and biologically transformed organic materials but also in lignite, oxidized bituminous coal and leonardite (Karaca *et al*., 2006).

Humic acids derived from coal are defined as dark coloured substances, which are soluble in aqueous alkali but insoluble in acid. These substances also occur naturally in some lignites and brown coals, but little or no alkali-soluble material is present in bituminous coals. Humic acids isolated from coal samples differ from one another according to the grade of coalification and conditions under which they were formed (Karaca *et al*., 2006; Skhonde *et al*., 2006).

Humic substances have marked influence on the species of cations and thereby can affect their bioavailability, physicochemical properties and environmental sorption or desorption of macro- and micronutrients, toxic metals and xenobiotic organic cations, this is because of their colloidal character and large number of surface functional groups, because of this they play an important role in determining the mobilization and immobilization behavior of metals in the environment. Humic acid has a strong retention of atmospheric gases such as O_2, N_2 and CO_2 making them available to microorganisms and plants and also for biomineralization. When they are adsorbed to mineral surfaces they may bind to metal ions (Chen *et al*., 2007).

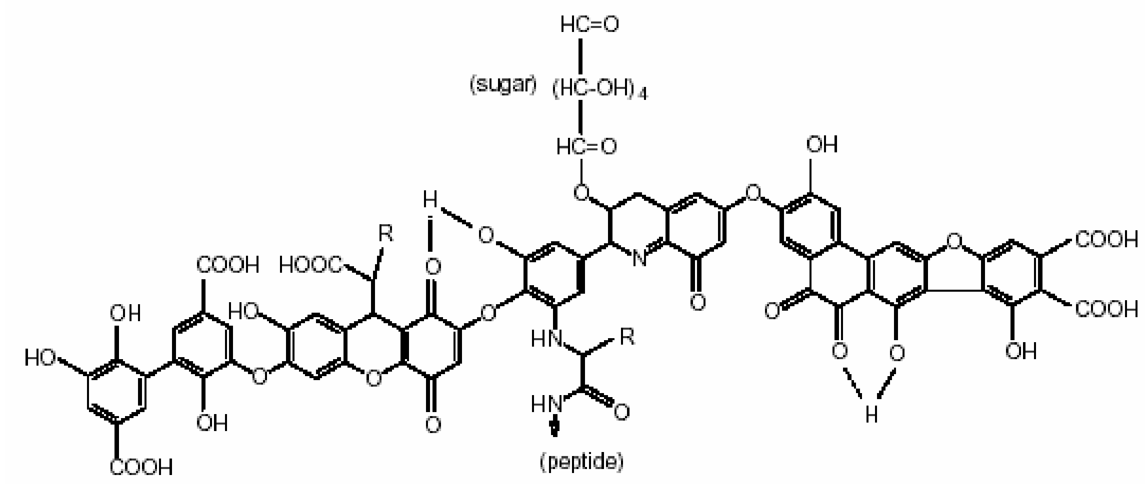

Fig. 1: Model structure of humic acid (Pena-Mendez *et al*., 2005)

Avena *et al*. (1998) proposed a structure for humic acids from a comprehensive investigation that combined different experimental techniques with molecular mechanisms and dynamic calculations. The optimized structure turned out to be a crosslink network with voids of various dimensions that can trap and bind other organic components such as carbohydrates or proteinaceous materials as well as inorganic components and water. When humic acids are naturally oxidized it gives a negative charge to which positive ions can attach. This creates sites for micronutrients and microflora to attach.

According to Christl *et al*. (2000) and Mikkelson (2005) humic substances are macromolecular, negatively charged, branched polyelectrolytes with mainly carboxylic and phenolic type acidic functional groups. An alternative model of humic acids have also been proposed stating that they are self-associated of small, uniform humic acid molecules held together by weak hydrophobic forces exhibiting both hydrophobic and hydrophilic properties.

2.3 Extraction of humic acid from different organic wastes/sources

Scheild (1989) found that bulky compost and paper or sewage sludge mixtures had significantly less HA than straw or organic refuse wastes. Two year old organic refuse waste compost showed the best humus quality with 23.8 per cent organic substances as HA and 7.5 per cent as FA.

Among the various extractants, 0.5 M NaOH was reported to be the best in extracting higher amounts of HA and is being recommended by the International Humic Substances Society (IHSS). Acidification of the alkaline extract promotes the precipitation of humic acids, leaving fulvic acids in solution (Benitez *et al*., 2005). This procedure leads to the separation of organic matter into fractions that are mixtures of compounds with similar chemical characteristics.

Sashikala and Ong (2007) extracted the humic acid from rice straw using alkaline extraction technique. Sodium hydroxide and potassium hydroxide solutions were used as extracting agents. The results showed that humic acid gain with sodium hydroxide as extracting agent was 57.33 g kg^{-1} while humic acid gain with potassium hydroxide was 72.67 g kg^{-1}.

Humic acids (HA) extracted from Mukah coals and different types of compost using potassium hydroxide (KOH) extraction method was low even under optimized extraction environment. However, when the coals were subjected to nitric acid (HNO_3) oxidation followed by KOH extraction, nitrohumic acids (NHA) yield 5–6 times higher than the HA equivalent and the amount of NHA extracted from composts was higher than the HA equivalent. (Muhammad Syahren and Wong, 2008).

Effect of extraction time on the alkaline extracts of humic substances from organic and mineral lake bottom sediments showed that the extraction performed with the use of 0.5 M NaOH for organic and mineral sediments was in the ratio of 1:10 and 1:50 (w/v). In both the variants the extraction time was 1, 5, 12, 24 and 48 hr (Joanna Cieoelewicz, 2009).

Lee Jia *et al*. (2010) showed that yields of HA isolated using different concentrations of NaOH and KOH showed significant difference at each level of concentrations. For the purpose of studying chemical characteristics, 0.2, 0.3 and 0.4 M of both NaOH and KOH were good enough in isolating HA.

Michael *et al*. (2010) isolated the humic acids (HAs) and fulvic acids (FAs) (in long term grassland) by the exhaustive extractions at pH 7, 10.6, and 12.6 of a Grey Brown podzol and Gley soil. A sequential extraction with dimethyl sulphoxide (DMSO) + 6 M concentrated H_2SO_4 isolated humin materials. Solid state CPMAS 13_C NMR spectroscopy showed readily observable differences between the compositions of the HAs and FAs isolated at the different pH values, and using base + urea solvent system.

Arashhemati *et al*. (2012) reported that the maximum yield of humic acid was obtained with 0.5 M NaOH and urea had an intermediate status and HA extracted by urea had higher N content and H/C ratio than HA extracted by NaOH. The acidic functional groups of the HA extracted by urea was more than that with NaOH and H decreased with increasing extraction time.

2.4 Characterization of humic acid extracted from different organic wastes

2.4.1 Spectroscopic characterization of humic acid

Spectroscopic measurements in different regions of the electro-magnetic spectrum are also used to understand the nature of humic substances. The ratio of absorbance in visible range at 465 and 665 nm, referred as E_4/E_6 ratio, has been widely used for characterization of humic substances.

Chen *et al.* (1977) characterized the humic substances based on E_4/E_6 ratio and found that E_4/E_6 ratios of humic and fulvic acids were mainly governed by the particle size. These ratios were affected by pH, free radical concentration, organic carbon and total acidity. The parameters are the functions of the particle size or molecular weight but not directly related to the relative concentration of condensed aromatic rings.

The most widely accepted absorption spectroscopic information of humic substances is the ratio of optical densities at 465 and 665 nm i.e. commonly called E_4/E_6. It appeared to be independent of the concentration of humic substances but varied with the differences in the genesis of soil organic matter in ambient soil environment (Kononova, 1966; Stevenson, 1982).

Prasad and Kumar (1989) stated that the difference in optical density curves and slopes may be attributed to varying degree of condensation of aromatic rings and also to the ratio of carbon in aromatic side chain to carbon in aliphatic side chain.

The optical characterization of humic substances derived from different soil and organic materials provides an insight into the degree of aromatization and condensation of aromatic rings in the molecules of humic acids. Visible spectra is useful in elucidating the nature of functional groups and their contribution to optical properties like absorption maxima at different wave lengths (Mishra and Srivastava, 1990).

The high E_4/E_6 ratio of humic substances indicates a relatively low concentration of condensed ring structure which reflects a low degree of aromatic condensation (Kadalli, 2000).

Humic substances extracted from municipal solid waste (MSW) compost recorded higher E_4/E_6 ratio (6.84) indicating higher content of aliphatic chains when compared to humic acid extracted from soil and MSW amended soil (Paola *et al.*, 2006).

Satisha and Devarajan (2011) characterized the humic substances extracted from effluent based pressmud composts and found that pressmud without any organic and inorganic additives recorded lower E_4/E_6 ratio (4.85) compared to enriched compost.

2.4.2 Elemental composition of humic acid extracted from different sources

Elemental composition of humus fractions were carried out only in the later part of the 20th Century by Chen *et al.* (1977). They observed that the humic acid recorded more carbon but less of oxygen than the fulvic acid. They also noted smaller quantitative differences in H, N and S contents of both the materials. They recorded appreciably higher amounts of total acidity in fulvic acid than that of humic acids.

The elemental composition of humic substances (Konnonova, 1966) showed that on dry ash free basis, the humic acid was found to have 52-62, 3.0-5.5, 30-33 and 3.5-5.0 per cent of C, H, O and N respectively. HA extracted from the farm waste compost contained 50.4 per cent OC,4.5 per cent N, 795 ppm P, 1.5 meq g^{-1} of carboxyl group and 5 meq g^{-1} of total acidity (Bangar *et al.*, 1985).

Humic substances are complex and organic in nature and consist of aromatic and aliphatic structure, primarly made up of carbon, hydrogen and oxygen atom (Gurunathan and Kaliyaperumal, 1989).

Ushashree *et al*. (1989) reported that humic acid has (56.3, 4.7, 36.3, and 2.7) percentage of C, H, O and N, respectively. The carbon nitrogen ratio of the material was 20.9. The atomic elementary composition of lignite humic acid was 39.5, 39.8, 19.1, 1.6 per cent, 1.01, 0.48 and 24.7 for C, H, O, N, H/C, O/C and C/N ratio, respectively (Chandrasekaran, 1992).

Varshovi and Sartain (1993) characterized a commercial humate and found that it consisted of 58 per cent OM, 32 per cent ash and 10 per cent moisture and the humic substances was mostly HA (76 %) with some FA (18 %).

Hai and Mir (1998) concluded from the various experiments that HA derived from lignitic coal of Pakistan contained 57 per cent C, 7 per cent N, 4 per cent H, 30 per cent O and 1 per cent S.

Kadalli *et al*. (2000) reported that carbon content of the humic acid (extracted from coir dust based compost) varied from 38.44 to 42.18 per cent and that of N from 0.12to 5.18 per cent.

Schinzter (2000) opined that the elemental composition of humic acid has two dimensional structure C_{308}, H_{334}, O_{90}, N_5 with molecular weight of 5540 daltons. The humic acid fraction has higher molecular weight than fulvic acid fraction (Sanyal, 2001) and due to greater degree of poly condensation of aromatic rings. (Stevenson, 1994).

Atiyeh *et al*. (2002) studied the elemental composition of humates extracted from food waste and pig manure vermi compost and recorded N (46.6 and 47.2 mg g^{-1}), P (2.19 and 1.01 mg g^{-1}), K (15.46 and 25.61 mg g^{-1}), Ca (0.77 and 2.91 mg g^{-1}), Mg (0.14 and 0.27 mg g^{-1}) and Fe (0.72 and 4.41 mg g^{-1}).

Paola *et al.* (2006) stated that humic acid derived from MSW compost had 52.4 per cent C, 5 per cent H, 4.7 per cent N, 37.9 per cent O, 1.21 per cent ash and H/C ratio of 1.14.

Sathisha and Devrajan (2011) studied the elemental composition of unenriched pressmud and reported that it contains 46.36 per cent of carbon, 6.05 per cent hydrogen, 4.3 per cent nitrogen and 43.29 per cent of Oxygen.

Keiji Jindo *et al.* (2012) extracted humic acid from sewage sludge and municipal solid waste (MSW) and studied the elemental composition and found that it contains carbon (54 and 51.5 %), hydrogen (9.2 and 7.1 %), oxygen (25.5 and 32.5 %), nitrogen (11.3 and 9.1 %) and had H/C, N/C, O/C ratio of (2.0 and 1.7), (17.9 and 14.8) and (0.4 and 0.5), respectively.

Humic substances isolated from industrially mined raised bog peat and analysed for elemental composition contained carbon (52 %), hydrogen (5 %), nitrogen (1.6 %), sulphur (0.5 %) and ash (2 %). The content of oxygen, (32–42 %) was determined by mass balance (Olga Muter *et al.*, 2015)

2.4.3 Functional groups of humic acid

The considerable and wide ranging action of humic acid is primarily due to the presence of functional groups in them, not only carboxyl, phenols and alcohols, but also quinines, amines and amides. Humic substances contains relatively high concentration of oxygen containing functional groups (per unit weight) (COOH, OH and C=O). Through these groups, the organic materials are capable of attaching and degrading soil minerals by complexing and dissolving metals. Fulvic acid was more acidic than humic acid and the acidity was mainly due to presence of more carboxyl groups (Schnitzer and Gupta, 1964). COOH, OH and CO groups account for 52-75 per cent of the total oxygen of HA and 86-100 per cent oxygen of FA.

Humic and fulvic acid contains high concentration of oxygen containing functional groups like carboxylic, phenolic, alcoholic and enolic groups (Stevenson and Ardakani, 1977).

Saha and Sanyal (1988) reported that the contents of carboxylic and phenolic groups in synthetic humic acids ranged from 0.71 to 1.40 m eq g^{-1}, respectively.

Ushashree *et al.* (1989) found that the total acidity, carboxyl and phenolic –OH groups in lignite humic acid was 5.44, 2.43 and 3.01 m eq g^{-1}, respectively.

Stevenson (1991) revealed that the basic structure of soil humic substances to be aromatic ring of di or trihydroxy phenyl type, bridged together by –O-, $-CH_2-$, -NH- and also contains carboxylic groups attached directly to the ring and on the aliphatic side chains.

The diversity and complexity of functions is associated with polychemical nature of humic substances whose molecules differ in size and functional groups and form a notable range of compounds differing in bonding ability and capacity of complex metal cations (Orlov, 1995).

Total acidity of 1161, 698, and 1135 c mol kg^{-1} was observed in humic acids extracted from soil, municipal solid waste compost (MSW) and MSW amended soil. MSW compost contains carboxyl groups (305 c mol kg^{-1}) and (393 c mol kg^{-1}) phenolic groups respectively (Paola *et al.*, 2006).

Humic acid extracted from unenriched and enriched pressmud varied in total acidity and the values were 10.24 and 10.75 m eq g^{-1} respectively (Satisha and Devrajan, 2011). Humic acid extracted from sludge and leonardite contain total acidity of 3.26 m mol g^{-1} (2.84 and 0.42 m mol g^{-1} of COOH and OH groups) and 7.12 m mol g^{-1} (4.38 and 2.72 m mol g^{-1} of COOH and OH groups) (Li and Li, 2013).

Shahein *et al*. (2014) reported that humic substances extracted from compost and biogas manure contain total acidity of 925 (590 and 335 m mol 100 g^{-1} of phenolic and carboxylic groups) and 875 (510 and 365 m mol 100 g^{-1} of phenolic and carboxylic groups) m mol 100 g^{-1}, respectively.

2.5 Effect of humic acid application on growth, yield and quality of crops

Mallikarjunarao *et al*. (1987) reported that dry matter yield of sorghum increased with an increase in levels of humic acid application up to 30 kg ha^{-1} and resulted in higher shoot and root ratio. The mean shoot and root weight of sorghum plants under different levels of humic acid application increased significantly (17.89 and 15.68 g pot^{-1}) over the control (7.46 and 5.37 g pot^{-1}).

Sripriya (1993) recorded that higher grain and straw yields of paddy when humic acid coated on fertilizer (2 %) was applied to soil @ 30 kg ha^{-1}.

Purchace *et al.* (1995) stated that humic substances stimulated plant growth and these stimulatory effects helped in increasing the root and shoot length. When coal derived humate product was applied as foliar spray to seedlings in petri dishes, a 268 per cent increase in root and shoot growth was recorded.

Application of humic acid up to 20 kg ha^{-1} increased the growth and yield of sesame (Singaravel *et al.*, 1998). A significant increase in the fruit yield of tomato due to the application of humic acid was recorded by Padem *et al,* (1999).

Balasubramanian *et al*. (2000) reported that the yield attributes grain and stover yield of soyabean increased significantly with addition of humic acid @ 20 kg ha^{-1} to soil along with spraying (0.01 %) at flowering stage. Khungar and Manoharan (2000) reported that the humic acid application @ 10 kg ha^{-1} to green gram and soyabean resulted in yield increase 80.65 and 71.07, respectively.

Humic acid when applied at 10 kg ha^{-1} significantly increased the green biomass of amaranthus (Sathyabama and Selvakumari, 2001).

Soil application of humic acid @ 10 kg ha^{-1} 0.1 per cent root dipping and 0.1 per cent foliar spray recorded a maximum plant height, length and breadth of leaves, number of tillers of paddy, etc. and was on par with soil application of humic acid at higher levels. (Baskar *et al.*, 2002).

Dhanasekaran and Govindasamy (2002) reported that application of N through various forms of urea significantly increased the grain and straw yields of rice over the control. Among the various forms of coated urea, humic acid coated urea (HACU) recorded the highest grain (6.63 t ha^{-1}) and straw (9.58 t ha^{-1}) yield followed by neem coated urea (NCU) (6.55 and 9.44 t ha^{-1} of grain and straw yield, respectively).

Govindasamy and Ravikumar (2002) reported that application of humic acid with and without Fe and Zn either as soil application (SA) or foliar spray (FS) or both significantly improved the yield attributes, quality of juice, yield of cane, sugar content and enhanced the nutrient uptake. Among the treatments, SA of HA along with $FeSO_4$ and $ZnSO_4$ recorded the highest yield of cane (131 t ha^{-1}) and sugar (19.62 t ha^{-1}) thereby enhancing the yield of cane and sugar by 18.6 and 26.2 per cent, respectively over control.

Muralidharan *et al*. (2002) reported that the combined application of humic acid upto 20 kg ha^{-1} as soil application and 0.1 per cent humic acid as foliar spray along with recommended NPK recorded highest cane and sugar yields and quality of juice when compared to soil application of 40 kg ha^{-1} and 0.1 per cent HA as foliar spray along with 75 per cent of recommended NPK.

Vasilenko (2002) found that application of humates increased the average diameter of tomato fruit by 16-17 per cent larger than fruits in control. Several studies have shown that humic substances have a positive effect on plant growth (Van de Venter *et al*, 1991; Arancon *et al*, 2003) through absorption thereby affecting the enzyme activities and membrane permeability (Nardi *et al*., 2002).

Atiyeh *et al*. (2002) reported that addition of humic acid derived from vermi compost based pig manure and food waste into soilless plant growth media increased the growth of tomato and cucumber significantly in terms of plant height, leaf area, shoot and root dry weight. Plant growth tended to be increased in treatments which received humic acid up to 50–500 mg kg^{-1} but decreased significantly when the concentrations exceeded 500–1000 mg kg^{-1}. These growth responses were most probably due to hormonal activity of humic acids from the vermi composts or due to plant growth hormones adsorbed onto the humates.

Veeral *et al.* (2003) conducted field experiments to evaluate the direct and residual effects of application of lignite flyash (LFA) at three levels viz., 10, 15 and 20 t ha^{-1} with or without farmyard manure (FYM) at 12.5 t ha^{-1} and humic acid (HA) at 30 kg ha^{-1} on rice-black gram cropping system. Application of Lignite fly ash at 10 t ha^{-1} along with FYM @ 12.5 t ha^{-1} and HA at 30 kg ha^{-1} exerts remarkable influence on the yield attributes, ultimately leading to increased rice yields upto 35 per cent over control. With respect to the residual crop black gram, showed distinct influence in both grain and haulm yield.

Nandakumar (2004) observed higher grain yield of rice with humic acid @ 20 kg ha^{-1} along with 100 per cent NPK and the per cent increase in grain yield over control was 50.41 and 53.84 per cent in clay loam and sandy loam soils respectively. More specifically humic acid was also used as growth regulator to regulate hormones, improve plant growth and enhance stress tolerance (Delfine *et al*., 2005).

Sharif *et al*. (2002) noticed that addition of 50 and 100 mg kg^{-1} HA resulted in significant increase (20 and 23 %) in shoot and (39 and 32 %) in root dry weight of maize plants as compared to control. Addition of HA increased the soil N concentration and plant N content significantly over control. Whereas plant P accumulation was not significantly affected by the application of different levels of HA.

Bhuvaneswari and Dhanasekaran (2007) studied the response of radish to the soil application of humic acid (HA) extracted from lignite. The results revealed that soil application of graded doses of humic acid from 0 to 40 mg kg^{-1} increased the growth and yield of radish up to 30 mg kg^{-1} and declined thereafter. Application of HA at 30 mg kg^{-1} increased the number of leaves, root and shoot length and improved the tuber yield by 41.0 per cent. In addition, available NPK status of post harvest soil also improved due to the soil application of HA. Thus, soil application of HA at 30 mg kg^{-1} was found to be optimum dose to improve the yield of radish.

Ertan Yildirim *et al.* (2007) reported that total soluble solids (TSS) increased with both foliar and soil application of HA. Foliar application @ 20 ml l^{-1} HA resulted in highest ascorbic acid (AA) content that led to higher leaf and stem dry matter contents than the control. Both foliar and soil application of HA affected fruit characteristics such as fruit diameter, fruit length, mean fruit weight and fruit number per plant. The highest yield was recorded through in foliar application @ 20 ml l^{-1}.

El-Ghamry *et al*. (2009) studied morphological characteristics yield components, macronutrients content and chlorophyll content of faba bean and found significant increase through foliar application of humic acid. Humic acid applied to wheat in a calcareous soil as soil application (1 and 2 g kg^{-1} soil) and foliar spray (0.1 and 0.2 %) had a significant and positive effect on dry weight and NPK uptake of wheat (Katkat *et al*., 2009).

Selim *et al.* (2009) reported that increasing humic substances application rates up to 120 kg ha^{-1} with surface and subsurface drip irrigation enhanced tuber yield, starch content and total soluble solid content of potato. Subsurface drip irrigation system was more efficient than surface drip irrigation system in improving tuber yield, quality parameter and nutrient concentration in addition to soil fertility after harvesting.

Verlinden *et al*. (2009) studied the effect of humic substances on yield and nutrient uptake of grass, maize, potato and spinach. The results showed that application of humic substances had an overall positive effect on dry matter yield of crops and its effect was statistically significant. Tuber production of potato showed high response to the application of humic substances while its effect on maize yield was limited.

Ferrara and Brunetti (2010) studied the effect of humic acid extracted from a clay soil of Apulia region and applied at concentration of 100 mg L^{-1} at different stages. Application of humic acid at full-bloom (II) induced a significant increase in berry size and other quality parameters (Titratable acidity and °Brix/titratable acidity) with respect to the control. The study confirmed that humic acids, if applied at full-bloom would significantly increase qualitative and quantitative parameters in table grape.

Fusun Gulser (2010) reported that application of humic acid and calcium nitrate significantly affected pepper seedling growth. Application of 1000 and 2000 mg kg^{-1} humic acid and 50 mg kg^{-1} calcium nitrate increased the fresh and dry leaf weight, fresh and dry root weight, stem diameter, root length and shoot length. The highest rates of humic acid application (4000 mg kg^{-1}) and calcium nitrate (100 and 150 mg kg^{-1}) decreased the yield of pepper seedling under the saline soil condition.

Kirn *et al*. (2010) reported significant increase in shoot and root fresh weight of okra by the application of lignite humic acid along with recommended fertilizer. Highest shoot fresh weight (112 g $plant^{-1}$) was recorded in treatment receiving humic acid at 20 mg kg^{-1} in combination with recommended fertilizer and was 60% higher than control. Similarly highest flower to fruit conversion (93 %), green pod yield (48 g $plant^{-1}$) and maximum N (1.28 %), P (1.37 %) and K (1.43 %) was recorded.

Selim *et al*. (2010) found that humic substances when added along with NPK through fertigation resulted in lesser leaching of N and K to deeper layer and higher availability of P in deeper layer of soil. The tuber yield increased by 16.47 per cent with addition of humic substances compared to application of recommended dose of fertilizer. The best combination for enhancing tuber yield, quality indicators, nutritional status of potato crop and soil fertility compared to the recommended dose of N, P and K (control) was addition of humic substances along with 100 per cent fertigation followed by 75 per cent fertigation of combined NPK fertilizer.

Mahmoud *et al.* (2011) recorded increase in plant height (86.5 cm), number of branches (4.00) and dry weight of shoot (108 g $plant^{-1}$) of soyabean due to application of 30 kg ha^{-1} humic acid along with 100 per cent RDF.

Farouk (2011) reported that application of humic acid @ 100 or 200 mg kg^{-1} of soil to radish crop significantly increased the length, fresh and dry weights of shoot and root systems as well as leaf number per plant.

Humic substances extracted from sewage sludge significantly increased the plant dry-matter production (up to 560 %), plant height (86-151 %) and leaf area (436-1397 %) during the early stages of pepper development. Net photosynthesis and stomatal conductance increased in the treatments with humic acid extracted with sewage sludge up to (48 % and 63 %, respectively) at the vegetative stages compared to humic substances derived from leonardite (Inaki Azcona *et al.*, 2011).

Tahir *et al.* (2011) reported significant differences with HA application levels on wheat growth (plant height and shoot weight) and N uptake. The largest increases in plant height (10 %), shoot fresh weight (25 %) and dry weight (18 %) were found with HA_2 60 kg ha^{-1} soil, over control. Humic acid application @ 60 kg ha^{-1} soil was more efficient than 90 kg ha^{-1} in promoting wheat growth.

Verlindena *et al*. (2009) showed that humic substances at the start of the growing season induced an overall positive effect on dry matter yield in the field and pot experiments. The observed effects were largest for the potato field followed by the grasslands and were smallest for the maize fields. Plant uptake of nitrogen, phosphorus, potassium, and magnesium was improved as well, while sodium and calcium uptake was not affected. Especially the increased uptake of nitrogen and phosphorus by plants and thus a more efficient use of fertilizers are very important in terms of nutrient legislation in high input cropping systems.

Aminifard *et al*. (2012) found that HA applied at 100 mg kg^{-1} resulted in the highest capsaicin (281.7 mg kg^{-1}) and lycopene contents (225 mg kg^{-1}) in hot pepper crop and the lowest values were observed in control. Total soluble solids and titratable acidity increased in response to HA treatments, and the highest values (34.6 mg l^{-1} and 11.25 °Brix) were obtained in the highest level of application (250 mg kg^{-1}).

Ferrara *et al.* (2012) observed that the grapevines treated with the humic acids exhibited a slight increase in shoot growth, increase in nitrogen and chlorophyll contents in the leaves and higher SPAD values. At harvest, the application of humic acids was found to increase total soluble solids (°Brix), °Brix-acidity ratio and pH but decreased the titratable acidity. Generally, application of humic acids significantly increased the berry size and thereby increase in the yield.

Muhammad Sajid *et al.* (2012) observed that the growth and yield parameters of onion cultivars were significantly influenced by various levels (0, 1, 2 and 3 kg ha^{-1}) of humic acid application. Treatment receiving 2 kg ha^{-1} of humic acid significantly increased neck height (7.6 cm), plant height (75.3 cm), bulb weight (96.4 g), yield $plot^{-1}$ (22.4 kg) and total yield ha^{-1} (35.86 tons) of onion(Parachinar Local) followed by cultivar "Swat-1" and the minimum yield was obtained from cultivar "NARC".

Sarwar *et al.* (2012) reported that application of humic acid @ 50 mg kg^{-1} along with 100 per cent recommended dose of P fertilizer (RDPF) improved the availability of soil organic matter (SOM), available P, K and B in soil. Soil application of humic acid @ 50 mg kg^{-1} along with 100% recommended dose of P fertilizer significantly enhanced grain weight by 72 per cent and number of pods $plant^{-1}$ by 22 per cent as compared to application of 100 per cent recommended dose of P fertilizer alone.

Results indicated that increasing humic acid application rates up to 120 kg ha^{-1} enhanced plant growth parameters, tuber production, biochemical indicators i.e., chlorophyll, ascorbic acid, nitrate, starch, total soluble solids and protein contents of potato (Selim *et al.*, 2012).

Harshad Thakur *et al.* (2013) reported that the combined application of RDF + humic acid granules @ 12.5 kg ha^{-1}(as basal) significantly influenced the growth parameters, yield attributes, seed and stalk yield of sunflower. Application of RDF + humic acid granules @ 12.5 kg ha^{-1} (as basal) registered significantly taller plants (183.3 cm) over RDF alone.

Ihsanullah and Bakhashwain (2013) recommended application of 25 kg HA ha^{-1} to improve growth and quality of fodder maize.

Khan *et al*. (2014) showed that plant fresh biomass increased by 23, 44 and 23 per cent dry biomass by when HA was applied at 25 and 50 mg kg^{-1}. Similarly the cob weight and grain weight increased significantly (29 % and 40 %) over control where in no HA was applied.

Muhammad Tufail *et al*. (2014) stated that application of humic acid @ 2.5 kg ha^{-1} recorded positive effect on growth and yield of wheat crop and also stimulated the growth of root and shoot.

Application of humic acid @ 3 kg ha^{-1} resulted in higher number of pods $plant^{-1}$, thousand grain weight and grain yield of mung bean when compared to application of HA @ 1 and 2 kg ha^{-1}. Similar results were obtained when mung bean seeds were treated with 1 and 2 per cent humic acid solution. (Muhammad Waqas *et al.,* 2014)

Shahein *et al*. (2014) reported that application of humic acid extracted from compost and biogas manure in combination with 50 per cent NPK through soil and as foliar spray recorded higher plant height, crop yield, chlorophyll and total soluble solids content in lettuce plant.

Vanitha and Mohandas (2014) studied the effect of humic acid on growth and yield attributes of aerobic rice under conventional, drip and subsurface drip fertigation system and reported that application of 100 per cent RDF (150:50:50 kg NPK ha^{-1}) along with humic acid recorded maximum root length (58.8 m $hill^{-1}$), higher chlorophyll content (2.61 mg g^{-1}), leaf area duration (151 days), increased grain filling per cent (69.1) and yield (5616 kg ha^{-1}).

Abeer *et al.* (2015) observed that humic acid significantly increased plant height, number of leaves, root length, shoot and root fresh and dry weights as well as chlorophyll content of common bean than control plants at 15, 30 and 45 DAP and also the graded levels of humic acid application showed significant increase in yield, titretable acidity, fruit weight and fruit diameter in tomato crop (Asri *et al.*, 2015)

Tuba Arjumend *et al.* (2015) reported that application of humic acid (HA) increased the growth of wheat in terms of shoot length (18 %), root length (29 %), shoot dry weight (76 %) and root dry weight (100 %). Response in terms of yield and yield components showed a significant increase in 1000 grain weight (8-16 %), biological yield (18-36 %), dry matter yield (15-25 %) and grain yield (19-58 %).

2.5.1 Effect of humic acid on root growth

In the plant-soil system the interaction between root cells and humic substances takes place when humic molecules present in the soil solution are small enough to flow in the apoplast and reach the plasma membrane (Varanini *et al.*, 1993). Humic substances absorbed by roots and translocated to shoot help in enhancing plant growth. Application of humic substances to soils with low clay and organic matter content has recorded significant growth response (Lulakis and Petsas, 1995) by stimulating root growth more apparently than shoot growth due to hormone-like activity of humic substances.

Ayuso *et al.* (1996) reported that the hydroxyl and carboxyl groups were mainly responsible for the response obtained with humic substances.

It has been found that application of granular humate induces significantly higher root mass than foliar applied humic acids due to more direct contact with plant roots than foliar applied humate (Cooper *et al.*, 1998).

Humic substances plays a favorable role in regulating the plant root metabolism by inducing the mechanism of protein synthesis, enzyme activation or inhibition resulting in morpho functional changes in plant root tissues (Cacco *et al.*, 2000).

Atiyeh *et al*. (2002) observed that humates had a direct effect on roots and this stimulating effect could be the result of alteration of membrane characteristics or as a result of plant energy metabolism.

2.6 Effect of humic acid on nutrients uptake by different crops

It is known that the concentration/content, uptake and transport of nutrients are influenced by humic substances. Thus, when nutrients are absorbed by an active metabolic process humic substances helps in absorption and tend to complex the ions but if the same ions are absorbed by means of passive mechanism such as diffusion through plant tissues humic substances do not intervene in the absorption Humic acids play an important role in the transport of trace elements (Huljev and Strohal, 1983).

Thangavelu and Ramabadram (1993) reported that in rice varieties (IR 50 and IR 20), application of lignite humic acid @ 20 kg ha^{-1} increased the total N, K and Ca content and thereafter it gradually decreased

The effects of humic substances on ion uptake appear to be more or less selective and variable in relation to their concentration and the pH of the medium (Nardi *et al*., 2002).

Humic substances plays a beneficial role in Fe acquisition by plants, which is due to its complexing properties which increase the availability of micronutrients from sparingly soluble hydroxides (Nardi *et al.*, 2002). Humic substances work on the metabolism of a plant and promote nutrient uptake or plant growth by acting as a hormone.

Application of HACU (Humic acid coated urea) recorded higher N uptake by rice, application of N at 150 kg ha^{-1} through HACU resulted in highest N uptake (103.9 kg ha^{-1}) by grain and (70.29 kg ha^{-1}) by straw. Whereas, nitrogen application at 150 kg ha^{-1} as HACU recorded the highest soil mineral N content of 40.12, 33.14 and 28.25 kg ha^{-1} at maximum tillering, panicle initiation and at harvest stage, respectively. Application of

NCU recorded highest mean response ratio (19.33) followed by HACU (19.3) (Dhanasekaran and Govindasamy 2002).

Sellamuthu *et al.* (2002) concluded that humic acid application along with $FeSO_4$ increased the active Fe content in leaves of groundnut and reduced chlorosis due to increased availability and translocation of Fe through chelation.

Soil application of humic acid @ 20 kg ha^{-1} along with 100 per cent recommended dose of fertilizer gave better nutrient content and uptake of major and trace elements in groundnut (Thenmozhi *et al.*, 2001).

Humic substances enhance the uptake of nutrients through stimulation of microbial activity (Mayhew, 2004). It increases P availability and uptake by inhibiting precipitation rates by calcium phosphate forming phosphohumates that increases or decreases adsorption sites by promoting dissolution of metal solid phases through chelation.

The stimulatory effects of humic substances have been directly correlated with enhanced uptake of macronutrients such as N, P, K and S (Delfine *et al*., 2005).

Khan *et al*. (2014) reported that HA application at 25 and 50 mg kg^{-1}along with N @ 150 and 300 mg kg^{-1} in maize increased the N content by 20 and 26 per cent, P by 14 and 20 per cent and K by 15 and 10 per cent, respectively. Thus HA application along with N improved growth, yield and nutrient uptake.

Asri *et al.* (2015) reported that humic acid application @ 80 L ha^{-1} along with recommended dose of fertilizers recorded higher concentration and uptake of N, P, K, Ca, Zn and Mn in tomato leaves. The relative increase in NPK uptake by plants grown with application of HA was 57, 96 and 62 per cent, respectively over the control. HA enhanced the nutrient status of soil by increasing soil organic matter (9 %), total N (30 %), available P (166 %) and available K (52 %) (Tuba Arjumend *et al.*, 2015).

2.7 Effect of humic acid application on physical, chemical and biological properties of soil

Humic acid contributes to soil organic matter and thereby improves degraded soil condition. It is an indicator of soil quality. The impact of humic acids can be seen through its effect on physical, chemical and biological properties of soil.

2.7.1 Physical properties

Application of organic matter to soil is known to significantly affect soil chemical (nutrient recycling) and physical characteristics which includes aggregate stability, bulk density, soil compaction, soil porosity and water infiltration rate. Attention is focused on identifying soil conditioners that can be effective at low rates and thus humic substances have been evaluated as potential soil conditioners.

Chaney and Swift (1984) reported significant correlation between aggregate stability, total organic matter, and total carbohydrates with humic materials.

Dhara and Gupta (1984) reported that application of humic acid improved the formation of water stable aggregates. With increase in the amount of humic acid application the mean weight diameter (MWD) of aggregates also increased. Bartoli and Phillippy (1990) found that the polyvalent cations such as Al^{3+} and Fe^{3+} ions enhances the hydrophobic effect of soil humic polymers.

Tarchitzky *et al*. (1993) studied humic acid of Na montmorillonite suspension and reported that HA increased the stability, due to interaction between the negatively charged HAs and the positively charged edges of soil clay particles.

Piccolo *et al*. (1996) stated that addition of highly humified organic substance such as coal- derived humic acid can improve the structural and water retention properties of degraded arable soils and also found that mode of action of humic substances was similar to that of synthetic conditioners, namely polyacrylamides (PAM) and polyvinylalcohols (PVA). The advantage of humic substances is its chemical structure that makes it more resistant to microbial attacks. Reports have shown that humic substances extracted from farmyard manure improved and prolonged aggregate stability more than application of bulky farmyard manure (Piccolo *et al*., 1997).

Humic acids can be inexpensively incorporated into soils through biowastes such as manure and the resulting organic matter improved soil physical properties (Mackowia *et al*., 2001). Moisture retention capacity of soil increased significantly with application of 1.0 mg kg^{-1} HA at 1.5 MPa. (Riaz *et al.*, 2013)

Field experiment conducted to study the impact of humic acid on soil physical properties and wheat yield using two different grades (Laboratory and commercial grade). Humic acid with eight levels for two years showed that humic acid levels improved the soil physical health such as aggregate stability and hydraulic conductivity of soil. The decrease in bulk density was more in laboratory grade humic acid compared to commercial grade (Ijaz Ahmad *et al.*, 2015).

2.7.2 Complexing properties of humic acid

Humic acid forms complexes with metals and soil nutrients through ionization at proton dissociating groups including carboxylic and phenolic groups. Among the important aspects of humus in soil, the most significant is its interaction with the clay constituents which gives rise to clay humus complex (Waksman, 1936). Clay-humus complex is important in plant nutrition because this organo-mineral complex is negatively charged and holds soil minerals.

The carboxyl, phenolichydroxyl and quinine groups are mainly responsible for binding humic molecules to clay minerals (Kononova, 1966 ; Rashid, 1972). Varadachari *et al*. (1991) reported that Al clay probably forms chelates with the COOH and phenolic OH groups of humic acid. The monovalent cations are held by cations through the formation of salts with COOH groups while multivalent cations have the potential of forming coordinate linkages with organic molecules.

Neo *et al*. (1991) found that humic acids form two types of complexes with Cu^{2+} ions, one with oxygen containing groups and the other with nitrogen containing groups. Relan *et al.*, (1993), through their infrared spectral studies, on humic and fulvic acid materials derived from FYM, reported that phenolic OH and COOH groups forms complex with Zn^{2+}, Cu^{2+}, Mn^{2+}, Fe^{2+}, Pb^{2+} and Cd^{2+}.

Copper has high tendency to form complex with humic acid (Reddy and Rao, 2000). Formation of organomineral complex with HA reduces P fixation capacity considerably, the reduction can be attributed to the removal of charges balancing aluminium hydroxyl species during organic treatment which is dependent. Increase in degree of polymerization and increase in nutrient availability from less soluble hydroxides, particularly iron, zinc and manganese (Chen *et al.*, 2004).

2.7.3 Chemical properties

There is a close relationship between soil organic matter content and soil fertility. Therefore, one of the most important ways to regenerate soil is through addition of organic material.

Tan and Nopammornbodi (1979) reported increased P availability in soil due to interaction of humic acid with P through its phenolic hydroxyl groups.

The humic substances have indirect effect on the plant growth by changing the soil structure, increase cation exchange capacity, stimulate microbial activity and also has the capacity to solubilize or complex certain ions in soil (Ayuso *et al.*, 1996).

Since humic acid bind to soil colloidal surfaces, it does not leach out of the soil and sorption of soil minerals like Cu and Zn (Mackowiak *et al.*, 2001).

Filip and Bielek (2002) reported that addition of organic substances enhanced the solubility of soil phosphorus by forming complex with Fe and Al in acid soils and with Ca in calcareous soils. One of the most striking characteristics of humic acid in soils and other environments is their ability to interact with metal ions and soil minerals and form complexes with increasing chemical stability.

Sathyabama (2002) reported that the application of humic acid at graded levels increased the soil available nutrients, organic carbon and CEC.

Nandakumar *et al.* (2004) conducted field experiments to evaluate the effect of humic acid (HA) in the form of potassium humate on soil nutrient availability at different growth stages of rice. Application of HA in combination with NPK increased the soil nutrient availability at all growth stages (tillering, flowering and harvesting) of rice in both Vertisol and Alfisol. Application of HA @ 10 kg ha^{-1} as soil application + 0.1 per cent HA as foliar spray (twice) + 0.3 per cent HA as root dip + 100 per cent NPK and HA at 20 kg ha^{-1} as soil application + 100 per cent NPK, was found to be best treatments for improving soil nutrient availability.

Jones *et al*. (2007) found that humic substances in organic matter enhances crop growth when present in high quantities but it was also observed that commercial humic acid is applied at low rates (1-3 lb $acre^{-1}$) enhances P availability and improves growth and yield of crop.

Mikkelsen (2005) stated that humic materials form complex with various cations and serve as a sink for polyvalent cations in the soil. Organic amendments increase the organic carbon and nitrogen contents (Melero *et al*., 2007).

The buffering capacity of a solution is more important than the pH value of that solution. Buffering capacity is an indication of the amount of acid or base that can be added before the buffer loses its ability to resist pH change and is dependent on the amount of conjugated acid or base available in the system and humic acids have acid groups and proton-binding abilities that have a direct effect on the acid-base buffering capacity of soils. It is strongly supported by literature that soils rich in humic substances are well buffered (Pertusatti and Prado, 2007). Soils with a strong buffering capacity and high carbonate content shows a little effect on the pH over an extended period (Melero *et al.*, 2007).

Pinheiro *et al.* (2007) reported that the beneficial effect of humic acids in an agricultural system is through its ability to complex metal ions. Humic acids can form aqueous solutions with micronutrients, though not to the same extent as many synthetic chelating agents.

Susilawati Kasim *et al*. (2009) reported that the application of both humic and fulvic acids could be effective in promoting NH_4^+ retention and will have great ability in controlling NH_3 loss, thereby retaining NH_4^+ in acid soils.

The increase of humic substances application rates was associated with decrease in nutrients leaching which was reflected in increasing macro and micronutrients concentration in potato tubers as well as increasing the concentration of these nutrients in soil after the harvest of tubers (Selim *et al.*, 2009). One of the most important properties of humic acids is its buffering capacity in a wide pH range, which arises essentially from the dissociation of acidic functional groups (Tahir *et al.*, 2011)

The growth of wheat and N uptake in the non-calcareous soil was higher than that in calcareous soil, the HA application significantly improved K content of the non-calcareous soil and P and NO_3-N content of the calcareous soil (Tahir *et al.*, 2011).

Soil application of humic acid @ 50 mg kg^{-1} along with 100 per cent recommended dose of P fertilizer significantly increased the availability of SOM (16 %), phosphorus (60 %), potassium (4 %) and boron (34 %) compared to 100 per cent RDPF alone respectively (Sarwar *et al.*, 2012).

Riaz *et al*. (2013) reported that CEC of saline-sodic soils was enhanced from 12.3 to 20.7 per cent over the control with additions of 1.5 and 3.0 mg kg^{-1} HA.

Addition of K^+ and NH_4^+ affected pH, CEC, K^+, NH_4^+, and water content of the buffer. Application of humic acid-based buffer significantly decreased the soil pH from > 7 to about 6.3, decreased soil EC to 0.9 mS cm^{-1} and increased the exchangeable Na from 0.40 to 0.56 me 100 g^{-1} soil, Ca from 15.57 to 20.21 me 100 g^{-1} soil, Mg from 1.76 to 6.52 me 100 g^{-1} soil and K from 0.05-0.51 me 100 g^{-1} soil (Mindari *et al.*, 2014).

Tuba Arjumend *et al.* (2015) reported that application of humic acid increased the soil nutrient status by increasing organic matter (9 %), total N (30 %), available P (166 %) and available K (52 %).

2.7.4 Biological properties of soil

Humic substances produce beneficial influence on microbes in several ways. They act as a source of food and energy for many microorganisms. The addition of organic materials results in increase in soil microbial biomass than that of inorganic fertilizers which is mainly due to higher organic carbon content**.**

Humic substance was found to stimulate plant growth by increasing the absorption of soil nutrients. Application of humic acid increases the growth of a wide range of taxonomic and functional groups of soil bacteria and it has been hypothesized that a modification of cellular activity and growth might be promoted by humic substances through their influence on cell membrane permeability or on nutrient absorption (Vallini *et al.*, 1993).

Valdrighi *et al*. (1996) in their studies found that application of humic acid resulted in the direct influence of surfactant activity on absorption of mineral nutrients and thereby enhanced microbial growth.

Deepa and Govindarajan (2002) concluded that, addition of humic acid to the soil considerably increased the bacteria, fungal and actinomycetes population in the root rhizosphere.

Charest *et al*. (2004) reported that humic acids supplying the essential cations such as chelated Fe or can chelate toxic concentrations of Cu thereby facilitates microbial growth.

Indirectly humic substances influence microorganisms through its cation exchange capacity which is five times greater than that of soil minerals. Hence essential cations are either made available such as Fe or toxic concentrations of Cu are chelated allowing microbial growth (Charest *et al.,* 2004). According to these authors humic substances can also influence microorganisms directly if humic substances of adequate size are to be taken up by microorganisms.

In a soil nutrient cycle, one of the most critical aspects is decomposition of litter for which microbes are directly responsible. These soil animals are micro arthropods, isopods and earthworms that can stimulate decomposition via litter fragmentation and defecating into the soil and through altering the activity and composition of the microbial activity (Ayres *et al*., 2005).

Organic amendments not only improve soil structure but also serves as a source of nutrients for soil microflora. Thus addition of good quality compost increases the microbial biomass and enhances soil enzyme activity (Perez-Piqueres *et al*, 2005).

2.7.5 Soil enzymes

Gaur and Bhardwaj (1971) found that the humic substances influenced the biological properties of soil by enhancing the microbial population and enzyme activity. Humic substances were found to serve as an energy source for various strains of micro organisms such as *Rhizobium, Aspergillus niger, Azotobacter sps*, etc.

The level of soil enzyme activity increases with increased soil organic matter content (Spier and Ross, 1976) which may be related to the population dynamics of the soil microbiota. Enzymes directly contributed by the addition of organic amendment may also influence the soil enzyme activity in soil. Many of these enzymes are important in the formation of recalcitrant organic molecules that contribute to the chemical stability of the soil ecosystem.

The increase in amylase activity with application of humic acid in paddy crop was also reported by Subramani and Kannaiyan (1989).

The effect of humic fraction on invertase and peroxidase activity in wheat seedlings studied by Concheri *et al.* (1996) found that humic fractions stimulated enzymatic activity of peroxidase and invertase.

Study conducted by Deepa (2001) on the root colonization of the organism of the *Glomous mosseae* on maize indicated 72 per cent increase in population with the application of 20 kg ha^{-1} humic acid along with 0.1 per cent foliar spary and 1 per cent seed treatment when compared to control.

The available nutrient status of the soil improved with the application of humic acid in combination with fertilizers owing to enhanced microbial activity and favorable conditions created in the soil (Thenmozhi, 2001)

Sellamuthu and Govindaswamy (2003) reported that higher amount of microbial population and enzymes were observed where fertilizer and humic acid were applied. Maximum bacteria, fungi and actinomycetes populations were recorded with application of 100 per cent NPK and 30 kg HA ha^{-1}. However application of humic acid @ 20 kg ha^{-1} was found to enhance the catalase and alkaline phosphatase activity. While application @ 30 kg ha^{-1} significantly influenced the dehydrogenase activity. Application of humic compounds combined with inoculation of phosphate solubilizing bacteria was found to increase the pH, the available P status and decreases exchangeable Al content of an Ultisol (Sugeng Winarso *et al.,* 2011)

Riaz *et al*. (2013) reported that HA treatment significantly increased the alkaline phosphatase activities and urease activities by 2.84, 5.71 and 20.73 per cent with application of 0.5, 1.0 and 2.0 mg HA kg^{-1} respectively, in normal soil and by 16.7 and 33.6 per cent with addition of 1.5 and 3.0 mg kg^{-1} in salt affected soils as compared to control (HA_0). Microbial activities, measured in terms of CO_2 evolved increased by 15.7, 36.7 and 78.8 per cent at no NPK, 14.8, 37.1 and 66.8 per cent at half NPK, and 15.4, 40.9 and 51.25 per cent at full NPK with addition of 0.3, 0.6, and 1.0 mg HA kg^{-1} soil, respectively as compared to control.

Study carried out by Shahein *et al*. (2014) on soil and foliar application of humic acid extracted from biogas manure and compost along with 50 per cent NPK recorded higher dehydrogenase and nitrogenase activity when compared to control.

III MATERIAL AND METHODS

The present investigation entitled "**Extraction and characterization of humic acid from organic wastes, evaluation of their impact on soil properties, growth and yield of crops**" was carried out at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru.

In order to meet the objectives of research, a pot experiment under greenhouse condition and a field experiment were carried out during *kharif* 2014 and 2015, respectively and the investigation was carried out in four phases.

a) Characterization of different organic waste materials viz., coco peat, coffee pulp, pressmud, biofuel waste, distillery biocompost, sewage sludge, poultry manure, vermicompost, urban compost and farmyard manure for their nutrient composition.

b) Extraction, fractionation, characterization and quantification of humic substance of different organic wastes.

c) Pot culture experiment under greenhouse condition during *kharif* 2014 to identify the best sources and levels of application of humic acid extracted from different organic wastes with maize and capsicum as test crops.

d) Field experiment during *kharif* 2015 to evaluate the efficiency of best source and level of humic acid application based on results of pot experiment on growth, yield and soil properties with capsicum as main crop followed by French bean as residual crop. The detail of the materials used and the methods followed during the course of investigation has been described in this chapter.

3.1 Characterization of organic wastes

Various agroindustrial and agricultural organic wastes were collected from different locations and the details of collection are furnished in Table 1. The organic waste samples were air dried, powdered and stored for further analysis.

Table 1: Organic wastes from different locations

Humic acid sources	Sources
Coco peat	Cocopeat industry, Doddaballapur
Coffee pulp	Farmers field, Chikkamagalur
Pressmud	Chamundeshwari Distillery, K.M Doddi, Mandya
Biofuel waste	Organic farming unit, UAS, GKVK, Bangalore
Distillery bio compost	Chamundeshwari Distillery, K.M Doddi, Mandya
Sewage sludge	Sewage treatment plant, Jakkur, Bangalore
Poultry manure	Poultry farm, Doddaballapur
Vermicompost	Zonal agricultural research station, UAS, GKVK
Urban compost	Karnataka compost development corporation, Bangalore
Farmyard manure	Farmer's field, Harohalli

3.1.1 Nutrient content of organic waste

Powdered samples of organic material was analyzed for pH and electrical conductivity in 1:10 and 1:100 ratio of organic waste and distilled water. Kjeldhal digestion cum distillation method was adopted for total N estimation. For other macro, secondary and micro nutrients the organic waste samples were digested separately using diacid mixture. The methods adopted are presented in Table 2.

Table 2: Methods adopted for the analysis of organic wastes

Parameter	Method	Reference
MWHC (%)	Keen's Cup	Piper (1966)
pH	Potentiometry	Jackson (1973)
EC (dS m^{-1})	Conductometry	Jackson (1973)
Organic carbon (%)	Dry combustion	Jackson (1973)
Total nitrogen (%)	Micro kjeldahl digestion and distillation	Piper (1966)
Total phosphorus (%)	Vanadomolybdic yellow colour spectrophotometry	Piper (1966)
Total potassium (%)	Flame photometry	Piper (1966)
Total calcium (%)	Versenate titrimetry	Piper (1966)
Total magnesium (%)	Versenate titrimetry	Piper (1966)
Total sulphur (%)	Turbidimetry	Bradsley and Lancester (1965)
Total Fe, Mn, Zn and Cu (ppm)	Atomic absorption spectrophotometry	Lindsay and Norvell (1978)
Total B (ppm)	Colorimetry using Azomethane-H reagent with continuous flow analyzer	Page *et al.* (1982)
Heavy metals content (Pb, Ni, Cr, Cd)	Atomic absorption spectrophotometry	Lindsay and Norvell (1978)

3.2 Extraction, fractionation and quantification of humic substances

3.2.1 Extraction of humic substances

Ten gram of air dried organic sample was weighed in to 250 ml conical flask 100 ml of 0.1 N NaOH was added (Schnitzer and Skinner, 1968) and shaken for 24 hours. The dark colored supernatant solution was separated by centrifugation and collected. The extraction procedure was repeated thrice using 50 ml of extractant each time for complete extraction of the humic substances.

3.2.2 Fractionation and purification of humic substances

The precipitated humic acid fraction was separated by centrifugation. Precipitation and centrifugation was repeated to attain partial purification of humic acid fraction as described by Stevenson (1981). The fractions were further purified by treating with HCI-HF mixture (5 ml of each HCI and HF acids were dissolved in 990 ml of double distilled water) for 24 hours and this acid mixture was separated by centrifugation. The residue so obtained was thoroughly washed with distilled water and freeze dried to obtain humic acid (Plate 1).

3.2.3 Purification of fulvic acid

The purification of fulvic acid was done by following the procedure as outlined by Wander and Traina (1996). The aqueous solution obtained after centrifugation was passed through exchange resin (Sera lite SRC-120) in the H^+ form. For this, an adsorption column of 20 cm length with a porcelain perforated bed was used. Over this, a glass wool packing of 0.5 cm was placed. The resin was uniformly packed up to 15 cm height using wet packing method. Over the column again a glass wool packing of 0.5 cm was again placed. The aqueous solutions were eluted through this column four times and the fulvic acid fraction eluted was directly transferred to 100 mwco dialysis bags and dialyzed against double distilled water for 24 hours. The dialyzed fraction was evaporated under low temperature and freeze dried to obtain fulvic acid.

3.2.4 Characterization of humic acid

Purified samples of humic acid extracted from different organic wastes were subjected to elemental analysis, total acidity, E_4/E_6 ratio and other nutrient analysis.

3.2.4.1 Elemental analysis

Humic acid extracted from different organic wastes were subjected to elemental analysis. The carbon, hydrogen, nitrogen and sulphur content of the humic acid was estimated by dry combustion method using CHNS analyser. The oxygen content was computed by recording the difference between the sum of the C, H, and N percentages from hundred.

The molar ratio of elements was computed by dividing the content of elements present in percentage by their atomic mass (Orlov *et al*., 1992).

3.2.4.2 Total acidity

Total acidity of humic acid was determined by $Ba(OH)_2$ method by Schnitzer and Gupta (1964). The sample was allowed to react with an excess of $Ba(OH)_2$. The unreacted $Ba(OH)_2$ was determined by back titrating with standard acid as per thevfollowing reactions.

$$Ba(OH)_2 + 2\ HA \text{ ----------------> } BaA_2 + 2\ H_2O$$

Fifty milligrams of HA and a blank (Ba $(OH)_2$) was taken in separate stoppered flasks and 20 mL of 0.2 N $Ba(OH)_2$was added. The flasks were shaken for 24 hours, the suspension was filtered and the residue washed with CO_2 free distilled water. The filtrate and washings were titrated against 0.5 N HCl to pH 8.4 potentiometrically.

$$\text{Total acidity (m eq g}^{-1}) = \frac{(\text{TV for blank-TV for sample}) \times 0.05 \text{ N} \times 1000}{\text{Wt. of the sample (mg)}}$$

Carboxyl groups

The method is based on the liberation of acetic acid when acids are treated with calcium acetate and its titration was carried out with standard 0.1 N NaOH (Schnitzer and Khan, 1972).

$$2R\text{-}COOH + (CH_3COO)_2\,Ca \text{ -------> } (RCOO)_2 + 2CH_3COOH$$

To fifty milligrams of HA in a stoppered flask, 10 ml of 1 N (CH_3COO) 2Ca and 40 ml of CO_2-free distilled water were added. A blank was also set up simultaneously. The flasks were shaken at room temperature for 24 hours and the residue was washed with CO_2-free distilled water. The filtrate and washings were titrated potentiometrically with standard 0.1 N Na OH to pH 9.8.

$$\text{-COOH group (m eq g}^{-1}) = \frac{(\text{TV for sample -TV for blank}) \times 0.1 \times 1000}{\text{Wt. of the sample (mg)}}$$

Phenolic –OH groups

The phenolic –OH groups was calculated as the difference between total acidity and –COOH acidity.

$$\text{Phenolic –OH groups (m eq g}^{-1}) = \underset{(\text{meq g}^{-1})}{(\text{Total acidity})} - \underset{(\text{meq g}^{-1})}{(\text{COOH acidity})}$$

3.2.4.3 E_4/E_6 ratio

The degree of humification and aromaticity of humic acid was measured using E_4/E_6 ratio. A known quantity of the sample was taken and dissolved in 10 ml of $1x10^{-2}$ M $NaHCO_3$ solution. The absorbance and ratio was recorded at wavelength 465 and 665 nm using UV-VIS spectrophotometer.

3.2.4.4 Digestion of humic acid sample for determination of other elements

A known weight of humic acid sample was taken in a 250 ml conical flask and was predigested by adding 10 ml of HNO_3 and keeping it overnight. Diacid mixture (10 ml) in 9:4 proportion (HNO_3:$HClO_4$) was added and heated on sand bath until a snow white residue was obtained. The residue was cooled and diluted to a known volume with distilled water, filtered and made up to 100 ml using distilled water it was further used for estimation of all other elements. The methods adopted are same as outlined in Table 2.

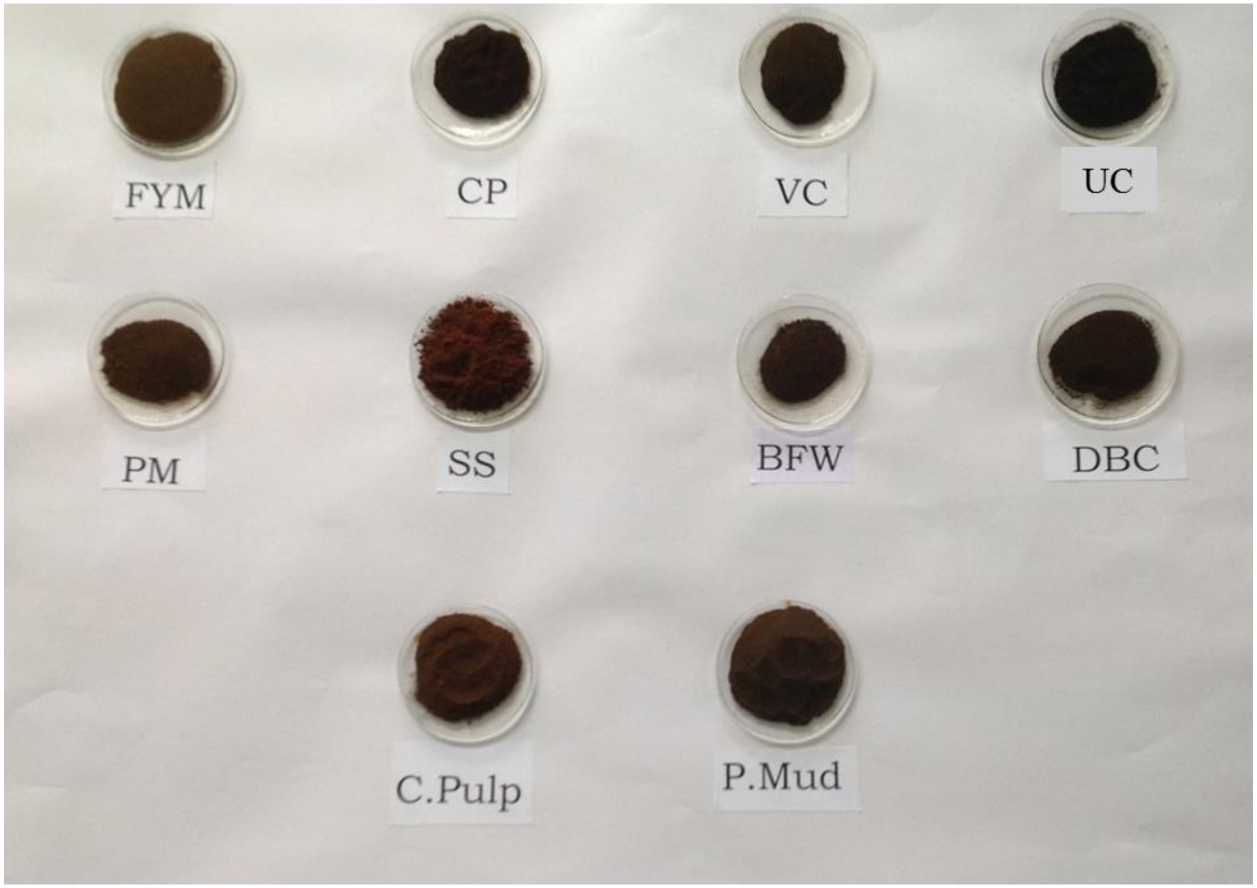

Plate 1: Humic acid extracted from different organic wastes

LEGEND

FYM - FARMYARD MANURE
CP - COCO PEAT
VC - VERMI COMPOST
UC - URBAN COMPOST
PM - POULTRY MANURE
SS - SEWAGE SLUDGE
BFW - BIOFUEL WASTE
DBC - DISTILLERY BIO COMPOST
C. Pulp - COFFEE PULP
P. Mud - PRESSMUD

3.3 Pot culture experiment to identify the better organic source and level of humic acid application

Based on characterization of humic acid extracted from different organic waste, graded levels of humic acids @ 30, 60, 90 kg ha^{-1} was applied to evaluate best source and application rate. Greenhouse pot experiment was conducted at GKVK during 2014 with maize and capsicum as test crops.

Soil sample was collected from a farmer's field at Harohalli village, Devanahalli Taluk, Bangalore rural district and analyzed for physical and chemical properties by following standard procedure (Table 3).

Table 3: Methods adopted for soil analysis

Parameters	Methods	References
Physical analysis		
Texture	International Pipette method	Piper (1966)
Bulk density (Mg m^{-3})	Core sampler method	Piper (1966)
MWHC (%)	Keen Raczkowski Cup method	Piper (1966)
Chemical analysis Field Capacity		
pH (1:2.5)	Potentiometric method	Jackson (1973)
EC (dS m^{-1})	Conductometric method	Jackson (1973)
Organic carbon (%)	Wet oxidation method	Walkley and Black (1934)
Cation exchange capacity [cmol (p+) kg^{-1} of soil]	Ammonium acetate leaching method	Jackson (1973)
Avail. N (kg ha^{-1})	Alkaline potassium permanganate distillation method	Subbiah and Asija (1956)
Avail. P (kg ha^{-1})	Olsen's extractant method, Colorimetry using ascorbic acid reagent	Jackson (1973)
Avail. K (kg ha^{-1})	Ammonium acetate extractant method, Flame photometry	Jackson (1973)
Exch. Ca and Mg [cmol (p^{+}) kg^{-1}]	Ammonium acetate extractant method, Versenate titration method	Jackson (1973)
Exch. Na [cmol (p^{+}) kg^{-1}]	Ammonium acetate extractant method, Flame photometry	Jackson (1973)
Avail. S (mg kg^{-1})	$CaCl_2$extractant method, Turbidimetry	Black (1965)
DTPA extractable Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norvell (1978)
Avail. B (mg kg^{-1})	Hot water extraction method and colorimetry using Azomethine-H reagent with continuous flow analyzer	John *et al.*(1975)

Five kg of air dried soil sample passed through 2mm sieve was filled in plastic pots. Required quantity of humic acid powder was dissolved in a small quantity of 0.01 N potassium hydroxide to alter the pH to 7.2. The pots were treated with graded levels of humic acid (30, 60 and 90 kg ha^{-1}) extracted from 10 different organic wastes along with recommended dose of fertilizer (150: 75: 40 and 150:100:150 kg ha^{-1} for maize and capsicum, respectively. The pots which received NPK alone and NPK+FYM were considered as checks since humic acid was not applied. Three maize seeds / pot were sown, and 25 days old capsicum seedlings were transplanted to the pots. After germination of maize seeds, single plant was maintained per pot. The pots were maintained at field capacity and kept under greenhouse condition by following timely plant protection measures. Treatments were replicated thrice Detailed treatment plan has been presented in Table 4.

Table 4: Treatment details for pot culture experiment

Treatments	**Humic acid sources**	**L_1**	**L_2**	**L_3**
		(kg ha^{-1})		
S_1	Coco peat	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_2	Coffee pulp	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_3	Pressmud	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_4	Biofuel waste	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_5	Distillery bio compost	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_6	Sewage sludge	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_7	Poultry manure	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_8	Vermicompost	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_9	Urban compost	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_{10}	Farmyard manure	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
Only NPK				
Rec. NPK + FYM				

N**ote: S= Source L= Level**

Experiment details

Sources: Humic acid was extracted from ten different sources of viz., coco peat, coffee pulp, pressmud, biofuel waste, distillery bio compos, sewage sludge, poultry manure, vermi compost urban compost and farmyard manure (FYM).

Levels of humic acid : 30, 60 and 90 kg ha^{-1}

Replications : 3

Design : CRD

Crops	**:**	Maize and capsicum
Date of sowing / transplanting	**:**	22.12.2014
Recommended dose of fertilizer	**:**	Maize: 150: 75: 40 kg ha^{-1} Capsicum: 150:100: 150 kg ha^{-1}

3.3.1 Growth parameters

Observations on growth parameters like plant height, number of leaves, number of branches, SPAD chlorophyll meter readings (SCMR) were recorded for both the crops. The experiment was carried out up to 60 days and at the end root and shoot biomass was separated to record the yield.

The methodology adopted for recording growth parameters of maize and capsicum has been detailed below.

3.3.1.1 Plant height (cm)

The plant height was measured from the base of the plant to base of the fully opened top leaf in maize and in case of capsicum at ground level to apex of the plant at different intervals 20, 40 and 60 days after sowing in case of maize, 20, 40 and 60 days after transplanting in case of capsicum.

3.3.1.2 Number of leaves per plant

The total number of green leaves produced per plant in each treatment was recorded and expressed as the average number of green leaves per plant at the time interval mentioned above.

3.3.1.3 Leaf area (dm^2 $plant^{-1}$)

Leaf area was measured by adopting Stickler's linear measurement method and expressed as dm^2 per plant. The length of fully opened leaf lamina was measured from the base to the tip and leaf breadth was measured at the widest point of the leaf lamina.

$$\text{Leaf area } (dm^2) = L \times B \times 0.747$$

L = Length of leaf

B = Breadth of leaf

3.3.1.4 SPAD Chlorophyll Meter Reading (SCMR)

The greenness or relative chlorophyll content of the leaves was measured using SPAD (Soil Plant Analytical Development) chlorophyll meter. The observations were made between 10.00 and 12.00 hours of the day.

3.3.1.5 Dry matter production (g pot^{-1})

At 60 DAS/transplanting, the plants were uprooted and separated into shoot and root, thoroughly washed and chopped into small pieces, dried in shade and then dried in a hot air oven at 65 °C to enable complete drying. Oven dry weight of whole plant including leaf and stem was recorded and expressed as grams per plant.

3.3.2 Soil analysis

After harvest of the crops, the soil sample was collected from each of the pots. The sample were dried in shade, gently ground using wooden pestle and mortar and passed through 2 mm sieve. The sieved samples were used for further analysis. The soil samples were analysed for pH, EC, OC, CEC, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B as per the procedure given in Table 3.

3.3.3 Plant Analysis

Collection and preparation of plant samples

The plant sample collected from each pot was washed with water and dried in shade for 6 hours and then in a hot air oven at 65 °C. The dried sample was powdered using stainless steel Willey mill. The powdered plant samples were stored in polythene bottles for further analysis. The methodology adopted has been outlined in Table 5.

Table 5: Methods followed for the analysis of plant samples

Plant analysis		
Parameter	**Method**	**Reference**
Nitrogen	Kjeldahl digestion and distillation method	Piper (1966)
Phosphorus	Diacid digestion and colorimetry using vanadomolybdate reagent	Piper (1966)
Potassium	Flame photometery	Piper (1966)
Calcium and Magnesium	Complexometry using versenate solution	Piper (1966)
Sulphur	Turbidometry	Bradsley and Lancester (1965)
Micronutrients cations (Fe, Mn, Zn & Cu)	Atomic absorption spectrophotometery	Lindsay and Norwell 1978
Boron	Colorimetry using Azomethine-H reagent with continuous flow analyzer	Page *et al.* (1982)

3.4 Field experiment to evaluate the effect of selected humic acid sources and graded levels of humic acid application on growth, yield and quality of capsicum

Based on the results of pot experiment humic acid extracted from selected three sources viz., humic acid extracted from coffee pulp, pressmud and poultry manure were selected. These three sources of humic acid at two levels (60 and 90 kg ha) were applied to plots to study their effect on growth, yield and quality of capsicum.

The experiment was conducted in farmer's field at Harohalli village, Devanahalli Taluk, Bangalore rural district during *Kharif* 2015 with capsicum as test crop.

The experimental site is situated at 13° 18' North latitude and 77° 44' East longitude and at an altitude of 901 meters above MSL. It falls under Eastern Dry Zone (Agro-Climatic Zone V) of Karnataka.

3.4.1 Climatic data and analysis

The weather data of the area was collected from Karnataka state natural disaster monitoring cell, Yelahanka, Bengaluru.

Annual mean maximum temperature ranged from 29.3 to 32.2 °C and minimum temperature ranged from 17.8 to 19.2 °C and dry condition prevailed during the months of May, August and October during 2014 and September and November during 2015.

The normal actual climatic condition during crop growth period at Devanahalli taluk (BRD) has been presented in Table 6.

An amount of 579.5 and 1052.5mm of rainfall was well distributed during 2014 and 2015, respectively as against the normal rainfall of 782.7 mm. This was designated as optimum rainfall having -26 deviation on the negative side during 2014 and 34 percent from the normal during the year 2015.

Table 6: Monthly distribution of rainfall (mm) at Harohalli, Devanahalli taluk, Bangalore Rural District during 2014 and 2015

Months	2014			2015		
	Normal	Actual	Deviation	Normal	Actual	Deviation
January	1.2	0	-1.2	1.2	13.5	12.3
February	5.8	0	-5.8	5.8	0	-5.8
March	25.4	5	-20.4	25.4	17.5	-7.9
April	38.4	6	-32.4	38.4	82.5	44.1
May	83.8	116	32.2	83.8	67.5	-16.3
June	72.1	40.5	-31.6	72.1	55.5	-16.6
July	87.5	41	-46.5	87.5	87	-0.5
August	110.2	114	3.8	110.2	65	-45.2
September	151.2	21.5	-129.7	151.2	425.5	274.3
October	146.1	192	45.9	146.1	52	-94.1
November	49.9	35	-14.9	49.9	174.5	124.6
December	11.3	8.5	-2.8	11.3	12	-0.7
Total	**782.7**	**579.5**	**-406.8**	**782.7**	**1052.5**	**268.2**

Layout

Experiments were conducted in a farmer's field at Harohalli, Devanahalli Taluk. The treatment details of the experiment are given in Table 7. The layout of experiment is depicted in Fig 2.

Experimental details:

Crop and variety

Capsicum (Main crop)	: Variety- Indra
Spacing	: 100 cm × 40 cm
Number of treatments	: 8
Design	: RCBD
Number of replications	: 3
Gross Plot size	: 4.0 m × 3.6 m
Date of transplanting	: 19.07.2015

Table 7: Treatment details for field experiment

T_1	Recommended dose of NPK
T_2	Recommended dose of NPK + FYM
T_3	Recommended dose of NPK + 60 kg Humic acid extracted from coffee pulp
T_4	Recommended dose of NPK + 90 kg Humic acid extracted from coffee pulp
T_5	Recommended dose of NPK + 60 kg Humic acid extracted from pressmud
T_6	Recommended dose of NPK+ 90 kg Humic acid extracted from pressmud
T_7	Recommended dose of NPK + 60 kg Humic acid extracted from poultry manure
T_8	Recommended dose of NPK + 90 kg Humic acid extracted from poultry manure

Note:

1. RDF 150:100: 150 kg N P_2O_5 K_2O ha^{-1} common to all the treatments applied through fertigation.
2. Statistical analysis has been done adopting the following humic acid treatments T_3 to T_8 have been analysed adopting two factor (levels and sources) RCBD design.
3. The treatments T_1 to T_8 have been analysed adopting simple RCBD.

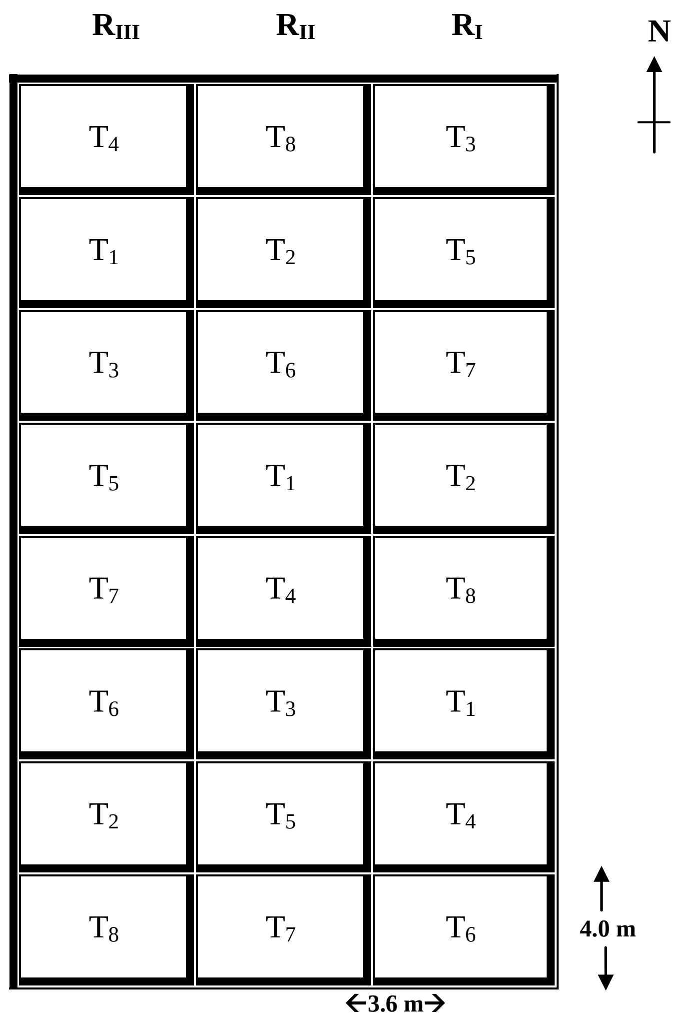

Fig. 2: Layout plan of field experiment

3.3 Soil characteristics of experimental site

Soil sampling

A composite soil sample was collected at 0 to 15 cm depth from the experimental plot and was brought to the laboratory, dried under shade, powdered gently using wooden pestle and mortar and passed through 2 mm sieve. The soil sample (< 2 mm fraction) was stored in plastic container for determining the available nutrient status. The methodology adopted is as outlined in Table 3.

3.5 Cultural practices

3.5.1 Preparation of land

The experimental plot was ploughed twice with disc plough and brought to fine tilth by harrowing. The land was leveled and the individual plot was prepared by raising small bunds around each plot.

3.5.2 Preparation of raised beds

Raised beds of 25 cm height, 3.6 m length and 0.60 m width were prepared with spacing of 40 cm between the two.

3.5.3 Fertilizer application

At the time of transplanting 15-15-12 kg NPK was applied as basal dose as per the treatments to respective plots and incorporated into soil before transplanting. The remaining fertilizer dose was supplied through fertigation (27 fertigations) from 21 DAP to 129 DAP for a period of 4 month duration (two splits/ week). Potassium nitrate, 19:19:19 and calcium nitrate were used as water soluble fertilizers.

3.5.4 Application of Humic acid

After preparation of seedbed and application of basal dose of fertilizer calculated quantity of humic acid extracted from coffee pulp, pressmud and poultry manure was added uniformly to raised beds on v/w basis according to treatments. The treatment NPK alone (T_1) and NPK + FYM (T_2) were considered as control and compared with those treated with humic acid.

3.5.5 Mulching

Silver colored polyethylene sheet of 30 micron thickness was spread in each plot as mulch mainly to conserve the soil moisture and prevent weed growth.

3.5.6 Transplanting

According to the spacing (100 cm × 40 cm) marking was done on the polyethylene sheet spread on raised beds. Holes were made using PVC pipe and 25 days old healthy capsicum seedlings of uniform growth were transplanted.

3.5.7 Training and Aftercare

The main stem of plant was trained five weeks after transplanting. Weeding was done once in 30 days to keep the plots weed free and suitable plant protection measures were taken up when ever required.

3.6 Recording of experimental data

Observations on growth parameters, yield parameters and fruit quality parameters were recorded from five randomly selected plants from the net plot area in each treatment. The techniques used and the details of observations recorded is provided in Table 7.

Harvesting

The mature fruits were harvested periodically at 65 days after transplanting at different intervals from five randomly selected plants in each treatment (Table 7). The procedure followed for recording observations on growth parameters viz., plant height (cm), number of branches per plant, number of leaves per plant, SPAD chlorophyll meter reading (SCMR) was similar to that followed in pot culture experiment.

Table 8: Details of observations recorded during the field experiment

Observations	**Method followed**	**Interval**
Growth parameters		
Plant height (cm)	Ground level to the tip of fully opened leaf of the plant.	30, 60, 90 and 120 DAT and at harvest
No. of branches	Well-developed branches on the main stem were recorded	30, 60, 90 and 120 DAT and at harvest
No. of leaves	Fully opened leaves were recorded	30, 60, 90 and 120 DAT and at harvest
SPAD Chlorophyll content	SPAD Chlorophyll meter	30, 60, 90 and 120 DAT and at harvest
Per cent fruit set	Considering ratio of number of fruits to number of flowers produced in a cluster of each plant multified by 100	At flowering stage
Dry matter production	Oven dry weight of plant (average of five plants)	At harvest
Yield parameters:		
Number of fruits per plant	Fruits at each harvest was recorded. Total number was computed out by summing the fruits from all the harvests and averaged	At different dates of fruit picking and at last harvest
Yield per plant (kg)	The weight of matured fruits harvested during each picking was recorded untill the final harvest and total yield of fruits per plant was computed in kilograms.	At different fruit picking dates and at last harvest
Yield per hectare (t)	The average yield per plant and plant population the total yield of fruits per hectare was computed	At different fruit picking dates and at last harvest
Fruit parameters:		
Fruit length (cm)	The length of five fruits of the net plot was measured and averaged	60, 90 DAT and at harvest
Fruit breadth (cm)	The breadth of five fruits of the net plot was measured and averaged	60, 90 and at harvest
Pericarp thickness (cm)	The thickness of pericarp was measured using vernier calipers	60, 90 and at harvest

3.7 Quality parameters

3.7.1 Total soluble solids (°Brix)

A drop of fresh capsicum fruit juice (5^{th} picking) was used to determine the TSS using hand refractometer and TSS was recorded as °Brix at room temperature.

3.7.2 Ascorbic acid content (mg 100^{-1} g)

The ascorbic acid content was estimated titrimetrically using 2, 6 Dichlorophenol indo phenol dye as per modified procedure of AOAC (1997).

Five gram of fresh fruit juice was taken (5^{th} picking) and diluted to a known volume with four per cent oxalic acid solution. The mixture was filtered using a muslin cloth to get a clear juice. Five ml of extract was titrated against 2, 6- Dichlorophenol indo phenol dye. The result was expressed as mg of ascorbic acid per 100 g of fruit juice (Srivastava and Singh, 1993).

$$\text{Ascorbic acid (mg } 100^{-1} \text{ g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up} \times 100}{\text{Volume of filtrate taken} \times \text{Wt. or volume of sample taken}}$$

3.8 Analysis of soil and plant samples

3.8.1 Physical and chemical properties of soil

After the harvest of capsicum soil samples were collected from each plot, dried in shade, and powdered using pestle and mortar passed through 2 mm sized sieve and analyzed for physical and chemical properties. The methodology adopted for analysis is outlined in Table 3.

3.8.2 Analysis of plant samples

The leaves, stem and fruit samples of capsicum were drawn at harvest and analyzed for nutrient concentration and uptake. Adopting the procedure outlined in Table 6.

3.9 Residual effect of different sources and levels of humic acid on growth and yield of French bean and on soil properties

Field experiment was conducted with French bean as test crop to study the residual effect of humic acid applied to the main crop capsicum.

Residual crop	: French bean
Variety	: Arka suvidha
Spacing	: 30 cm × 15cm
Number of treatments	: 8
Design	: RCBD
Number of replications	: 3
Gross Plot size	: 4.0 m × 3.6 m

The growth and yield parameters were recorded by following standard procedure as in Table 9.

Table 9: Details of observations recorded for residual crop

Observations	Method followed	Interval
Growth parameters		
Plant height (cm)	Plant height was recorded in centimeters from ground level to apex of the plant	30, 60 DAS and at harvest
No. of branches	well-developed branches on the main stem was recorded	30, 60 DAS and at harvest
No. of leaves	Fully opened leaves were recorded	30, 60 DAS and at harvest
Dry matter	Oven dry weight of plant sample	At harvest
Yield parameters		
Number of pods per plant	Number of pods at each picking was recorded. Total number was computed out by adding the number of pods at each harvest and then averaged	At different dates of pods picking and at harvest
Yield per plant (kg)	The weight of pods from each picking was recorded till the final harvest and total yield of pods per plant was computed in kilograms.	At different dates of pod picking and at last harvest
Yield per hectare (t)	The weight of pods harvested at each picking was recorded till final harvest and the total yield of pods per hectare was computed	At different dates of pod picking and at last harvest

3.9.1 Soil sample collection

After the harvest of French bean soil samples were collected from each plot, dried in shade, powdered using wooden pestle and mortar passed through 2 mm sieve and analyzed for physical and chemical properties. The methodology adopted for soil and plant samples analysis is as outlined in Table 3 and 6.

3.10 Statistical analysis and interpretation of data

The analyses and interpretation of the data was done using the Fisher's method of analysis and variance technique as outlined by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test was 5 % probability and wherever 'F' test was found significant, the 't' test was performed to estimate critical differences among various treatments.

IV RESULTS AND DISCUSSION

Utilization of organic wastes generated by different agroindustrial units and urban centers in agriculture has been identified as one of the most promising alternative to maintain soil health and also help to prevent environmental pollution. Substantial quantities of organic matter as well as nutrient elements present in these wastes helps in improving the soil physical properties and soil health. Huge quantities of these organic wastes pose problems of disposal. Thus, effective utilization of these organic wastes can be done through extraction of humic acid and subsequent use of humic acid both as a source of plant nutrients and a soil conditioner.

With this in view an investigation was carried which involved extraction and characterization of humic acid from organic wastes, evaluation of their impact on soil properties, growth and yield of crops. The study consisted of (a) Characterization and extraction of humic acid (HA) from ten different organic materials, (b) Pot culture experiment under greenhouse condition during *kharif* 2014 to identify the selected organic sources and application levels of humic acid extracted from different organic wastes with maize and capsicum as test crops, (c) Selected humic acid sources based on results of pot experiment were tried in the farmer's field using capsicum as main crop during *kharif* 2015 and French bean as residual crop. The results obtained in these experiments are described and discussed in this chapter.

4.1 Characterization of organic wastes

4.1.1 Physical and physicochemical properties of organic wastes

The data on the characteristics of organic waste used for extracting humic acid are presented in Table 10 and 11. The bulk density of different organic wastes ranged from 0.22 Mg m^{-3} in coco peat to 0.69 Mg m^{-3} of biofuel waste. The water holding capacity was more in coco peat (85.50 %) and lowest in biofuel waste (40.21%). The analysis of the samples revealed that poultry manure (pH 8.32) and distillery biocompost (pH 8.03) was alkaline in nature while coffee pulp (pH 7.78), pressmud (pH 7.18) urban compost (pH 7.59) and FYM (pH 7.12) were slightly alkaline compared to vermicompost, sewage sludge, coco peat and biofuel waste with pH value of 6.52, 5.95, 5.68 and 5.28, respectively which were acidic to slightly acidic in nature. Electrical conductivity was high 1.89 dS m^{-1} in coffee pulp followed by FYM 1.50 dS m^{-1}. EC of 0.99 dS m^{-1} was recorded in vermicompost.

The increase in water holding capacity was due to decreased bulk density and increase in finer particle size which resulted in higher surface area thereby high moisture holding capacity. Similar results were observed by Soumare *et al.* (2003). The change in pH may be attributed to the presence of fairly good source of cations particularly calcium (Gajanan *et al.,* 1999). The alkaline nature and high salt content of organic waste material might be due to the presence of basic cations. Similar results was reported by Kasongo *et al.* (2011). The higher electrical conductivity was due to accumulation of higher concentration of salts as a result of decomposition of organic matter or higher organic carbon content as reported by Francou *et al.* (2005).

Table 10: Physico-chemical properties, major and secondary nutrient composition of different organic wastes used for extracting humic acid

Organic wastes	BD (Mg m^{-3})	WHC (%)	pH 1:50	EC (dS m^{-1}) 1:100	OC (%)	Major nutrients			Secondary nutrients		
						N	P	K	Ca	Mg	S
					(%)						
Coco peat	0.22	85.50	5.68	1.19	35.61	0.43	0.12	0.49	1.64	0.79	0.26
Coffee pulp	0.53	40.86	7.78	1.49	38.36	2.01	0.52	1.56	3.44	1.05	0.41
Pressmud	0.54	41.78	7.18	1.12	36.11	1.75	1.27	1.25	3.72	1.15	0.46
Biofuel waste	0.69	40.21	5.28	1.05	40.99	0.61	0.16	0.47	2.00	0.85	0.20
Distillery biocompost	0.51	47.42	8.03	1.59	18.56	1.59	1.04	1.40	3.20	1.42	0.31
Sewage sludge	0.55	42.50	5.95	1.12	14.13	0.43	1.03	0.20	3.54	5.84	0.75
Poultry manure	0.52	48.05	8.32	1.26	34.29	2.85	1.56	1.92	3.89	1.93	0.48
Vermicompost	0.58	44.00	6.52	0.99	18.26	0.74	0.30	0.47	1.76	0.89	0.28
Urban compost	0.56	45.23	7.59	1.36	24.01	1.24	0.49	1.15	3.08	1.62	0.42
FYM	0.49	43.29	7.12	1.50	17.43	0.42	0.35	0.51	1.52	0.86	0.24

Table 11: Micronutrients and heavy metals content of different organic wastes used for extracting humic acid

Organic wastes	Micronutrients					Heavy metal			
	Fe	Mn	Cu	Zn	B	Ni	Cd	Pb	Cr
	(mg kg^{-1})								
Coco peat	2049	309.20	29.40	32.30	45.20	29.98	BDL	BDL	24.20
Coffee pulp	3407	480.70	63.50	225.00	56.80	30.19	BDL	BDL	25.03
Pressmud	3642	525.00	67.50	182.40	64.20	33.80	BDL	BDL	23.57
Biofuel waste	1602	182.20	27.20	25.10	25.87	26.09	BDL	BDL	20.41
Distillery biocompost	2091	312.00	66.90	101.00	59.15	29.10	BDL	BDL	25.90
Sewage sludge	3450	365.60	93.00	370.60	85.40	31.24	8.75	36.1	33.91
Poultry manure	3850	541.30	76.00	476.00	72.28	27.87	BDL	BDL	19.23
Vermicompost	2897	282.30	48.00	83.60	51.65	34.48	BDL	BDL	26.29
Urban compost	3025	319.10	71.20	112.00	69.48	41.70	BDL	14.6	20.26
FYM	1968	264.40	41.90	85.00	43.27	30.24	BDL	BDL	23.45

Note: BDL – Below detectable limit

The organic carbon content was higher (40.99 %) in biofuel waste. While it was lowest (14.13 %) in sewage sludge. With respect to major nutrients poultry manure recorded higher total N,P, K and Ca (2.85, 1.56, 1.92 and 3.89 %, respectively) followed by higher N (2.01 %), in coffee pulp and P (1.27 %) in pressmud. Similar findings were recorded by Mohamed *et al.* (2010). However lowest N (0.42 %) was in FYM, P content was low (0.12 %) in coco peat and sewage sludge recorded low K (0.2 %). Among secondary nutrients highest calcium content was recorded in poultry manure (3.89 %). With respect to magnesium and sulphur higher (5.84 and 0.75 %) was recorded in sewage sludge. Low magnesium (0.86 %) and sulphur (0.24 %) was in FYM. This might be due to variations in composition of different waste materials used for decomposition. Higher content of sulphur in sewage sludge can be attributed to presence of chemical alkyl benzene sulfonate which is a widely surfactant in detergent formulations which is a common commodity used in households (Smith, 2009).

With respect to micronutrients higher concentrations 3850, 541.30, 76 and 476 mg kg^{-1} of iron, manganese, copper and zinc, respectively was observed in poultry manure followed by higher iron and manganese content in pressmud (3642 and 525 mg kg^{-1}, respectively) and coffee pulp (3407 and 480.7 mg kg^{-1}, respectively). However, highest copper (93 mg kg^{-1}) and zinc (370 mg kg^{-1}) was in sewage sludge. Lower concentration of 1602, 182.20, 27.20 and 25.10 mg kg^{-1} of iron, manganese, copper and zinc was in biofuel waste. The sewage sludge recorded higher boron content (85.40 mg kg^{-1}) followed by poultry manure (72.28 mg kg^{-1}) and it was lower (25.87mg kg^{-1}) in biofuel waste. Similar results were obtained by Gomez *et al*. (1993) who reported that the nutrient contents of different organic materials act as an alternative nutrient source with beneficial effect in improving soil properties and supply of nutrients for adequate plant growth and development.

Among the heavy metals in organic wastes higher (41.7 mg kg^{-1}) of nickel was observed in urban waste while cadmium (8.75 mg kg^{-1}), lead (36.1 mg kg^{-1}) and chromium (33.91 mg kg^{-1}) were higher in sewage sludge. Lead and cadmium were not detected in other organic samples except sewage sludge and urban compost. The results are in agreement with studies conducted by Manju *et al*. (2013) on characterization of MSW and also by (Gomez *et al.*, 1993).

4.1.2 Per cent recovery of humic acid and fulvic acid from different organic wastes

The results of the recovery percentage of humic acid and fulvic acid from different organic wastes are presented in Table 12. Higher recovery of 8.92 and 4.21 per cent humic and fulvic acid was recorded for pressmud followed by poultry manure and coffee pulp. The results are in concurrence with work carried out by Satisha and Devarajan *et al.* (2011) and Gayathri *et al*. (2011). However lower humic and fulvic acid 3.43 and 2.45 per cent was recorded in coco peat, respectively. Scheild *et al*. (1989) reported low recovery of humic acid in sewage sludge materials. The humic acid extracted from different organic wastes is dark brown to black in color, which might be due to elemental configuration and melanin pigment (Kumuda, 1987).

Table 12: Recovery percentage of humic and fulvic acid from different organic wastes

Organic wastes	Humic acid (%)	Fulvic acid (%)
Coco peat	3.43	2.45
Coffee pulp	7.42	3.21
Pressmud	8.92	4.21
Biofuel waste	6.09	2.59
Distillery biocompost	3.62	2.57
Sewage sludge	4.87	2.75
Poultry manure	8.20	3.88
Vermicompost	4.98	3.76
Urban compost	6.30	2.85
FYM	4.17	3.17

4.1.3 Elemental composition and molar ratios of humic acid extracted from different organic wastes

The elemental composition and molar ratios of humic acid extracted from different organic wastes are presented in Table 13.

The humic acid extracted from biofuel waste recorded higher content of carbon (61.04 %) followed by coco peat (50.91 %) and distillery biocompost (48.48 %) followed by coffee pulp and pressmud (47.10 and 46.4 %, respectively). Sathisha and Devarajan (2011) also reported 46.36 per cent of organic carbon in the humic acid extracted from pressmud which may be due to higher organic carbon content of the test materials in the present study. With respect to hydrogen, higher (8.89 %) concentration was recorded in biofuel waste sample and lower concentration (4.08 %) was observed in poultry manure. The nitrogen content of humic acid was reflected by nature of raw material. Poultry manure recorded higher (6.01 %) nitrogen followed by pressmud (5.37 %), coffee pulp (5.07 %) and urban compost (4.95 %) while least was in FYM (2.32 %). Similar findings were observed with respect to urban compost and sewage sludge (Atiyeh *et al.,* 2002 and Keiji Jindo *et al.,* 2012).With respect to oxygen content, higher value (52.31 %) was recorded in sewage sludge followed by FYM (52.19 %) and vermi compost (47.56 %).

The results of the molar ratios of elements suggest the stoichiometric relationship that exist among the elements. The H/C ratio in different organic samples ranged from 0.09 to 0.15. Lower H/C ratio in poultry manure (0.09) followed by coffee pulp, pressmud and urban compost suggest that polymerisation and or condensation takes place well, due to introduction of carbohydrate and oxidation of phenolic compounds with methoxyl groups or aliphatic side chain in the humic acids (Vila *et al.*, 1982).With respect to O/C ratio higher (1.30) was recorded in sewage sludge and FYM, and lower (0.44) was recorded in biofuel waste. The presence of C, H and O in humic acid is accounted in the form of carboxyl, methoxyl and carbonyl groups (Govindasamy *et al.*, 1989). These values are highly helpful in judging the extent of the role dehydrogenation as well as removal of alkyl or carboxyl groups during the operational process of extracting humic acid. The difference in the ratios studied could be attributed to the dissimilar splitting of the peripheral aliphatic chains as well as to an increase in the number and length of aliphatic chains (Govindasamy *et al.*, 1989; Kononova, 1966).

The N/C ratio was higher in poultry manure (0.13) followed by pressmud (0.12), coffee pulp (0.11) and urban compost (0.11) indicating that acid insoluble humic nitrogen increased considerably.

4.1.4 Functional groups of humic acid extracted from different organic wastes

The data on functional groups and E_4/E_6 ratio of humic acid extracted from different organic wastes are presented in Table 14. Higher content of carboxyl group (6.08 meq g^{-1}), phenolic hydroxyl group (1.94 meq g^{-1}) and total acidity (8.02 meq g^{-1}) was recorded in poultry manure, this was followed by pressmud and coffee pulp. While lower content of carboxyl (2.84 meq g^{-1}), phenolic hydroxyl group (1.32 meq g^{-1}) and total acidity (4.16 meq g^{-1}) was observed in biofuel waste. Higher content of carboxyl group compared to phenolic hydroxyl group suggest that the carbohydrates and phenolic

Table 13: Elemental composition and molar ratios of humic acid extracted from different organic wastes

Organic wastes	Contents of elements (%)				Molar ratios of elements		
	C	H	N	O	H/C	N/C	O/C
Coco peat	50.91	5.80	3.05	40.24	0.11	0.06	0.79
Coffee pulp	47.10	4.40	5.07	43.43	0.09	0.11	0.92
Pressmud	46.40	4.35	5.37	43.88	0.09	0.12	0.95
Biofuel waste	61.04	8.89	3.01	27.06	0.15	0.05	0.44
Distillery biocompost	48.48	4.91	4.09	42.52	0.10	0.08	0.88
Sewage sludge	40.35	4.39	2.95	52.31	0.11	0.07	1.30
Poultry manure	45.06	4.08	6.01	44.85	0.09	0.13	0.99
Vermicompost	44.54	5.06	2.84	47.56	0.11	0.06	1.07
Urban compost	46.57	4.39	4.95	44.09	0.09	0.11	0.95
FYM	40.02	5.47	2.32	52.19	0.14	0.06	1.30

Table 14: Functional groups and E_4/E_6 ratio of humic acid extracted from different organic wastes

Organic wastes	Total acidity (meq g^{-1})	Carboxylic group (COOH) (meq g^{-1})	-OH (Phenolic groups) (meq g^{-1})	E_4/E_6 ratio
Coco peat	5.03	3.60	1.43	4.70
Coffee pulp	7.68	5.89	1.79	5.10
Pressmud	7.84	5.97	1.87	5.12
Biofuel waste	4.16	2.84	1.32	4.58
Distillery biocompost	5.57	3.79	1.58	4.95
Sewage sludge	5.40	3.73	1.47	4.78
Poultry manure	8.02	6.08	1.94	5.21
Vermicompost	5.12	3.78	1.34	4.85
Urban compost	7.41	5.75	1.71	5.01
FYM	4.92	3.53	1.39	4.61

compounds present in these substances are easily degradable and are readily converted to carboxyl group on subsequent oxidation (Masaaki *et al.*, 1992). Similar results were reported by Satisha and Devarajan (2011); Ushashree *et al.* (1989). The higher acidity or exchange-capacity of these humic substances could be attributed to the occurrence of ionisable H^+ ions of carboxyl and hydroxyl groups found in aliphatic chains or aromatic rings of molecules (Schnitzer, 1982). It is also evident from the present study that carboxylic and phenolic hydroxyl groups were present in varying quantities and these findings corroborate with that that of Prasad and Sinha (1981) who reported that the variation in molecular weight may be responsible for the difference in the quantities of functional groups.

The E_4/E_6 ratio is a valid and informative index for characterization of humic substance with respect of aromaticity (Kononova, 1966). In the present study, the E_4/E_6 ratio was high in the humic acid extracted from poultry manure (5.21) followed by pressmud (5.12), coffee pulp (5.10) and urban compost (5.01) lower E_4/E_6 ratio was recorded in biofuel waste (4.58).

Higher E_4/E_6 ratio indicates more aliphatic nature of the fractions (Garcia *et al.*, 1991) and in turn also reflects a low degree of aromatic condensation. Similar observations were also reported by Pandeya (1992) and Kadalli *et al.* (2000).

4.1.5 Physico-chemical properties and nutrient content of humic acid extracted from organic wastes

The data on the characteristics of humic acid extracted from different organic waste are presented in Table 15.

Analysis of the humic acid samples extracted from different organic wastes was found to be acidic in reaction and the pH ranged from 4.01 to 4.25 in poultry manure. The electrical conductivity of biofuel waste was low (0.11 dS m^{-1}) and the range of the EC was 0.11 to 0.51 dS m^{-1}. The concentration of phosphorus and potassium was high (0.071 % and 0.25 %) respectively in poultry manure, while it was low (0.026 % and 0.06 %) in biofuel waste. The sulphur concentration was high (1.96 %) in sewage sludge while it was (0.57 %) in FYM. This could be attributed variation in the composition of raw materials used for extracting humic acid (Keiji Jindo *et al.,* 2012). The high Sodium content (810 mg kg^{-1}) in distillery bio compost maybe attributed to higher amount of soluble salts in spent wash which was used for preparation of distillery biocompost. The calcium content of humic acid was high in poultry manure (1830 mg kg^{-1}) followed by pressmud (1245 mg kg^{-1}) and coffee pulp (1090 mg kg^{-1}). With respect to magnesium, humic acid extracted from sewage sludge recorded higher Mg content (1100 mg kg^{-1}) while least was in cocopeat (114 mg kg^{-1}).

The micronutrients and heavy metals content of humic acid extracted from different organic wastes are presented in Table 16.

The average concentration of Fe and Mn was more in humic acid extracted from poultry manure (6054.5 and 992.3 mg kg^{-1}, respectively) followed by pressmud (5992.5

Table 15: Chemical composition of humic acid extracted from different organic wastes

Organic wastes	pH (1:50)	EC (dS m^{-1}) (1:100)	P	K	S	Na	Ca	Mg
			%			($mg\ kg^{-1}$)		
Coco peat	4.03	0.12	0.038	0.08	0.96	600	630	114
Coffee pulp	4.20	0.28	0.048	0.11	1.74	578	1090	185
Pressmud	4.18	0.21	0.061	0.15	1.80	375	1245	237
Biofuel waste	4.04	0.11	0.026	0.06	0.46	140	710	120
Distillery biocompost	4.15	0.45	0.051	0.10	0.97	810	924	139
Sewage sludge	4.06	0.22	0.045	0.16	1.96	640	630	1100
Poultry manure	4.25	0.32	0.071	0.25	1.90	715	1830	290
Vermicompost	4.08	0.21	0.040	0.11	0.91	116	810	184
Urban compost	4.14	0.43	0.038	0.15	1.30	585	1200	220
FYM	4.01	0.17	0.039	0.13	0.57	165	734	192

Table 16: Micronutrients and heavy metals content of humic acid extracted from different organic wastes

Organic wastes	Fe	Mn	Cu	Zn	B	Ni	Cd	Pb	Cr
	($mg\ kg^{-1}$)								
Coco peat	3090.0	578.3	107.5	165.0	145.0	13.15	BDL	BDL	10.60
Coffee pulp	5645.0	795.8	140.3	378.5	165.0	10.0	BDL	BDL	5.70
Pressmud	5992.5	802.8	145.5	280.6	195.0	9.55	BDL	BDL	5.50
Biofuel waste	2265.0	327.3	81.0	93.5	105.0	8.35	BDL	BDL	6.70
Distillery biocompost	3832.0	628.0	123.3	268.8	151.0	19.7	BDL	BDL	16.00
Sludge	5053.5	528.8	127.0	474.3	160.0	21.8	BDL	BDL	17.00
Poultry manure	6054.5	992.3	148.3	595.0	220.0	13.3	BDL	BDL	12.00
Vermicompost	3345.0	515.3	118.5	263.0	142.0	14.6	BDL	BDL	11.60
Urban compost	5280.0	726.0	135.3	385.3	154.0	20.85	BDL	BDL	14.10
FYM	2900.0	579.8	116.3	251.0	115.0	17.4	BDL	BDL	13.15

Note: BDL – Below detectable limit

and 802.8 mg kg^{-1}, respectively) and coffee pulp (5645 and 795.8 mg kg^{-1}, respectively). Least concentration of Fe (2265 mg kg^{-1}) and Mn (327.3 mg kg^{-1}) was in biofuel waste.

The concentration of copper and zinc was high (148.3and 595 mg kg^{-1}, respectively) in humic acid extracted from poultry manure followed by pressmud (145.5 and 280.6 mg kg^{-1}, respectively) and coffee pulp (140.3 and 378.5 mg kg^{-1}, respectively) while lower concentration of Cu and Zn was recorded in biofuel waste.

Higher boron content (220 mg kg^{-1}) was observed in poultry manure while lower (105 mg kg^{-1}) was in biofuel waste. Butuzova *et al*. (1997) opined that the physico-chemical properties of humic acids and their physiological activity are mostly determined by the quantitative and qualitative composition of oxygen-containing functional groups. Similar observations were made by Satishkumar (1997), Herviyanti *et al*. (2010) and Keiji Jindo *et al.* (2012) who opined that humic acid extracted from different sources contained all nutrients and hence can be used as organic manure.

Among heavy metals, slightly higher concentration of nickel (21.8 mg kg^{-1}) and chromium (17 mg kg^{-1}) were observed in humic acid of sewage sludge. However lower concentration of nickel (8.35 mg kg^{-1}) was in biofuel waste and chromium (5.50 mg kg^{-1}) was in pressmud. Lead and cadmium were not detected in any of the samples.

4.2 Initial properties of soil used for pot experiment during 2014

The soil used for the pot experiment was sandy clay loam in texture with sand content of 62.45 per cent. The bulk density was 1.49 Mg m^{-3}. The field capacity and maximum water holding capacity values were 21.4 per cent and 35.63 per cent, respectively (Table 17).

With respect to chemical properties, the soil was slightly acidic in reaction (pH 6.61) with low electrical conductivity of 0.49 dS m^{-1}. The organic carbon content of soil was high (0.81 %). With respect to major nutrients, the available nitrogen content was medium (293.68 kg ha^{-1}) available P_20_5 was high (91.53 kg ha^{-1}) and the available K_2O content was medium (284.70 kg ha^{-1}). The Ca, Mg and S contents were 6.05 cmol (p+) kg^{-1}, 2.36 cmol (p+) kg^{-1} and 16.29 mg (mg kg^{-1}) respectively. The DTPA extractable micronutrients (Fe, Mn, Zn and Cu) content was found to be higher (13.55, 25.02, 2.59 and 1.33 mg kg^{-1} respectively). The boron and cation exchange capacity of soil were low (0.46 mg kg^{-1} and 14.80 (cmol (p+) kg^{-1}, respectively).

4.3 Green house experiment I

4.3.1 Effect of different levels and sources of humic acid on growth of Maize

The data on growth of maize *viz.*, height, number of leaves, leaf area and chlorophyll content at different stages (20, 40 and 60 DAS) of maize are presented in Tables 18, 19, 20 and 21 and Plate 2.

Table 17: Initial characteristics of soil used for pot experiment

Parameters		Content
Physical properties		
Particle size distribution	Sand (%)	62.45
	Silt (%)	11.80
	Clay (%)	24.95
	Texture	Sandy clay loam
Field capacity (%)		21.4
Bulk density (Mg m^{-3})		1.49
Maximum water holding capacity (%)		35.63
Chemical properties		
pH (1:2.5)		6.61
EC (dS m^{-1}) (1:2.5)		0.49
OC (%)		0.81
CEC (cmol (p+) kg^{-1})		14.80
Available nitrogen (kg ha^{-1})		293.68
Available phosphorus (kg ha^{-1})		91.53
Available potassium (kg ha^{-1})		284.70
Exchangeable calcium (c mol (p+) kg^{-1})		6.05
Exchangeable magnesium (c mol (p+) kg^{-1})		2.36
Available sulphur (mg kg^{-1})		16.29
Exchangeable sodium (c mol (p+) kg^{-1})		0.35
DTPA-iron (mg kg^{-1})		13.55
DTPA-manganese (mg kg^{-1})		25.02
DTPA-copper (mg kg^{-1})		2.59
DTPA-zinc (mg kg^{-1})		1.33
Boron (mg kg^{-1})		0.46

Plate 2: General view of green house experiment

Plant Height

The results of plant height at different stages (20.40, 60 DAS) revealed that there was significant difference in plant height at all stages (Table 18) due to treatments.

The plant height was significantly influenced by different levels and sources of humic acid. Application of higher levels of humic acid resulted in increase in plant height during all the stages of plant growth and maximum plant height was recorded at 60 DAS. Application of humic acid @ 90 kg ha^{-1} showed significantly higher plant height (135.9 cm) compared to that of 53.4 cm and 17.4 cm at 40 and 20 DAS, respectively. There was significant difference in plant height with application of humic acid @ 30 kg ha^{-1} and @ 90 kg ha^{-1} during all the growth stages of maize. The plant height recorded was on par with application of HA @ 60 kg ha^{-1} and @ 90 kg ha^{-1}. However, at 60 DAS, the treatments which received NPK alone recorded lower plant height (99.8 cm) compared to treatments which received NPK + FYM (121.9 cm). Similar was the trend at 20 and 40 DAS. Application of NPK + FYM was on par with application of humic acid @ 30 kg ha^{-1}.

Among different sources of humic acid, application of humic acid extracted from poultry manure (S_7) resulted in higher plant height (137.7 cm) at all the stages and was maximum at 60 DAS followed by humic acid extracted from pressmud (136.1 cm), coffee pulp (135.1 cm) and urban compost (133.9 cm). However, lower plant height (121.7 cm) was observed due to HA of biofuel waste (S_4). With respect to interaction between levels and sources the interaction was non-significant.

Number of leaves and leaf area

The results on number of leaves and leaf area (dm^2) of maize at different stages (20, 40 and 60 DAS) as influenced by different levels and humic acid are presented in Tables 19 and 20.

Higher number of leaves (11.9) and leaf area (337.87 dm^2) were recorded at 60 DAS with application of humic acid @ 90 kg ha^{-1} and significantly lower number of leaves (9.2) and leaf area (324.74 dm^2) was observed on application of HA @ 30 kg ha^{-1}. Similar results were also recorded at 20 and 40 DAS. Both number of leaves and leaf area (dm^2) increased with increase in the levels of humic acid and duration of the crop.

However, the pots which received NPK alone recorded lesser number of leaves (7.6) and lower leaf area (301.20 dm^2) compared to 10.2 and 332.75 dm^2 number of leaves and leaf area (dm^2) respectively in pots which received NPK + FYM at 60 DAS. Similar was the trend at 20 and 40 DAS. Application of NPK + FYM was on par with application of humic acid @ 30 kg ha^{-1}.

There was significant difference in the number of leaves as a result of addition of humic acid from different types of organic wastes during all the stages of plant growth. Application of humic acid extracted from poultry manure (S_7) recorded significantly higher number of leaves (11.9) and leaf area (343.10 dm^2) followed by S_3 (11.8 and 342.51 dm^2), S_2 (11.7 and 340.79 dm^2) and S_9 (11.7 and 340.53 dm^2). However lower

Table 18: Plant height (cm) of maize as influenced by different sources and levels of humic acid

Humic acid sources	20 DAS				40 DAS				60 DAS			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	14.4	16.5	16.9	15.9	44.1	50.7	51.7	48.8	113.8	129.5	131.9	125.1
S_2	15.7	17.9	18.2	17.3	48.1	54.9	55.9	53.0	123.4	139.8	142.0	135.1
S_3	15.8	18.1	18.4	17.4	48.5	55.3	56.4	53.4	124.3	140.8	143.2	136.1
S_4	14.1	16.0	16.4	15.5	43.1	49.0	50.1	47.4	111.3	125.6	128.3	121.7
S_5	14.7	16.7	17.2	16.2	45.1	51.2	52.6	49.6	116.2	130.7	133.6	126.9
S_6	14.5	16.6	17.1	16.1	44.4	51.0	52.3	49.2	114.5	130.2	133.0	125.9
S_7	16.0	18.3	18.7	17.7	48.9	56.2	57.2	54.1	125.3	142.7	145.1	137.7
S_8	14.8	16.6	17.0	16.1	45.2	51.0	52.0	49.4	116.5	130.2	132.7	126.5
S_9	15.7	17.7	18.0	17.1	48.0	54.2	55.3	52.5	123.1	138.1	140.6	133.9
S_{10}	14.4	16.1	16.4	15.6	44.0	49.3	50.3	47.9	113.5	126.3	128.7	122.9
Mean of levels	15.0	17.1	17.4		46.0	52.3	53.4		118.2	133.4	135.9	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.18	0.51			0.55	1.55			1.32	3.73
S			0.33	0.92			1.00	2.83			2.41	6.82
L × S			0.57	NS			1.73	NS			4.17	NS
NPK only	12.5				37.5				99.8			
NPK + FYM	15.9				47.5				121.9			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Table 19: Number of leaves of maize at different intervals as influenced by different sources and levels of humic acid

Humic acid sources	20 DAS				40 DAS				60 DAS			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	4.2	5.2	5.4	4.9	8.0	9.9	10.2	9.4	8.7	10.7	11.1	10.2
S_2	4.7	5.9	6.0	5.5	9.2	11.3	11.7	10.7	10.0	12.3	12.8	11.7
S_3	4.9	5.9	6.1	5.6	9.2	11.4	11.8	10.8	10.0	12.4	12.9	11.8
S_4	4.0	5.0	5.2	4.7	7.7	9.6	10.0	9.1	8.4	10.4	10.9	9.9
S_5	4.4	5.2	5.6	5.1	8.2	10.2	10.4	9.6	8.9	11.1	11.3	10.5
S_6	4.3	5.2	5.5	5.0	8.1	10.1	10.4	9.5	8.8	11.0	11.3	10.4
S_7	4.9	6.1	6.3	5.7	9.3	11.6	11.9	11.0	10.2	12.7	13.0	11.9
S_8	4.2	5.2	5.6	5.0	8.0	10.0	10.4	9.5	8.7	10.9	11.3	10.3
S_9	4.5	5.6	5.9	5.4	9.1	11.3	11.7	10.7	10.0	12.3	12.8	11.7
S_{10}	4.2	5.2	5.4	4.9	8.0	9.9	10.3	9.4	8.7	10.8	11.2	10.3
Mean of levels	4.4	5.4	5.7		8.5	10.5	10.9		9.2	11.5	11.9	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.10	0.28			0.17	0.49			0.19	0.54
S			0.18	0.51			0.32	0.90			0.35	0.98
L × S			0.31	NS			0.5	NS			0.60	NS
NPK only	3.2				6.7				7.6			
NPK + FYM	5.0				9.3				10.2			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Table 20: Leaf area of maize as influenced by different sources and levels of humic acid

Humic acid sources	20 DAS				40 DAS				60 DAS			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
									(kg ha^{-1})			
S_1	49.21	51.96	52.94	51.37	97.43	102.88	104.82	101.71	319.04	327.11	329.97	325.37
S_2	53.81	57.22	58.85	56.63	106.54	113.29	116.53	112.12	332.53	342.52	347.32	340.79
S_3	54.19	57.95	59.50	57.21	107.30	114.74	117.82	113.28	333.65	344.67	349.23	342.51
S_4	48.67	51.16	52.18	50.67	96.36	101.30	103.32	100.33	317.45	324.76	327.76	323.32
S_5	49.52	52.41	54.11	52.01	98.06	103.77	107.13	102.99	319.96	328.43	333.41	327.27
S_6	49.50	52.16	53.81	51.83	98.02	103.28	106.55	102.61	319.90	327.69	332.54	326.71
S_7	54.48	58.23	59.53	57.41	107.86	115.30	117.88	113.68	334.49	345.50	349.32	343.10
S_8	49.34	52.05	53.63	51.67	97.69	103.05	106.18	102.31	319.42	327.36	332.00	326.26
S_9	53.62	57.16	58.83	56.54	106.17	113.17	116.49	111.94	331.97	342.34	347.26	340.53
S_{10}	49.18	51.78	52.91	51.29	97.38	102.53	104.76	101.55	318.96	326.58	329.89	325.14
Mean of levels	51.15	54.21	55.63		101.28	107.33	110.15		324.74	333.70	337.87	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.65	1.85			1.29	3.66			1.91	5.41
S			1.19	3.37			2.36	6.67			3.49	9.89
L × S			2.06	NS			4.09	NS			6.05	NS
NPK only	43.77				89.38				301.20			
NPK + FYM	53.89				106.69				332.75			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

number of leaves (9.9) and leaf area (323.32 dm^2) was recorded due toin S_4. Similar results were also recorded at 20 and 40 DAS.

SPAD chlorophyll meter reading

The chlorophyll (SPAD meter) reading in maize recorded significant difference due to application of graded levels of humic acid (Table 21). Higher SPAD reading (39.44) was recorded at 60 DAS when humic acid was applied @ 90 kg ha^{-1} and lower SPAD reading (22.35) was recorded at 20 DAS. Application of NPK alone and NPK + FYM, recorded maximum SPAD reading at 60 DAS (30.12 and 35.62, respectively).

The humic acid extracted from poultry manure (S_7), pressmud (S_3), coffee pulp (S_2) and urban compost (S_9) resulted in higher plant height, number of leaves, leaf area and chlorophyll content compared to humic acid extracted from other sources like cocopeat (S_1), biofuel waste (S_4), distillery biocompost (S_5), sewage sludge (S_6), vermi compost (S_8) and FYM (S_{10}).

Humic acid extracted from S_7 (poultry manure) recorded higher chlorophyll content (39.46) followed by 39.24 in S_3 (pressmud), 39.11 in S_2 (coffee pulp) and 39.06 in S_9 (urban compost) at 60 DAS. Similar was the trend at 20 and 40 DAS. However lower SPAD meter reading was recorded at 20, 40 and 60 DAS with values 19.92, 30.82 and 36.25, respectively due to humic acid extracted from biofuel waste (S_4).

The increase in plant height number of leaves and leaf area with respect to varied levels and sources of humic acid application may be due to better cell division, cell elongation and increased physiological processes which contribute to greater plant height (Harshad Thakur *et al.*, (2013). Higher N content in humic acid of poultry manure (N- 6.01 %), resulted in increase in plant height due to cell elongation. The increase in chlorophyll content with graded levels of humic acid application may be due to increase in the amount of nitrogen and magnesium supplied which help to increase the leaf chlorophyll content. Similar observations were recorded by Ferrara *et al.* (2012) who reported that application of humic acid exhibited an increase in shoot growth due to increases in nitrogen and chlorophyll contents in the leaves and higher SPAD values. Some of the possible reasons for lower plant height, number of leaves and chlorophyll content was due to poor root growth (Rath *et al.*, 2011).

4.3.2 Dry matter yield

The data on shoot and root dry weight (g pot^{-1}) as influenced by different levels and sources of humic acid are presented in Table 22, Fig. 3 and Plate 3.

With increase in levels of humic acid application both shoot and root dry weight increased. Maximum shoot and root dry weight of (70.45 and 15.32 g pot^{-1}, respectively) was recorded with addition of humic acid @ 90 kg ha^{-1} and minimum shoot and root dry weight of (56.96 and 13.03 g pot^{-1}, respectively) was recorded with humic acid @ 30 kg ha^{-1}. However, application of humic acid @ 60 kg ha^{-1} was found to be on par with application at 90 kg ha^{-1}. Addition of NPK alone recorded shoot and root dry weight of

Table 21: Chlorophyll (SPAD meter reading) content of maize leaves as influenced by different sources and levels of humic acid

Humic acid sources	20 DAS				40 DAS				60 DAS			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	18.44	21.30	21.64	20.46	29.16	32.36	32.75	31.42	34.29	38.06	38.51	36.96
S_2	19.95	22.94	23.40	22.10	30.85	34.21	34.72	33.26	36.28	40.23	40.83	39.11
S_3	20.04	23.05	23.51	22.20	30.95	34.32	34.84	33.37	36.40	40.36	40.97	39.24
S_4	17.99	20.68	21.10	19.92	28.65	31.68	32.14	30.82	33.70	37.25	37.79	36.25
S_5	18.56	21.34	21.77	20.56	29.30	32.42	32.89	31.54	34.45	38.12	38.68	37.09
S_6	18.51	21.32	21.75	20.53	29.24	32.39	32.87	31.50	34.39	38.09	38.65	37.04
S_7	20.19	23.22	23.68	22.36	31.12	34.51	35.03	33.56	36.60	40.59	41.20	39.46
S_8	18.49	21.52	21.67	20.56	29.22	32.61	32.78	31.54	34.36	38.35	38.55	37.09
S_9	19.92	22.90	23.36	22.06	30.82	34.16	34.68	33.22	36.24	40.17	40.78	39.06
S_{10}	18.42	21.24	21.60	20.42	29.14	32.30	32.70	31.38	34.26	37.98	38.46	36.90
Mean of levels	19.05	21.95	22.35		29.85	33.10	33.54		35.10	38.92	39.44	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.22	0.62			0.25	0.70			0.29	0.82
S			0.40	1.13			0.45	1.27			0.53	1.49
L × S			0.69	NS			0.78	NS			0.91	NS
NPK only	17.14				26.63				30.12			
NPK + FYM	19.44				30.29				35.62			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

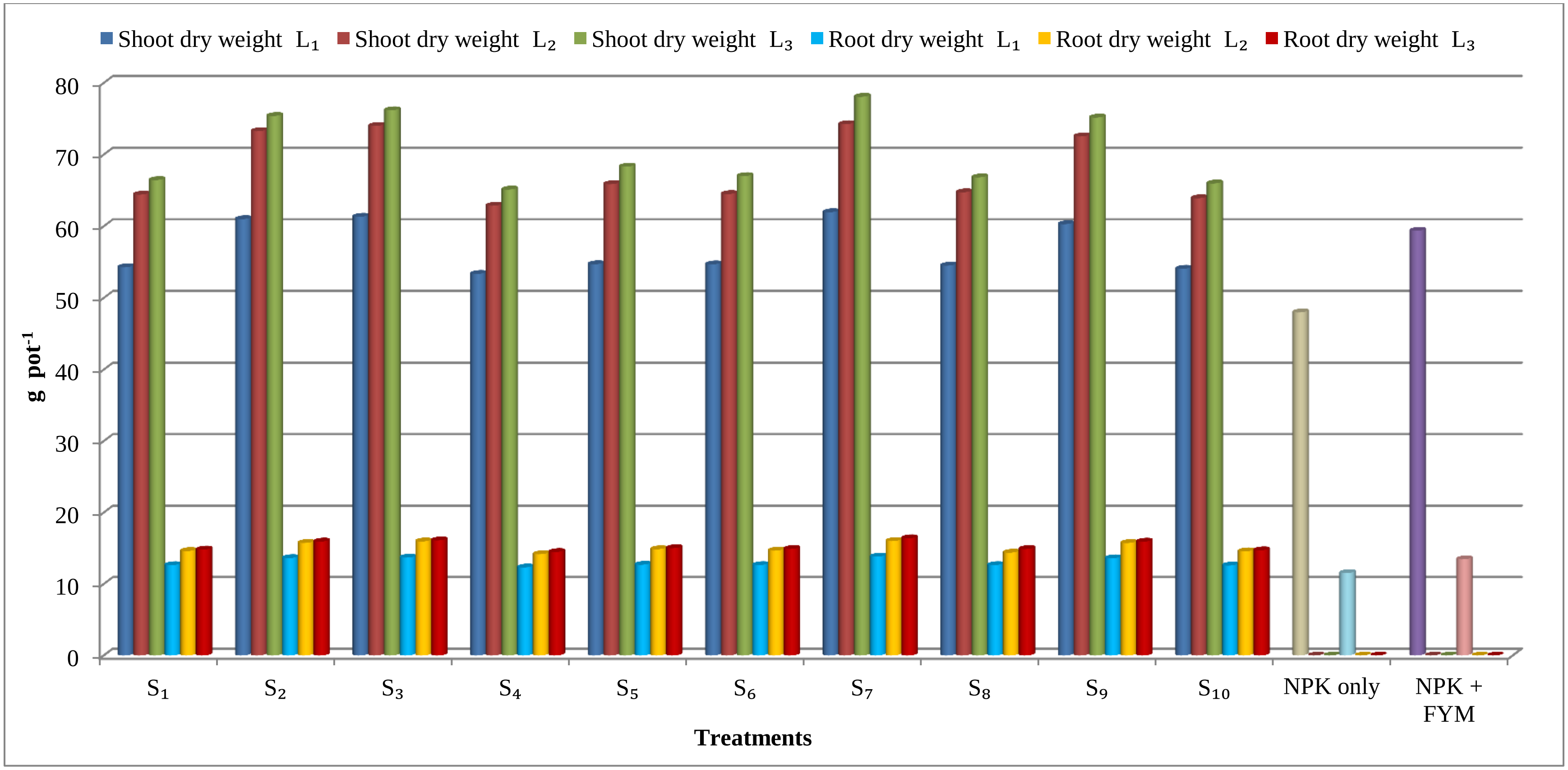

Fig. 3: Shoot and root dry weight (g pot^{-1}) of maize as influenced by different sources and levels of humic acid extracted from different organic wastes

LEGEND

S_1- Coco peat
S_2 - Coffee pulp
S_3- Pressmud
S_4 - Biofuel waste
S_5 - Biodistillery compost
S_6- Sewage sludge
S_7- Poultry manure
S_8 - Vermi compost
S_9 - Urban compost
S_{10}- FYM
L_1- 30 kg ha^{-1}
L_2- 60 kg ha^{-1}
L_3- 90 kg ha^{-1}

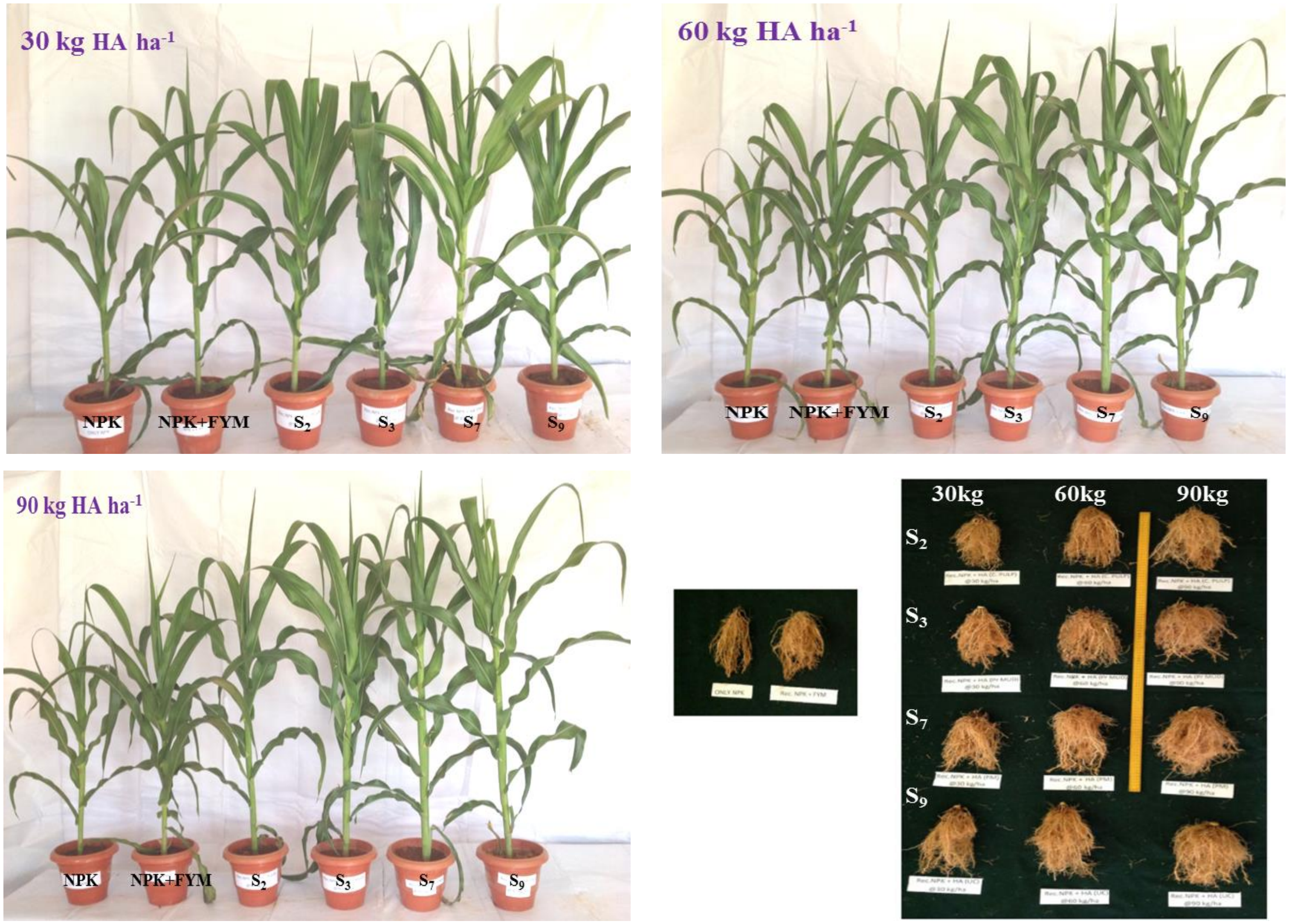

Plate 3: Above ground biomass and root biomass of maize as influenced by different levels and sources of humic acid

Table 22: Shoot and root dry matter yield (g pot^{-1}) of maize as influenced by different sources and levels of humic acid

Humic acid sources	Shoot dry weight (g pot^{-1})				Root dry weight (g pot^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	54.28	64.42	66.45	61.72	12.64	14.62	14.82	14.03
S_2	61.00	73.27	75.39	69.89	13.63	15.75	15.94	15.11
S_3	61.33	74.00	76.19	70.51	13.70	15.96	16.11	15.26
S_4	53.36	62.87	65.13	60.46	12.32	14.18	14.48	13.66
S_5	54.71	65.88	68.32	62.97	12.70	14.87	15.02	14.19
S_6	54.69	64.5	67.00	61.86	12.65	14.67	14.91	14.08
S_7	61.97	74.25	78.07	71.43	13.83	16.01	16.4	15.42
S_8	54.51	64.75	66.83	62.03	12.65	14.39	14.9	13.98
S_9	60.30	72.54	75.17	69.34	13.60	15.74	15.93	15.09
S_{10}	54.07	63.92	65.98	61.33	12.59	14.57	14.72	13.96
Mean of levels	56.96	68.04	70.45		13.03	15.08	15.32	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			1.00	2.84			0.16	0.45
S			1.83	5.18			0.29	0.82
L × S			3.17	NS			0.5	NS
NPK only	47.99				11.53			
NPK + FYM	59.37				13.46			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

47.99 and 11.53 g pot^{-1}, respectively. While treatment receiving NPK + FYM additives was on par with application of humic acid @30 kg ha^{-1} and recorded shoot (59.37 g pot^{-1}) and root (13.46 g pot^{-1}) dry weight.

Significant difference was noticed among different sources of humic acid. Significantly higher shoot (71.43 g pot^{-1}) and root (15.42 g pot^{-1}) dry weight was recorded in S_7 (poultry manure) followed by shoot and root dry weight of 70.51 and 15.26 g pot^{-1} in S_3 (pressmud), 69.89 and 15.11 g pot^{-1} in S_2 (coffee pulp) and 69.34 and 15.09 g pot^{-1} in S_9 (urban compost). Lower shoot and root dry weight (60.46 and 13.66 g pot^{-1}, respectively) was in S_4 (biofuel waste).

The interaction effect between different sources and levels of humic acid application was found to be non-significant.

The increase in dry matter yield of maize plant with increasing levels of HA application might be due to the ability of humic acid to form stable soluble complex with nutrient metal ions. Which are made available to the plants over a period. The improved root growth might be responsible for better absorption of macro and micro nutrients held by HA and improved growth and yield of crops (Dhanasekaran and Govindasamy, 1992; Dhanasekaran *et al.*, 2008). Similar findings were observed by Albuzio *et al.* (1994) and Khaled and Fawy (2011) who reported that humic acid application enhanced the dry matter yield of corn and oat seedlings. Tahir *et al.* (2011) reported that application of medium dose of HA (60 mg kg^{-1} soil) was either more efficient in promoting growth or at par with higher doses @ 90 mg kg^{-1} soil with wheat crop. The present findings were also similar to those reported by Lee and Bartlett (1976).

Ahmed and Tan (1991) reported that maize plants grown for 30 days with application of 100 mg pot^{-1} of HA increased the shoot and root dry weight of maize. Similar results were also observed by Sarir (1998) who stated that application of humic acid enhanced the availability of plant nutrients which in turn improved growth of maize. With respect to humic acid extracted from poultry manure (S_7), pressmud (S_3), coffee pulp (S_2) and urban compost (S_9) higher dry matter yield of shoot and root may be attributed to presence of larger amount of functional groups and higher nutrients concentration when compared to humic acid extracted from other sources.

4.3.3 Concentration of nutrients in maize plant at harvest

Major nutrients

The data pertaining to concentration of nitrogen, phosphorus and potassium in shoot and root has been presented in Tables 23 and 24.

The levels of humic acid increased nitrogen, phosphorous and potassium content in shoot and root of maize. Among shoot and root, the nutrient content increased with graded levels of humic acid application. Higher content of nitrogen (1.79 %) was recorded in shoot compared to in root (0.78 %). However, the N content was low in pots which received NPK alone (0.56 and 1.08 % in root and shoot, respectively). While N

Table 23: Nitrogen, phosphorus and potassium content (%) of maize shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	**Nitrogen**				**Phosphorus**				**Potassium**			
	L_1	**L_2**	**L_3**	**Mean of sources**	**L_1**	**L_2**	**L_3**	**Mean of sources**	**L_1**	**L_2**	**L_3**	**Mean of sources**
	30	**60**	**90**		**30**	**60**	**90**		**30**	**60**	**90**	
									(kg ha^{-1})			
S_1	1.31	1.64	1.68	1.55	0.35	0.39	0.40	0.38	1.69	1.87	1.91	1.82
S_2	1.49	1.89	1.91	1.76	0.40	0.47	0.50	0.46	1.89	2.09	2.15	2.07
S_3	1.50	1.91	1.93	1.78	0.41	0.48	0.50	0.46	1.91	2.16	2.19	2.09
S_4	1.31	1.58	1.64	1.51	0.34	0.37	0.39	0.37	1.68	1.80	1.86	1.78
S_5	1.33	1.70	1.75	1.59	0.35	0.40	0.42	0.39	1.70	1.90	1.96	1.85
S_6	1.32	1.68	1.74	1.58	0.35	0.39	0.42	0.39	1.70	1.89	1.94	1.84
S_7	1.53	1.92	1.95	1.80	0.42	0.49	0.51	0.47	1.94	2.18	2.22	2.11
S_8	1.32	1.67	1.73	1.57	0.35	0.39	0.41	0.38	1.69	1.88	1.94	1.83
S_9	1.49	1.87	1.90	1.75	0.41	0.47	0.51	0.46	1.90	2.05	2.14	2.05
S_{10}	1.30	1.61	1.66	1.52	0.34	0.38	0.39	0.37	1.67	1.83	1.88	1.79
Mean of levels	1.39	1.75	1.79		0.37	0.42	0.45		1.78	1.96	2.02	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.03	0.08			0.01	0.03			0.03	0.09
S			0.05	0.15			0.02	0.05			0.06	0.17
L × S			0.09	NS			0.03	NS			0.10	NS
NPK only	1.08				0.28				1.56			
NPK + FYM	1.53				0.41				1.94			

L= Level S= Source NS = Non significant

S_{1}= Coco peat
S_{2}= Coffee pulp
S_{3}= Pressmud
S_{4}= Biofuel waste
S_{5}= Distillery biocompost
S_{6}= Sewage sludge
S_{7}= Poultry manure
S_{8}= Vermicompost
S_{9}= Urban compost
S_{10}= Farmyard manure

Table 24: Nitrogen, phosphorus and potassium content (%) of maize root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	Levels (kg/ha)			Mean of sources	Levels (kg/ha)			Mean of sources	Levels (kg/ha)			Mean of sources
	L_1 30 (kg ha^{-1})	L_2 60	L_3 90		L_1 30 (kg ha^{-1})	L_2 60	L_3 90		L_1 30 (kg ha^{-1})	L_2 60	L_3 90	
S_1	0.63	0.71	0.73	0.69	0.12	0.15	0.16	0.14	0.77	0.86	0.90	0.84
S_2	0.73	0.82	0.84	0.80	0.16	0.21	0.22	0.20	0.90	1.01	1.03	0.98
S_3	0.73	0.83	0.85	0.80	0.16	0.22	0.23	0.20	0.91	1.03	1.04	0.99
S_4	0.61	0.69	0.71	0.67	0.10	0.14	0.15	0.13	0.75	0.83	0.86	0.81
S_5	0.64	0.74	0.76	0.71	0.13	0.17	0.18	0.16	0.80	0.89	0.92	0.87
S_6	0.64	0.73	0.75	0.71	0.12	0.16	0.17	0.15	0.79	0.88	0.91	0.86
S_7	0.75	0.84	0.87	0.82	0.17	0.22	0.23	0.20	0.92	1.04	1.05	1.00
S_8	0.64	0.72	0.74	0.70	0.12	0.17	0.18	0.16	0.79	0.87	0.91	0.85
S_9	0.73	0.82	0.84	0.80	0.15	0.21	0.22	0.20	0.90	1.00	1.02	0.97
S_{10}	0.62	0.70	0.72	0.68	0.11	0.15	0.16	0.14	0.76	0.84	0.88	0.83
Mean of levels	0.67	0.76	0.78		0.13	0.18	0.19		0.83	0.93	0.95	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.014	0.039			0.006	0.018			0.017	0.048
S			0.025	0.071			0.012	0.033			0.031	0.088
L × S			0.043	NS			0.020	NS			0.05	NS
NPK only	0.56				0.093				0.69			
NPK + FYM	0.74				0.15				0.89			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

content of 1.53 per cent with NPK + FYM in shoot and 0.74 per cent in root and was on par with application of humic acid @ 30 kg ha^{-1}.

The phosphorus content in shoot was higher with application of humic acid @ 90 kg ha^{-1} (0.45 %) compared to that in root (0.19 %). Similarly application of NPK alone recorded lower P content of 0.28 and 0.093 per cent, respectively in shoot and root and it was 0.41 and 0.15 per cent in shoot and root of maize which received NPK + FYM.

The potassium content in shoot and root of maize followed the same trend as that of nitrogen and phosphorus. Higher potassium content (2.02 %) was observed in shoot compared to root (0.95 %). With respect to NPK alone and NPK + FYM the trend was same with lower value of 1.56 and 0.69 per cent respectively in shoot and root compared to humic acid treatments. However application of NPK + FYM was on par with application of humic acid @ 30 kg ha^{-1}.

With respect to the sources, application of humic acid extracted from poultry manure (S_7) recorded significantly higher content of nitrogen in both shoot (1.80 %) and root (0.82 %) followed by S_3 (pressmud 1.78 % and 0.80 %, respectively), S_2 (coffee pulp 1.76 and 0.80 %, respectively) and S_9 (urban compost 1.75 % and 0.80 %, respectively). However, S_4 (biofuel waste) recorded lower N content in shoot and root (1.51 % and 0.67 %, respectively). The interaction effect between different sources and levels of humic acid application was non significant.

Among the different sources, the phosphorus content in shoot and root showed same trend as that of nitrogen with higher content of phosphorus in shoot (0.47 %) and root (0.20 %) humic acid extracted from poultry manure (S_7) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost).

The interaction effect between different sources and levels of humic acid application was non-significant.

Significantly higher concentration of potassium was observed in S_7 (poultry manure) with 2.11 and 1.00 per cent in shoot and root respectively followed by S_3 (pressmud: 2.09 and 0.99 %, respectively) S_2 (coffee pulp: 2.04 and 0.98 %, respectively) and S_9 (urban compost: 2.02 and 0.97 %, respectively) in shoot and root, respectively. However the interaction effect between different levels and sources of humic acid was non-significant.

Humic acid extracted from other sources like cocopeat (S_1), biofuel waste (S_4), distillery biocompost (S_5), sewage sludge (S_6), vermicompost (S_8) and FYM (S_{10}) showed significant differences compared to poultry manure (S_7), pressmud (S_3), coffee pulp (S_2) and urban compost (S_9) with respect to N,P and K content.

Secondary nutrients

The data on concentration of calcium, magnesium and sulphur in shoot and root of maize varied significantly due to different levels and sources of humic acid application (Tables 25 and 26).

Higher content of calcium in shoot and root (0.54 and 0.21 %, respectively), magnesium (0.24 and 0.11 %) and sulphur (0.45 and 0.19 %) was recorded on application of humic acid @ 90 kg ha^{-1} and lower content was recorded at humic acid application @30 kg ha^{-1}. The NPK alone treatment recorded calcium (0.33 and 0.15 %, respectively), magnesium (0.13 and 0.06 %, respectively) and sulphur (0.30 and 0.12 %, respectively) content in shoot and root, respectively. The treatment receiving NPK + FYM (calcium 0.55 % and 0.22 %, magnesium 0.23 % and 0.10 % and sulphur 0.43 and 0.19 %, respectively) was in shoot and root of maize and was on par with application of humic acid @ 30 kg ha^{-1}. Significantly higher concentration of calcium, magnesium and sulphur was observed due to application of humic acid extracted from poultry manure in shoot (0.60 %, 0.26 % and 0.50 %, respectively) and (0.23 %, 0.12 % and 0.21 %, respectively) in root followed by S_3 (pressmud) with 0.59, 0.25 and 0.48 per cent in shoot and 0.22, 0.11 and 0.20 per cent in root, respectively. The humic acid of biofuel waste recorded lower concentration of calcium, magnesium and sulphur (0.43 %, 0.19 % and 0.36 %, respectively) in shoot and (0.18 %, 0.09 % and 0.15 %, respectively) in root. The interaction effect between different sources and levels of humic acid application was non-significant.

Micronutrients

The concentration of micronutrients (iron, manganese and zinc) in shoot and root of maize as influenced by different sources and levels of humic acid application is presented in Tables 27 and 28.

Higher content of iron (375.35 and 146.40 mg kg^{-1}), manganese (86.64 and 30.64 mg kg^{-1}) and zinc (37.80 and 16.30 mg kg^{-1}) in shoot and root of maize was recorded at higher level of humic acid application 90 kg ha^{-1}. While lower content of iron, manganese and zinc was recorded with humic acid application @30 kg ha^{-1}. Addition of NPK alone and NPK + FYM resulted in Fe (287.29 and 357.13 in shoot and 106.66 and 138.91 mg kg^{-1} in root, respectively), manganese (64.87 and 83.09 mg kg^{-1} in shoot and 24.79 and 30.22 mg kg^{-1} in root, respectively) and zinc (27.99 and 36.60 in shoot and 12.09 and 15.72 mg kg^{-1} in root, respectively). The concentration was high due to NPK + FYM, in shoot and root and was on par with application of humic acid @ 30 kg ha^{-1}. Significantly higher concentration of iron, manganese and zinc was observed due to S_7 (HA of poultry manure) in shoot and root of maize (392.29 and 151.49 mg kg^{-1}, 95.90 and 31.98 mg kg^{-1} and 40.30 and 16.64 mg kg^{-1}, respectively) followed by S_3 (pressmud) with (389.39 and 149.95 mg kg^{-1} (Fe), 89.28 and 31.60 mg kg^{-1} (Mn) and 40.03 and 16.49 mg kg^{-1} (Zn), respectively) in shoot and root, S_2 (coffee pulp) with (381.92 and 148.23 mg kg^{-1} (Fe), 92.65 and 31.31 mg kg^{-1} (Mn) and 39.50 and 16.40 mg kg^{-1} (Zn), respectively) in shoot and root and S_9 (urban compost) with (380.21 and 147.21 mg kg^{-1} (Fe), 87.31 and 31.22 mg kg^{-1} (Mn) and 39.36 and 16.35 mg kg^{-1} (Zn), respectively) in shoot and root. While lower content of iron, manganese, zinc both in shoot and root was recorded in biofuel

Table 25: Calcium, magnesium and sulphur content (%) of maize shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	**Calcium**				**Magnesium**				**Sulphur**			
	L_1 30	**L_2 60**	**L_3 90**	**Mean of sources**	**L_1 30**	**L_2 60**	**L_3 90**	**Mean of sources**	**L_1 30**	**L_2 60**	**L_3 90**	**Mean of sources**
	(kg ha^{-1})				**(kg ha^{-1})**				**(kg ha^{-1})**			
S_1	0.43	0.47	0.49	0.46	0.18	0.20	0.22	0.20	0.35	0.39	0.41	0.38
S_2	0.53	0.60	0.62	0.58	0.23	0.25	0.27	0.25	0.44	0.49	0.51	0.48
S_3	0.54	0.61	0.62	0.59	0.23	0.26	0.27	0.25	0.45	0.49	0.51	0.48
S_4	0.40	0.45	0.45	0.43	0.18	0.19	0.20	0.19	0.33	0.37	0.37	0.36
S_5	0.44	0.49	0.50	0.48	0.18	0.22	0.24	0.21	0.36	0.41	0.42	0.39
S_6	0.45	0.51	0.52	0.49	0.19	0.22	0.23	0.21	0.37	0.42	0.43	0.41
S_7	0.56	0.61	0.63	0.60	0.24	0.27	0.28	0.26	0.46	0.50	0.52	0.50
S_8	0.44	0.49	0.50	0.48	0.18	0.21	0.23	0.21	0.37	0.40	0.41	0.39
S_9	0.53	0.60	0.61	0.58	0.22	0.25	0.27	0.25	0.44	0.48	0.50	0.47
S_{10}	0.41	0.46	0.47	0.45	0.18	0.20	0.21	0.20	0.34	0.38	0.39	0.37
Mean of levels	0.47	0.53	0.54		0.20	0.23	0.24		0.39	0.43	0.45	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.014	0.040			0.006	0.017			0.011	0.033
S			0.026	0.073			0.011	0.032			0.020	0.058
L × S			0.045	NS			0.019	NS			0.037	NS
NPK only	0.33				0.13				0.30			
NPK + FYM	0.55				0.23				0.43			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 26: Calcium, magnesium and sulphur content (%) of maize root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Calcium				Magnesium				Sulphur			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.17	0.19	0.19	0.18	0.08	0.09	0.10	0.09	0.15	0.16	0.17	0.16
S_2	0.21	0.23	0.24	0.22	0.10	0.11	0.11	0.11	0.19	0.21	0.21	0.20
S_3	0.21	0.23	0.24	0.22	0.10	0.11	0.11	0.11	0.19	0.21	0.22	0.20
S_4	0.17	0.19	0.19	0.18	0.07	0.09	0.10	0.09	0.14	0.16	0.16	0.15
S_5	0.18	0.20	0.21	0.19	0.08	0.10	0.10	0.09	0.15	0.17	0.17	0.17
S_6	0.18	0.19	0.19	0.19	0.08	0.10	0.10	0.09	0.16	0.18	0.19	0.17
S_7	0.22	0.24	0.25	0.23	0.11	0.12	0.13	0.12	0.20	0.22	0.23	0.21
S_8	0.18	0.19	0.19	0.19	0.09	0.10	0.10	0.09	0.15	0.17	0.17	0.17
S_9	0.21	0.22	0.24	0.22	0.10	0.11	0.11	0.11	0.19	0.21	0.21	0.20
S_{10}	0.17	0.18	0.19	0.18	0.07	0.09	0.10	0.09	0.14	0.16	0.16	0.16
Mean of levels	0.19	0.20	0.21		0.09	0.10	0.11		0.17	0.18	0.19	
L			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
S			0.005	0.014			0.002	0.007			0.004	0.012
L × S			0.009	0.025			0.004	0.012			0.008	0.023
			0.016	NS			0.007	NS			0.016	NS
NPK only	0.15				0.06				0.12			
NPK + FYM	0.22				0.10				0.19			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 27: Iron, manganese and zinc content (mg kg^{-1}) of maize shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	**Iron**				**Manganese**				**Zinc**			
	L_1 30	**L_2 60**	**L_3 90**	**Mean of sources**	**L_1 30**	**L_2 60**	**L_3 90**	**Mean of sources**	**L_1 30**	**L_2 60**	**L_3 90**	**Mean of sources**
	(kg ha^{-1})				**(kg ha^{-1})**				**(kg ha^{-1})**			
S_1	316.39	349.78	357.89	341.35	72.95	80.34	82.55	78.62	31.45	34.80	35.76	34.00
S_2	352.33	391.29	402.13	381.92	81.07	90.14	92.65	87.95	36.80	40.40	41.31	39.50
S_3	360.60	398.61	408.97	389.39	81.82	91.82	94.21	89.28	37.06	41.15	41.88	40.03
S_4	305.40	331.67	336.37	324.48	69.78	76.42	77.50	74.57	30.65	32.63	33.42	32.23
S_5	318.78	355.57	365.35	346.57	73.73	81.92	84.73	80.13	32.33	35.66	36.50	34.83
S_6	317.94	355.23	365.06	346.08	73.68	81.85	84.10	79.87	31.98	35.03	36.21	34.40
S_7	361.93	404.39	410.55	392.29	82.81	93.18	95.90	90.63	37.14	41.41	42.37	40.30
S_8	314.12	351.63	362.46	342.74	72.69	81.02	83.51	79.07	31.79	34.87	35.44	34.03
S_9	351.76	389.67	399.19	380.21	80.87	89.00	92.08	87.31	36.63	40.25	41.20	39.36
S_{10}	309.28	337.36	345.57	330.74	70.92	77.59	79.17	75.89	30.93	33.08	33.93	32.65
Mean of levels	330.86	366.52	375.35		76.03	84.33	86.64		33.67	36.93	37.80	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			5.97	16.89			1.32	3.74			0.85	2.40
S			10.90	30.83			2.41	6.82			1.55	4.37
L × S			18.88	NS			4.18	NS			2.68	NS
NPK only	287.29				64.87				27.99			
NPK + FYM	357.13				83.09				36.60			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 28: Iron, manganese and zinc content (mg kg^{-1}) of maize root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Iron				Manganese				Zinc			
	L_1	L_2	L_3	Mean of sources	L_2	L_3	L_1	Mean of sources	L_3	L_1	L_2	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	121.07	133.91	139.56	131.51	27.28	28.73	29.42	28.48	14.48	15.45	15.80	15.24
S_2	136.50	151.51	156.68	148.23	29.72	31.81	32.41	31.31	15.53	16.62	17.05	16.40
S_3	136.97	153.61	159.28	149.95	29.95	32.11	32.75	31.60	15.57	16.78	17.12	16.49
S_4	117.75	127.80	130.93	125.49	26.63	28.35	28.70	27.89	13.95	15.16	15.47	14.86
S_5	123.34	138.24	143.21	134.93	27.55	29.29	29.90	28.91	14.62	15.67	16.04	15.44
S_6	122.04	136.44	141.24	133.24	27.16	28.94	29.62	28.57	14.59	15.59	15.86	15.35
S_7	138.62	155.96	159.90	151.49	30.50	32.39	33.04	31.98	15.69	16.93	17.32	16.64
S_8	121.54	135.55	141.17	132.75	27.21	28.78	29.67	28.55	14.55	15.56	15.76	15.29
S_9	135.78	150.50	155.36	147.21	30.09	31.50	32.07	31.22	15.50	16.52	17.02	16.35
S_{10}	120.35	131.08	136.68	129.37	26.86	28.06	28.80	27.91	14.40	15.27	15.61	15.09
Mean of levels	127.40	141.46	146.40		28.29	29.99	30.64		14.89	15.96	16.30	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			2.28	6.44			0.38	1.08			0.16	0.44
S			4.16	11.76			0.70	1.98			0.29	0.81
L × S			7.20	NS			1.21	NS			0.50	NS
NPK only	106.66				24.79				12.09			
NPK + FYM	138.91				30.22				15.72			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

waste (S_4) with (324.48 and 125.49 mg kg^{-1} (Fe), 77.50 and 27.89 mg kg^{-1} (Mn) and 32.23 and 14.86 mg kg^{-1} (Zn), respectively).

The concentration of copper and boron in shoot and root of maize as influenced by sources and levels of humic acid application is presented in Table 29 and 30.

Copper and boron contents both in shoot and root of maize increased with increase in levels of humic acid application. Higher concentration of both copper and boron was observed with application of humic acid @ 90 kg ha^{-1} and lower concentration was with application of humic acid@ 30 kg ha^{-1}.

Among sources significantly higher concentration of copper in shoot and root (16.69 and 6.49 mg kg^{-1}) and boron (8.64 and 3.01 mg kg^{-1}) was observed in S_7 (poultry manure) followed by (16.53 and 6.44 mg kg^{-1}) and boron (8.53 and 2.97 mg kg^{-1}) in S_3 (pressmud), S_2 (coffee pulp) with (16.31 and 6.40 mg kg^{-1}) and boron (8.40 and 2.93 mg kg^{-1}) and 16.19 and 6.38 mg kg^{-1} of copper and 8.34 and 2.91 mg kg^{-1} of boron in urban compost (S_9). However, there was no significant interaction effect between different sources and levels of humic acid application.

4.3.4 Uptake of nutrients by maize plant at harvest

The data on nutrient uptake of nitrogen, phosphorus and potassium by maize varied significantly due to different sources and levels of humic acid (Table 31).

The nitrogen, phosphorus and potassium uptake by maize increased with increase in levels of humic acid application. There was significantly higher nitrogen (1.39 g pot^{-1}), phosphorus (0.35 g pot^{-1}) and potassium (1.57 g pot^{-1}) uptake by the crop on application of humic acid @ 90 kg ha^{-1} compared to lower nitrogen, phosphorus and potassium uptake of 0.89, 0.23 and 1.12 g pot^{-1}, respectively with application of humic acid @ 30 kg ha^{-1}. However application of humic acid @ 60 kg ha^{-1} was on par with application @ 90 kg ha^{-1}. The treatments NPK alone recorded 0.58 g pot^{-1} of N, 0.15 g pot^{-1} of P and 0.83 g pot^{-1} of K and NPK + FYM recorded N(1.01 g pot^{-1}), P (0.26 g pot^{-1}) and K (1.27 g pot^{-1}) was in NPK+FYM treatment and was on par with application of humic acid @30 kg ha^{-1}.

Among humic acid sources higher uptake of N,P and K was recorded in S_7 (poultry manure) (1.43, 0.37 and 1.67 g pot^{-1}, respectively) followed by S_3 : pressmud (N, P and K uptake of 1.39 ,0.36 and 1.63 g pot^{-1}, respectively), S_2 : coffee pulp (1.37, 0.35 and 1.58 g pot^{-1} of N, P and K, respectively) and S_9: urban compost (1.36 g pot^{-1} of N,0.36 g pot^{-1} of P and 1.57 g pot^{-1} of K, respectively). However lower uptake of N, P, K (1.01, 0.24 and 1.19 g pot^{-1}, respectively) was observed in biofuel waste (S_4).

Uptake of the secondary nutrients (calcium, magnesium and sulphur) by maize varied significantly due to different sources and levels of humic acid application (Table 32).

Table 29: Copper and boron content (mg kg^{-1}) of maize shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Copper				Boron			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	13.35	14.48	15.14	14.32	6.44	7.78	7.97	7.40
S_2	15.11	16.68	17.15	16.31	7.29	8.87	9.05	8.40
S_3	15.14	17.00	17.44	16.53	7.38	9.02	9.19	8.53
S_4	12.89	14.01	14.34	13.75	6.27	7.46	7.71	7.15
S_5	13.48	15.09	15.58	14.72	6.53	8.04	8.27	7.61
S_6	13.40	14.86	15.41	14.56	6.45	7.97	8.25	7.56
S_7	15.33	17.24	17.51	16.69	7.48	9.12	9.31	8.64
S_8	13.36	14.63	15.46	14.48	6.50	7.89	8.21	7.53
S_9	15.06	16.47	17.05	16.19	7.31	8.75	8.96	8.34
S_{10}	13.02	14.10	14.42	13.85	6.31	7.50	7.82	7.21
Mean of levels	14.01	15.46	15.95		6.80	8.24	8.47	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.27	0.76			0.14	0.39
S			0.49	1.39			0.25	0.71
L × S			0.85	NS			0.43	NS
NPK only	11.86				5.44			
NPK + FYM	15.20				7.50			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 30: Copper and boron content (mg kg^{-1}) of maize root at harvest (60 DAS) as influence by different sources and levels of humic acid

Humic acid sources	Copper				Boron			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	5.04	5.70	5.91	5.55	2.25	2.71	2.78	2.58
S_2	5.85	6.57	6.77	6.40	2.54	3.09	3.15	2.93
S_3	5.89	6.60	6.82	6.44	2.57	3.14	3.20	2.97
S_4	4.92	5.41	5.59	5.31	2.19	2.58	2.67	2.48
S_5	5.13	5.79	6.07	5.66	2.27	2.79	2.85	2.64
S_6	5.08	5.76	6.02	5.62	2.25	2.76	2.84	2.62
S_7	5.92	6.69	6.85	6.49	2.61	3.18	3.25	3.01
S_8	5.07	5.78	6.00	5.62	2.27	2.75	2.83	2.61
S_9	5.84	6.55	6.74	6.38	2.55	3.05	3.12	2.91
S_{10}	5.03	5.57	5.83	5.48	2.19	2.62	2.71	2.51
Mean of levels	5.38	6.04	6.26		2.37	2.87	2.94	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.11	0.31			0.05	0.14
S			0.20	0.57			0.09	0.25
L × S			0.35	NS			0.15	NS
NPK only	4.16				1.90			
NPK + FYM	5.99				2.61			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Table 31: Nitrogen, phosphorus and potassium uptake (g pot^{-1}) by maize (shoot + root) as influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.79	1.16	1.23	1.06	0.19	0.27	0.29	0.25	1.02	1.33	1.40	1.25
S_2	1.02	1.51	1.57	1.37	0.28	0.37	0.41	0.35	1.27	1.69	1.79	1.58
S_3	1.03	1.54	1.61	1.39	0.28	0.39	0.42	0.36	1.30	1.76	1.84	1.63
S_4	0.77	1.09	1.17	1.01	0.18	0.25	0.28	0.24	0.99	1.25	1.33	1.19
S_5	0.80	1.23	1.31	1.11	0.20	0.29	0.32	0.27	1.03	1.39	1.46	1.29
S_6	0.80	1.20	1.28	1.09	0.20	0.28	0.30	0.26	1.02	1.35	1.44	1.27
S_7	1.05	1.56	1.66	1.43	0.29	0.39	0.43	0.37	1.33	1.78	1.91	1.67
S_8	0.80	1.18	1.26	1.08	0.19	0.27	0.30	0.26	1.02	1.34	1.43	1.26
S_9	1.02	1.48	1.57	1.36	0.27	0.37	0.42	0.36	1.27	1.67	1.76	1.57
S_{10}	0.78	1.13	1.20	1.04	0.19	0.26	0.28	0.25	1.00	1.29	1.37	1.22
Mean of levels	0.89	1.31	1.39		0.23	0.32	0.35		1.12	1.48	1.57	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.04	0.11			0.01	0.04			0.04	0.12
S			0.07	0.20			0.02	0.06			0.08	0.22
L × S			0.12	NS			0.04	NS			0.14	NS
NPK only	0.58				0.15				0.83			
NPK + FYM	1.01				0.26				1.27			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 32: Calcium, magnesium and sulphur content (g pot^{-1}) by maize (shoot + root)) as influenced by different sources and levels of humic acid

Humic acid sources	Calcium				Magnesium				Sulphur			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.25	0.33	0.35	0.31	0.11	0.14	0.16	0.14	0.22	0.30	0.32	0.28
S_2	0.36	0.47	0.50	0.45	0.15	0.20	0.22	0.19	0.31	0.41	0.44	0.39
S_3	0.36	0.48	0.51	0.45	0.15	0.21	0.23	0.20	0.32	0.42	0.45	0.39
S_4	0.23	0.31	0.32	0.29	0.10	0.14	0.14	0.13	0.21	0.27	0.28	0.25
S_5	0.26	0.35	0.37	0.33	0.11	0.16	0.18	0.15	0.23	0.31	0.32	0.29
S_6	0.27	0.36	0.37	0.33	0.11	0.16	0.17	0.15	0.23	0.31	0.33	0.29
S_7	0.38	0.49	0.53	0.47	0.16	0.22	0.24	0.21	0.33	0.43	0.47	0.41
S_8	0.26	0.34	0.36	0.32	0.11	0.15	0.17	0.14	0.23	0.30	0.32	0.28
S_9	0.36	0.47	0.50	0.44	0.15	0.20	0.22	0.19	0.31	0.41	0.43	0.38
S_{10}	0.24	0.32	0.34	0.30	0.11	0.14	0.15	0.13	0.21	0.28	0.29	0.26
Mean of levels	0.30	0.39	0.42		0.13	0.17	0.19		0.26	0.34	0.36	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.016	0.044			0.006	0.019			0.014	0.038
S			0.029	0.081			0.012	0.032			0.025	0.070
L × S			0.05	NS			0.02	NS			0.043	NS
NPK only	0.18				0.07				0.16			
NPK + FYM	0.35				0.15				0.29			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Increased levels of humic acid application (@ 90 kg ha^{-1}) resulted in increase in uptake of calcium (0.42 g pot^{-1}), magnesium (0.19 g pot^{-1}) and sulphur (0.36 g pot^{-1}) compared to that of humic acid application @ 30 kg ha^{-1} with calcium (0.30 g pot^{-1}), magnesium (0.13 g pot^{-1}) and sulphur (0.26 g pot^{-1}). However uptake of secondary nutrients @ 60 kg ha^{-1} was on par with application of humic acid @ 90 kg ha^{-1}. Among NPK alone and NPK + FYM, the uptake of calcium (0.18 and 0.35 g pot^{-1}), magnesium (0.07 and 0.15 g pot^{-1}, respectively) and sulphur (0.16 and 0.29 g pot^{-1}, respectively) was more in pots which received NPK + FYM compared to application of NPK alone.

Among sources the uptake of calcium, magnesium and sulphur in maize was higher in S_7 (0.47 g pot^{-1}, 0.21 g pot^{-1} and 0.41 g pot^{-1}, respectively) followed by S_3 (0.45, 0.20, 0.39 g pot^{-1}, respectively), S_2 (0.45, 0.19, 0.39 g pot^{-1}, respectively) and S_9 (0.44, 0.19 and 0.38 g pot^{-1}, respectively). However lower uptake of 0.29, 0.13 and 0.25g pot^{-1}, respectively was due HA application in biofuel waste (S_4).

There was no significant interaction effect between different sources and levels of humic acid application.

The data on uptake of iron, manganese and zinc by maize varied significantly due to different sources and levels of humic acid application (Table 33).

Significantly higher uptake of micronutrients (Fe, Mn and Zn) was recorded on application of humic acid @ 90 kg ha^{-1} compared to 30 kg ha^{-1}. Higher uptake of iron (28.72 mg pot^{-1}), manganese (6.57 mg pot^{-1}) and zinc (2.92 mg pot^{-1}) was recorded with humic acid applied @ 90 kg ha^{-1} and was on par with uptake of iron (27.26 mg pot^{-1}), manganese (6.23 mg pot^{-1}) and zinc (2.77 mg pot^{-1}) with application of humic acid @ 60 kg ha^{-1}. The uptake of Fe (24.35 mg pot^{-1}), Mn (5.64 mg pot^{-1}) and Zn (2.51 mg pot^{-1}) was more in NPK + FYM compared to NPK alone (15.48, 3.50 and 1.53 g pot^{-1}, respectively).

With respect to humic acid sources higher uptake of Fe (30.18 mg pot^{-1}), Mn (6.93 mg pot^{-1}) and Zn (3.12 mg pot^{-1}) was recorded in S_7 (poultry manure) followed by S_3 (pressmud: 29.56, 6.74 and 3.06 mg pot^{-1}, respectively), S_2 (coffee pulp: 28.95, 6.62 and 3.01mg pot^{-1}, respectively) and S_9 (urban compost: 28.76, 6.57 and 2.99 mg pot^{-1} ,respectively) Fe, Mn and Cu, respectively. However, lower uptake of iron (21.72 mg pot^{-1}), manganese (4.95 mg pot^{-1}) and zinc (2.18 mg pot^{-1}) was in S_4 (biofuel waste).

The interaction effect was non-significant between different sources and levels of humic acid application.

The uptake of copper and boron by maize varied significantly due to different sources and levels of humic acid application (Table 34). The uptake of copper (1.22 mg pot^{-1}) and boron (0.80 mg pot^{-1}) was significantly higher with application of humic acid @ 90 kg ha^{-1} and was on par with application @ 60 kg ha^{-1}. Among NPK alone and NPK + FYM treatments higher copper (1.04 mg pot^{-1}) and boron (0.64 mg pot^{-1}) uptake was in treatment NPK + FYM and was on par with application of humic acid @ 30 kg ha^{-1}.

Table 33: Iron, manganese and zinc uptake (mg pot^{-1}) by maize (shoot + root) as influenced by different sources and levels of humic acid

Humic acid sources	Iron				Manganese				Zinc			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	18.08	24.14	25.55	22.59	4.16	5.51	5.86	5.18	1.82	2.43	2.59	2.28
S_2	23.38	30.86	32.62	28.95	5.36	7.06	7.46	6.62	2.46	3.20	3.37	3.01
S_3	23.87	31.89	32.93	29.56	5.40	7.30	7.52	6.74	2.47	3.31	3.38	3.06
S_4	17.69	23.40	24.07	21.72	4.04	5.38	5.45	4.95	1.80	2.34	2.39	2.18
S_5	19.25	25.28	27.35	23.96	4.47	5.79	6.29	5.52	1.96	2.56	2.76	2.43
S_6	18.78	25.10	26.62	23.50	4.34	5.75	6.08	5.39	1.91	2.51	2.67	2.36
S_7	24.37	32.21	33.98	30.18	5.56	7.37	7.87	6.93	2.52	3.31	3.52	3.12
S_8	18.88	25.11	25.97	23.32	4.36	5.75	5.94	5.35	1.94	2.52	2.58	2.34
S_9	23.26	30.52	32.48	28.76	5.35	6.93	7.44	6.57	2.44	3.17	3.36	2.99
S_{10}	18.05	24.04	25.62	22.57	4.14	5.50	5.83	5.16	1.84	2.39	2.55	2.26
Mean of levels	20.56	27.26	28.72		4.72	6.23	6.57		2.12	2.77	2.92	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.75	2.11			0.17	0.48			0.09	0.25
S			1.36	3.85			0.31	0.87			0.16	0.46
L × S			2.36	NS			0.53	NS			0.28	NS
NPK only	15.48				3.50				1.53			
NPK + FYM	24.35				5.64				2.51			

L= Level   S= Source   NS = Non significant

$S_{1=}$ Coco peat $S_{6=}$ Sewage sludge
$S_{2=}$ Coffee pulp $S_{7=}$ Poultry manure
$S_{3=}$ Pressmud $S_{8=}$ Vermicompost
$S_{4=}$ Biofuel waste $S_{9=}$ Urban compost
$S_{5=}$ Distillery biocompost $S_{10=}$ Farmyard manure

Table 34: Copper and boron uptake (mg pot^{-1}) by maize (shoot + root) as influenced by different sources and levels of humic acid

Humic acid sources	Copper				Boron			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	0.76	1.00	1.08	0.95	0.46	0.66	0.71	0.61
S_2	1.00	1.32	1.39	1.24	0.60	0.87	0.91	0.79
S_3	1.00	1.36	1.40	1.26	0.60	0.90	0.92	0.81
S_4	0.75	0.99	1.01	0.92	0.45	0.65	0.67	0.59
S_5	0.82	1.07	1.17	1.02	0.49	0.71	0.77	0.66
S_6	0.79	1.05	1.13	0.99	0.47	0.70	0.74	0.64
S_7	1.04	1.38	1.46	1.29	0.63	0.91	0.96	0.83
S_8	0.80	1.05	1.11	0.98	0.49	0.70	0.73	0.64
S_9	1.00	1.29	1.39	1.23	0.61	0.85	0.91	0.79
S_{10}	0.76	1.01	1.07	0.95	0.46	0.66	0.72	0.61
Mean of levels	0.87	1.15	1.22		0.52	0.76	0.80	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.03	0.09			0.02	0.06
S			0.06	0.17			0.04	0.11
L × S			0.11	NS			0.07	NS
NPK only	0.64				0.36			
NPK + FYM	1.04				0.64			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Among different sources of humic acid, S_7 (poultry manure) recorded higher copper (1.29 mg pot^{-1}) and boron (0.83 mg pot^{-1}) uptake followed by pressmud (S_3) with (1.26 mg pot^{-1} and 0.81 mg pot^{-1}, respectively), coffee pulp (S_2) with (1.24 and 0.79 mg pot^{-1}, respectively) and urban compost (S_9) with (1.23 and 0.79 mg pot^{-1}, respectively) of copper and boron uptake. However, lower uptake of copper (0.92 mg pot^{-1}) and boron (0.59 mg pot^{-1}) was recorded in S_4 (biofuel waste).

The nutrient concentration and uptake increased with increasing levels of HA application from 30 to 90 kg ha^{-1}. But significant increase was observed up to 60 kg ha^{-1} and beyond that dose non-significant difference was found with respect to nutrient content and uptake. The response to varied levels HA application observed in the present study may be due to the fact that humic substances may stimulate microbiological activity in soil and enhances nutrients uptake. Delfine *et al.* (2005) documented that enhanced uptake of macronutrients (N, P, K) was due to the stimulatory effect of humic substances. HA increases P availability and uptake by decreasing calcium phosphate (Ca-P) precipitation rates (Inskeep and Silvertooth, 1988), competing for adsorption sites (Sibanda and Young, 1986), and decreasing the number of adsorption sites by promoting dissolution of metals present on solid phases by chelation (Guppy *et al.*, 2005). Similarly, increase in K content and uptake recorded in this study may be due to the reduced K fixation with the addition of HA. Tahir *et al*. (2011) reported that HA significantly improved wheat K contents of the non-calcareous soil and P and NO_3-N contents in calcareous soil. Many researchers reported that soil or foliar application of HA significantly increased the macro (N, P, K, Ca and Mg) and micro nutrient (Fe, Cu, Zn and Mn) contents of different crops i.e., in gerbera (Nikbakht *et al.*, 2008; Haghighi *et al.*, 2014); in maize (Celik *et al.*, 2011); in wheat (Taha *et al.*, 2006); in cucumber (El-nemer *et al.*, 2012). Application of HA at optimal level resulted in highly branched roots and this might have resulted in increased surface area and facilitated more efficient nutrient absorption (Mallikarjunarao *et al.*, 1987).

4.3.5 Changes in soil properties after harvest of maize

Chemical properties

Changes in pH, EC, organic carbon content and CEC of soil after harvest of maize has been presented in Table 35.

The pH of soil recorded very small increase with increase in levels of humic acid application compared to initial value (6.61). Application of humic acid @ 90 kg ha^{-1} resulted in increase in pH (6.78) while pH was lower (6.73) with application of humic acid @ 30 kg ha^{-1}. Treatment receiving NPK alone decreased pH (6.55) compared to initial (6.61). The interaction effect between different sources and levels of humic acid application was non-significant. Among different sources of humic acid the pH was higher in S_7 (6.81) followed by S_3 (6.77) and S_2 (6.76).

Electrical Conductivity (EC)

The data on electrical conductivity of soil with application of graded levels of humic acid showed slight increase in EC compared to the initial value of 0.49 dS m^{-1}.

Table 35: Effect of different sources and levels of humic acid on pH, EC, OC and CEC of soil after harvest of maize

Humic acid sources	pH (1:2.5)				EC (dS m^{-1}) (1:2.5)				OC (%)				CEC (cmol (P^+) kg^{-1})			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	6.72	6.74	6.77	6.74	0.53	0.55	0.55	0.54	0.87	0.90	0.93	0.90	15.49	15.65	16.01	15.72
S_2	6.74	6.75	6.8	6.76	0.53	0.55	0.56	0.55	0.87	0.89	0.92	0.89	15.83	16.01	16.42	16.08
S_3	6.75	6.76	6.81	6.77	0.54	0.55	0.56	0.55	0.84	0.87	0.91	0.87	15.86	16.05	16.49	16.13
S_4	6.71	6.73	6.75	6.73	0.53	0.55	0.55	0.54	0.88	0.92	0.95	0.92	15.39	15.55	15.92	15.62
S_5	6.73	6.75	6.78	6.75	0.55	0.56	0.56	0.55	0.86	0.88	0.91	0.88	15.55	15.69	16.10	15.78
S_6	6.73	6.74	6.78	6.75	0.54	0.55	0.55	0.54	0.83	0.84	0.87	0.85	15.49	15.65	16.01	15.72
S_7	6.79	6.81	6.84	6.81	0.54	0.55	0.56	0.55	0.84	0.87	0.90	0.87	15.91	16.10	16.55	16.19
S_8	6.72	6.75	6.79	6.75	0.54	0.55	0.55	0.54	0.83	0.85	0.88	0.85	15.49	15.64	16.00	15.71
S_9	6.74	6.76	6.81	6.77	0.55	0.55	0.56	0.55	0.84	0.87	0.90	0.87	15.82	15.98	16.38	16.06
S_{10}	6.71	6.73	6.76	6.73	0.54	0.54	0.55	0.54	0.83	0.85	0.87	0.85	15.45	15.60	15.96	15.67
Mean of levels	6.73	6.75	6.79		0.54	0.55	0.55		0.85	0.87	0.90		15.63	15.79	16.19	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.016	NS			0.005	NS			0.005	0.015			0.05	0.14
S			0.030	NS			0.009	NS			0.009	0.026			0.09	0.25
L × S			0.052	NS			0.016	NS			0.016	NS			0.15	NS
NPK only	6.55				0.52				0.76				14.46			
NPK + FYM	6.68				0.53				0.86				15.79			
Initial	**6.61**				**0.49**				**0.81**				**14.8**			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Humic acid application @ 90 kg ha^{-1} recorded increase in EC (0.55 dS m^{-1}) compared to EC (0.54 dS m^{-1}) recorded to humic acid application @ 30 kg ha^{-1}.

Among different sources of humic acid, the humic acid extracted from poultry manure (S_7) recorded significantly higher EC of 0.55 dS m^{-1}. While lower EC of 0.54 dS m^{-1} was in the order of S_1 (coco peat), S_4 (biofuel waste), S_6 (sewage sludge), S_8 (vermi compost) and S_{10} (FYM).However there was no significant interaction between different source and levels of humic acid application.

The organic carbon content of soil increased significantly with graded levels of humic acid application compared to initial content of organic carbon (0.81 %). Higher organic carbon content (0.90 %) was recorded with application of humic acid @ 90 kg ha^{-1} and lower (0.85 %) was with humic acid application @ 30 kg ha^{-1}. Addition of NPK alone recorded lower organic carbon content (0.76 %) compared to the initial value (0.81 %) whereas in NPK + FYM recorded (0.86 %).

Among different sources of humic acid, application of humic acid extracted from S_4 (biofuel waste) resulted in significant increase in organic carbon (0.92 %) followed by 0.90, 0.89 and 0.87 per cent, respectively due to S_1 (coco peat), S_2 (coffee pulp) and S_3 (pressmud). However the interaction effect was non-significant between different sources and levels of humic acid application.

The CEC of soil increased with increase in levels of humic acid application compared to initial value (14.8 cmol (p+) kg^{-1}).

Among the levels of humic acid higher CEC (16.19 cmol (p+) kg^{-1}) was recorded on application of humic acid @ 90 kg ha^{-1} kg ha^{-1}. While it was lower (15.63 cmol (p+) kg^{-1}) with application of humic acid @ 30 kg ha^{-1}. Addition of NPK alone, recorded lower CEC (14.46 cmol (p+) kg^{-1}) compared to initial. Whereas NPK + FYM recorded higher CEC value of (15.79 cmol (p+) kg^{-1}).

Among different sources of humic acid application the humic acid extracted from poultry manure (S_7) resulted in significant increase (16.19 cmol (p+) kg^{-1}) in CEC followed by S_3 (pressmud16.13 cmol (p+) kg^{-1}), S_2 (coffee pulp16.08 cmol (p+) kg^{-1}) and S_9 (urban compost 16.06 cmol (p+) kg^{-1}). However the humic acid extracted from FYM (S_{10}) recorded CEC of (15.67 cmol (p+) kg^{-1}). There was no significant interaction between different sources and levels of humic acid application.

The non-significant effect of HA on soil pH and electrical conductivity recorded in this study is in close agreement with the findings of Tahir *et al*. (2011), who stated that the buffering effect of HA resisted the change in soil pH. The buffering capacity and properties of HA was explained in detail by the study of Boguta and Sokotowska (2012). The changes that occur in organic carbon (OC) influences the soil fertility, the results of the present study clearly showed enhanced application of humic acid @ 90 kg ha^{-1}. The positive effect might be due to high content of organic carbon in the raw materials used for extraction. Similar findings were observed by Tuba Arjumend *et al.* (2015) who reported that application of humic acid increased the organic matter content by 9 per cent. The inherent capacity of soil to supply the essential cations for plant growth is made possible due to increased adsorption of ions and thereby enhances CEC, this was achieved by the application of HA at varied levels and sources. The negative charges of humus or the high exchange capacity might be associated with enolic, carboxylic and phenolic groups (Brady, 1996; Lax, 1991). The characterization studies of different HA extracted from different sources confirmed the presence of these groups functional groups in it which resulted in high CEC in humic acid extracted from different sources. When such substances with high exchange properties are added to soils, there would be an increase in the cation exchange capacity.

The data on available nitrogen, phosphorus and potassium content of soil after harvest of maize are presented in (Table 36 and Fig. 4, 5 and 6).

The available nitrogen content of soil has varied significantly due to graded levels of humic acid application. Higher available nitrogen content of 312.99 kg $ha^{-1}$and lower value (303.47 kg ha^{-1}) was recorded on application of humic acid @ 90 and 30 kg ha^{-1}, respectively. Application of NPK alone resulted in decrease in available N content (287.69 kg ha^{-1}) of soil while NPK + FYM recorded higher N content of 302.84 kg ha^{-1}.

Humic acid extracted from poultry manure (S_7) recorded significant increase in available nitrogen (314.84 kg ha^{-1}) followed by 312.24 kg ha^{-1}, 311.12 kg ha^{-1} and 311.03 kg ha^{-1} in S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost), respectively. However the buildup of N status of soil was less (305.22 kg ha^{-1}) in S_4 (biofuel waste).

The data on available phosphorus content of soil after the harvest of maize showed significant increase with graded levels of humic acid application over initial content of 91.53 kg ha^{-1}. Higher available P content (105.82 kg ha^{-1}) was observed with humic acid @ 90 kg ha^{-1} and lower value (95.03 kg ha^{-1}) was with humic acid @ 30 kg ha^{-1}. Between NPK alone and NPK + FYM treatments, lower available P (87.28 kg ha^{-1}) was recorded due to NPK alone. While NPK + FYM recorded 98.42 kg ha^{-1}, P.

The effect of application of humic acid extracted from different sources on available phosphorus content of soil showed similar trend as that of nitrogen. Higher available phosphorus content of 104.45 kg ha^{-1} was in recorded in S_7 (poultry manure) followed by 103.89 kg ha^{-1} and 103.54 in S_3 (pressmud) and S_2 (coffee pulp) and 103.35 kg ha^{-1} in S_9 (urban compost). However lower phosphorus status (95.01 kg ha^{-1}) was due to S_4 (biofuel waste). The interaction effect was non-significant between different sources and levels of humic acid.

The available potassium content of soil varied significantly with increase in graded levels of humic acid application. Higher potassium content (299.43 kg ha^{-1}) was recorded with humic acid application @ 90 kg ha^{-1} while lower potassium content (289.08 kg ha^{-1}) was due to humic acid application @ 30 kg ha^{-1}. Application of NPK alone resulted in decrease in available K content (276.85 kg ha^{-1}) compared to initial

Table 36: Effect of different sources and levels of humic acid on available nitrogen, phosphorus and potassium content of soil after harvest of maize

Humic acid sources	Available-N(kg ha^{-1})				Available-P_2O_5 (kg ha^{-1})				Available-K_2O (kg ha^{-1})			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	301.00	306.07	310.70	305.92	92.83	95.64	102.17	96.88	286.63	289.48	296.15	290.75
S_2	306.23	310.63	316.50	311.12	98.45	101.84	110.65	103.54	292.83	296.12	303.76	297.57
S_3	307.20	312.43	317.10	312.24	98.28	102.10	111.03	103.80	293.38	296.86	305.00	298.42
S_4	300.53	305.27	309.87	305.22	90.44	93.61	100.97	95.01	284.73	287.61	294.59	288.98
S_5	302.27	306.50	311.83	306.87	94.15	97.38	104.92	98.81	287.73	290.95	297.89	292.19
S_6	301.07	305.63	309.77	305.49	93.62	96.90	103.76	98.09	286.20	289.28	296.18	290.55
S_7	308.80	314.53	321.20	314.84	99.16	102.90	111.30	104.45	294.37	297.83	306.26	299.48
S_8	300.78	305.27	308.43	304.83	93.05	95.85	102.14	97.01	286.57	289.41	296.08	290.69
S_9	306.33	310.73	316.03	311.03	98.52	101.73	109.79	103.35	292.63	295.66	303.06	297.12
S_{10}	300.50	304.58	308.50	304.53	92.16	94.88	101.44	96.16	285.73	288.54	295.26	289.85
Mean of levels	303.47	308.16	312.99		95.03	98.28	105.82		289.08	292.17	299.43	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.74	2.22			0.80	2.25			0.89	2.52
S			1.35	4.02			1.45	4.11			1.63	4.60
L × S			2.65	NS			2.52	NS			2.82	NS
NPK only	287.69				87.28				276.85			
NPK + FYM	302.84				98.42				292.20			
Initial	**293.68**				**91.53**				**284.70**			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

value of 284.70 kg ha^{-1}. However NPK + FYM (292.20 kg ha^{-1}) recorded increased K content over initial.

Among the different sources of humic acid, S_7 (poultry manure) resulted in significant build up of available potassium (299.48 kg ha^{-1}) followed by S_3 (pressmud) (298.42 kg ha^{-1}), S_2 (coffee pulp) (297.57 kg ha^{-1}) and S_9 (urban compost) (297.12 kg ha^{-1}). Lower (288.98 kg ha^{-1}) was due to S_4 (biofuel waste).

The data on exchangeable calcium, magnesium and available sulphur of soil after harvest of maize are presented in Table 37.

The exchangeable calcium and magnesium content of soil after harvest of maize has increased significantly with increase in levels of humic acid application compared to initial. Application of humic acid @ 90 kg ha^{-1}recorded higher exchangeable calcium, magnesium and available sulphur (6.21 cmol (p+) kg^{-1}), (2.50 cmol (p+) kg^{-1}) and (17.99 mg kg^{-1}) compared to application @ 30 kg ha^{-1} (6.08 cmol (p+) kg^{-1}) (2.43 cmol (p+) kg^{-1}) and (17.03 mg kg^{-1}). Addition of NPK alone decreased exchange calcium (5.85 cmol (p+) kg^{-1}), magnesium (2.34 cmol (p+) kg^{-1}) and available sulphur (15.57 mg kg^{-1}) compared to initial value of (5.98 cmol (p+) kg^{-1}), (2.36 cmol (p+) kg^{-1}) and (16.29 mg kg^{-1}), respectively.

Among the different sources of humic acid, S_7 (poultry manure) recorded significantly higher exchangeable calcium (6.25 cmol (p+) kg^{-1}), magnesium (2.51 cmol (p+) kg^{-1}) and sulphur (17.70 mg kg^{-1}) followed by 17.65, 17.63 and 17.62 mg kg^{-1}, respectively due to S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost), respectively. Lower exchangeable calcium (6.08 cmol (p+) kg^{-1}), exchangeable magnesium (2.44 cmol (p+) kg^{-1}) and sulphur (17.32 mg kg^{-1}) was recorded in S_4 (biofuel waste).

The data on available (DTPA extractable) iron, manganese and zinc content of soil after harvest of maize is presented in Table 38 and available copper and boron content of soil is presented in Table 39.

The available iron, manganese, zinc, copper and boron content of soil increased compared to initial content. Higher iron (17.10 mg kg^{-1}), manganese (28.28 mg kg^{-1}), zinc (1.66 mg kg^{-1}), copper (2.87 mg kg^{-1}) and boron (0.56 mg kg^{-1}) was recorded on humic acid application @ 90 kg ha^{-1} and lower content of iron (14.20 mg kg^{-1}), manganese (26.44 mg kg^{-1}), zinc (1.47 mg kg^{-1}), copper (2.68 mg kg^{-1}) and boron (0.51 mg kg^{-1}) was with humic acid application @ 30 kg ha^{-1}. There was decrease in iron (12.20 mg kg^{-1}), manganese (22.85 mg kg^{-1}), zinc (1.24 mg kg^{-1}), copper (2.34 mg kg^{-1}) and boron (0.44 mg kg^{-1}) content of soil in NPK alone treatment compared to initial content of 13.55 mg kg^{-1}, 25.02 mg kg^{-1}, 1.33 mg kg^{-1}, 2.59 mg kg^{-1} and 0.46 mg kg^{-1} of iron, manganese, zinc, copper and boron, respectively. The NPK + FYM treatment recorded increase in iron (14.66 mg kg^{-1}), manganese (25.02 mg kg^{-1}), zinc (1.58 mg kg^{-1}), copper (2.71 mg kg^{-1}), boron (0.51 mg kg^{-1}) compared to initial value.

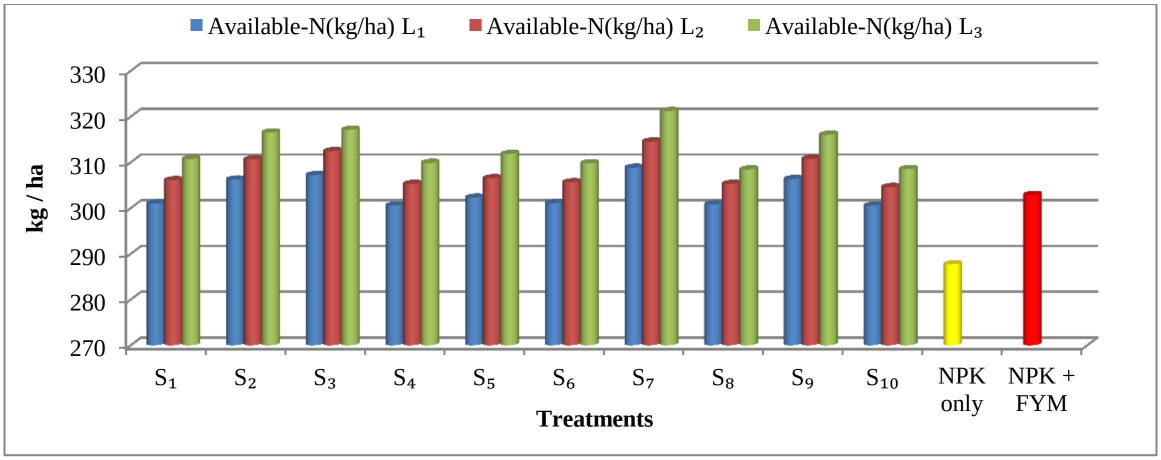

Fig. 4: Available nitrogen content of soil after harvest of maize as influenced by different sources and levels of humic acid

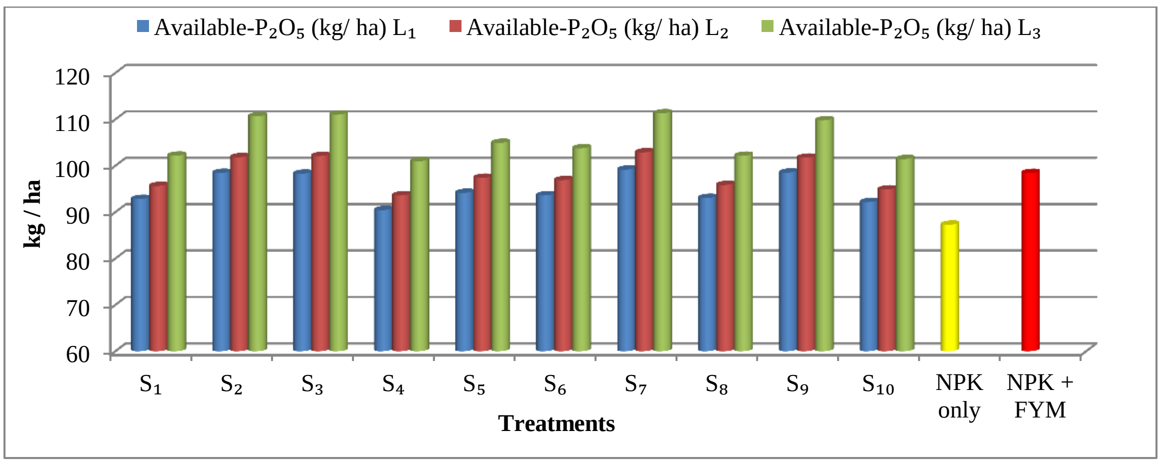

Fig. 5: Available phosphorus content of soil after harvest of maize as influenced by different sources and levels of humic acid

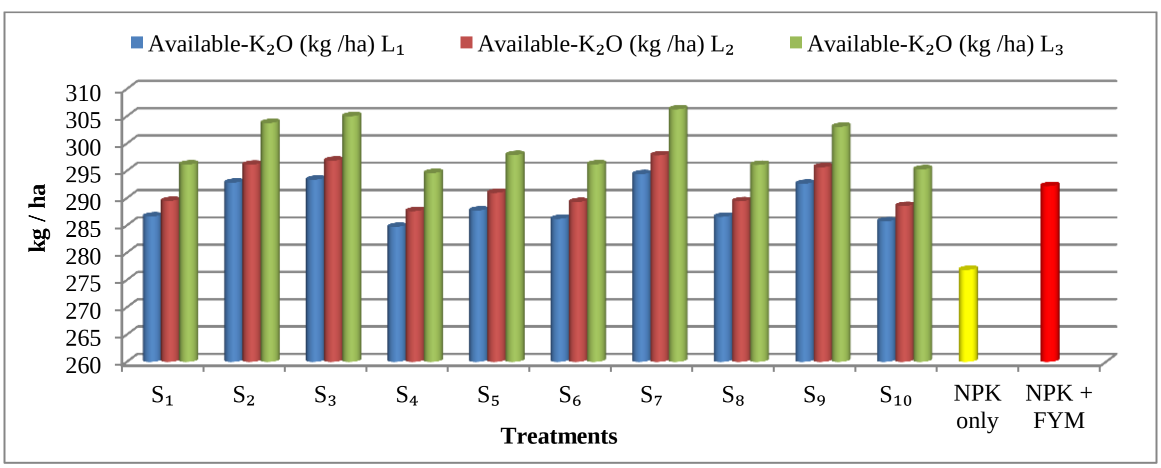

Fig. 6: Available potassium content of soil after harvest of maize as influenced by different sources and levels of humic acid

Table 37: Effect of different sources and levels of humic acid on exchangeable calcium, magnesium and available sulphur content of soil after harvest of maize

Humic acid sources	Exch. Ca [cmol (p+) kg^{-1}]				Exch. Mg [cmol (p+) kg^{-1}]				Avail-S (mg kg^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	6.03	6.09	6.15	6.09	2.41	2.45	2.48	2.44	16.90	17.28	17.88	17.36
S_2	6.15	6.20	6.28	6.21	2.46	2.49	2.53	2.49	17.21	17.55	18.14	17.63
S_3	6.15	6.21	6.29	6.22	2.46	2.50	2.53	2.50	17.22	17.56	18.16	17.65
S_4	6.02	6.08	6.14	6.08	2.40	2.44	2.47	2.44	16.79	17.30	17.86	17.32
S_5	6.04	6.11	6.17	6.11	2.42	2.45	2.48	2.45	16.98	17.35	17.93	17.42
S_6	6.03	6.10	6.15	6.09	2.41	2.44	2.48	2.44	17.01	17.33	17.88	17.41
S_7	6.17	6.24	6.33	6.25	2.47	2.51	2.55	2.51	17.25	17.62	18.24	17.70
S_8	6.02	6.08	6.14	6.08	2.41	2.44	2.47	2.44	16.94	17.30	17.85	17.36
S_9	6.14	6.20	6.27	6.20	2.46	2.49	2.52	2.49	17.21	17.54	18.12	17.62
S_{10}	6.02	6.07	6.13	6.07	2.40	2.44	2.46	2.43	16.83	17.71	17.83	17.46
Mean of levels	6.08	6.14	6.21		2.43	2.46	2.50		17.03	17.45	17.99	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.016	0.045			0.007	0.019			0.03	0.09
S			0.029	0.083			0.012	0.034			0.06	0.18
L × S			0.051	NS			0.021	NS			0.11	NS
NPK only	5.85				2.340				15.57			
NPK + FYM	6.14				2.456				17.19			
Initial	**5.98**				**2.36**				**16.29**			

L=Level S= Source ***NS = Non significant***

S_1=	***Coco peat***	***S_6=***	***Sewage sludge***
S_2=	***Coffee pulp***	***S_7=***	***Poultry manure***
S_3=	***Pressmud***	***S_8=***	***Vermicompost***
S_4=	***Biofuel waste***	***S_9=***	***Urban compost***
S_5=	***Distillery biocompost***	***S_{10}=***	***Farmyard manure***

Table 38: Effect of different sources and levels of humic acid on iron, manganese and zinc content of soil after harvest of maize

Humic acid sources	DTPA-Fe (mg kg^{-1})				DTPA-Mn (mg kg^{-1})				DTPA-Zn (mg kg^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	13.76	15.03	16.54	15.11	25.47	26.27	27.18	26.31	1.40	1.47	1.56	1.48
S_2	14.79	16.02	17.91	16.24	27.77	28.60	29.66	28.68	1.58	1.68	1.77	1.67
S_3	14.83	16.09	17.97	16.30	27.80	28.67	29.90	28.79	1.60	1.70	1.80	1.70
S_4	13.67	14.71	16.35	14.91	25.29	26.10	26.97	26.12	1.36	1.43	1.52	1.44
S_5	13.83	15.05	16.63	15.17	25.65	26.49	27.49	26.55	1.41	1.49	1.58	1.49
S_6	13.98	15.22	16.80	15.33	26.02	26.87	27.99	26.96	1.43	1.52	1.62	1.52
S_7	14.96	16.26	18.02	16.41	28.00	28.90	30.03	28.98	1.63	1.72	1.82	1.72
S_8	13.72	15.06	16.53	15.10	25.41	26.25	27.13	26.26	1.39	1.48	1.59	1.49
S_9	14.77	16.00	17.77	16.18	27.63	28.47	29.50	28.54	1.57	1.68	1.77	1.67
S_{10}	13.70	14.91	16.42	15.01	25.33	26.14	26.92	26.13	1.37	1.45	1.54	1.45
Mean of levels	14.20	15.43	17.10		26.44	27.28	28.28		1.47	1.56	1.66	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.14	0.39			0.27	0.77			0.025	0.07
S			0.25	0.71			0.49	1.40			0.045	0.13
L × S			0.44	NS			0.86	NS			0.078	NS
NPK only	12.20				22.85				1.24			
NPK + FYM	14.66				28.16				1.58			
Initial	**13.55**				**25.02**				**1.33**			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 39: Effect of different sources and levels of humic acid on copper and boron content of soil after harvest of maize

Humic acid sources	DTPA-Cu (mg kg^{-1})				Hot water-B (mg kg^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	2.62	2.70	2.79	2.70	0.50	0.52	0.54	0.52
S_2	2.75	2.83	2.97	2.85	0.53	0.56	0.59	0.56
S_3	2.76	2.83	2.98	2.86	0.53	0.57	0.60	0.56
S_4	2.61	2.68	2.77	2.69	0.50	0.52	0.54	0.52
S_5	2.63	2.70	2.81	2.72	0.50	0.52	0.54	0.52
S_6	2.65	2.73	2.85	2.74	0.51	0.53	0.56	0.53
S_7	2.77	2.85	3.02	2.88	0.54	0.58	0.62	0.58
S_8	2.61	2.71	2.80	2.71	0.50	0.52	0.53	0.52
S_9	2.75	2.83	2.97	2.85	0.53	0.56	0.59	0.56
S_{10}	2.62	2.69	2.78	2.70	0.50	0.52	0.54	0.52
Mean of levels	2.68	2.76	2.87		0.51	0.54	0.56	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.017	0.049			0.005	0.014
S			0.032	0.089			0.009	0.027
L × S			0.055	NS			0.016	NS
NPK only	2.348				0.44			
NPK + FYM	2.715				0.51			
Initial	**2.59**				**0.46**			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Humic acid extracted from different sources showed significant build up in micronutrients in soil. Higher iron (16.41 mg kg^{-1}), manganese (30.03 mg kg^{-1}), zinc (1.72 mg kg^{-1}), copper (2.88 mg kg^{-1}) and boron (0.58 mg kg^{-1}) content of soil was observed in poultry manure (S_7) followed by pressmud (S_3) with (16.30, 28.79, 1.70, 2.86 and 0.56 mg kg^{-1}, respectively of Fe, Mn Zn, Cu and B), coffee pulp (S_2) (16.24, 28.68, 1.67, 2.85 and 0.56 mg kg^{-1}, respectively Fe, Mn Zn, Cu and B) and urban compost (S_9) (16.18, 28.54, 1.67 2.85 and 0.56 mg kg^{-1} Fe, Mn Zn, Cu and B), respectively .

The increase in the content of available nutrients of soil after harvest of crop was due to indirect effect of humic acid which stimulated the activities of microorganisms leading to release of native nutrients or through other positive interaction effects due to HA application. When a humic substance is combined with NPK fertilizers, the increase in nutrient availability would be from both the sources. The complementary effect of HA application along with NPK fertilizers produced marked effect on NPK availability. Our results are in line with that of Sharif *et al*. (2002) who revealed that application of HA in combination with NPK significantly improved nutrients accumulations in wheat and maize plants. The increased N availability might be due to decreased number of nitrifying micro organisms (Quraishi and Cornfield, 1973). Flaig (1964) reported that the newly formed quinines from HA was responsible for the inhibition of nitrification and consequently increased the N availability due to reduction in leaching losses. Similarly P and K availability was also significantly increased during crop growth period. Humic acid has the ability to reduce P fixation and solubilize insoluble P compounds and thereby resulted in increasing P concentration in soil (Sibanda and Young, 1986). Similarly, the increased soil available K observed in this study may be attributed to the reduced K fixation as well as release of fixed K by humic acid (Changva *et al.*, 2005). The increase in the micronutrient availability was through ion exchange reaction (Yingei, 1988). Humic acid attracts positive ions and forms chelate with micronutrients serving as a reservoir of essential plant nutrients. Humic acid being polyvalent molecule (Schnizter and Khan, 1972; Spostio, 1989) attracts micronutrient cation and release to the plants.

Increase in nutrient availability due to application of humic acid extracted from poultry manure, pressmud, coffeepulp and urban compost may be due to presence of higher content of carboxyl and phenolic hydroxyl groups which were mainly responsible for increasing the nutrient availability and also helps in binding humic molecules to clay minerals (Kononova, 1966) and contain higher E_4/E_6 ratio when compared to other sources. Asma Lodhi *et al*. (2013) reported that HA with higher E_4/E_6 ratio are good indicators of bioactivity.

4.4 Greenhouse experiment II

4.4.1 Effect of different levels and sources of humic acid on growth parameters of capsicum

The data on growth parameters like plant height, number of branches and SPAD meter reading are presented in following pages.

Plant height

Plant height differed significantly with increase in the levels of humic acid application (Table 40). Higher plant height was recorded when HA was applied @ 90 kg ha^{-1} (45.79 cm) and lower plant height was recorded at 20 DAP (14.12 cm). However, addition of NPK alone and NPK + FYM recorded maximum plant height at 60 DAS (29.18 and 37.36 cm, respectively) and application of NPK + FYM was on par with HA application @ 30 kg ha^{-1}.

Humic acid extracted from different sources of organic waste on plant height recorded significantly higher plant height of 44.04 cm due to S_7 (poultry manure) followed by 43.53 cm in S_3 (pressmud), 43.36 cm in S_2 (coffee pulp) and 43.23 cm in S_9 (urban compost) at 60 DAP, similar was the trend at 40 and 20 DAP. However, lower plant height (20.17, 24.20 and 38.19 cm, respectively) was recorded due to S_4 (bio fuel waste). The interaction effect between different sources and levels of HA application was non significant.

Number of branches

The number of branches of capsicum at different stages (40 and 60 DAP) as influenced by different levels and sources of HA are presented in Table 41.

Higher number of branches (6.80) was recorded at 60 DAP with application of HA @ 90 kg ha^{-1} and significantly lower number of branches (5.11) with application @ 30 kg ha^{-1} significant difference was recorded with increase in levels of humic acid and duration of the crop.

At 60 days after planting application of NPK recorded lesser number of branches (3.64) and addition of NPK + FYM recorded 5.28. Similar was the trend at 40 DAP. Application of NPK + FYM on par with application of HA @ 30 kg ha^{-1}.

Humic acid extracted from different sources of organic wastes significantly influenced number of branches at all stages of plant growth viz., 40 and 60 DAP.

Application of humic acid extracted from poultry manure (S_7) recorded significantly higher number of branches (6.54) followed by 6.40 in S_3 (pressmud), 6.35 in S_2 (coffee pulp) and 6.36 in S_9 (urban compost). However, lesser number of branches (5.39) was recorded in S_4. Similar was the results at 40 and 20 DAP.

Chlorophyll (SPAD meter reading) content

Chlorophyll (SPAD meter reading) content in case of capsicum, showed significant difference due to application of graded levels of HA extracted from different sources (Table 42). At 60 DAP higher chlorophyll (SPAD meter reading) content (42.79) was recorded when humic acid was applied @ 90 kg $ha^{-1}$and it was 27.25at 20 DAP. Application of NPK alone and NPK + FYM recorded maximum chlorophyll (SPAD reading) content at 60 DAP (34.43 and 41.90, respectively), and application of NPK + FYM was on par with HA application @ 30 kg ha^{-1}.

Table 40: Plant height (cm) of capsicum at different intervals as influenced by sources and levels of humic acid

Humic acid sources	20 DAP				40 DAP				60 DAP			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	10.38	12.16	13.66	12.07	20.63	24.82	28.85	24.77	33.90	39.35	43.51	38.92
S_2	11.39	13.18	14.78	13.12	23.27	27.96	31.99	27.74	37.78	43.93	48.37	43.36
S_3	11.42	13.28	14.91	13.20	23.39	28.18	32.25	27.94	37.90	44.10	48.58	43.53
S_4	10.14	11.76	13.26	11.72	20.17	24.43	28.01	24.20	32.95	38.76	42.86	38.19
S_5	10.62	12.28	13.91	12.27	20.83	25.71	29.38	25.31	34.24	40.19	44.64	39.69
S_6	10.45	12.23	13.83	12.17	20.63	24.87	29.08	24.86	34.07	39.80	44.36	39.41
S_7	11.51	13.48	15.12	13.37	23.80	28.60	32.97	28.46	38.02	44.30	49.79	44.04
S_8	10.64	12.23	13.76	12.21	20.76	24.77	28.86	24.80	34.13	39.57	44.10	39.27
S_9	11.35	13.09	14.71	13.05	23.12	27.83	32.06	27.67	37.68	43.73	48.26	43.23
S_{10}	10.36	11.84	13.28	11.82	20.53	24.45	28.41	24.46	33.96	39.33	43.48	38.93
Mean of levels	10.83	12.55	14.12		21.71	26.16	30.18		35.46	41.31	45.79	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.14	0.39			0.38	1.08			0.61	1.73
S			0.25	0.71			0.70	1.98			1.12	3.16
L × S			0.43	NS			1.21	NS			1.94	NS
NPK only	9.01				18.87				29.18			
NPK + FYM	11.46				23.49				37.36			

L= Level S= Source DAP = Days after palnting NS = Non significant

S_1= Coco peat S_6= Sewage sludge
S_2= Coffee pulp S_7= Poultry manure
S_3= Pressmud S_8= Vermicompost
S_4= Biofuel waste S_9= Urban compost
S_5= Distillery biocompost S_{10}= Farmyard manure

Table 41: Number of branches of capsicum at 40 and 60 days after planting as influenced by different sources and levels of humic acid

Humic acid sources	40 days				60 days			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	2.97	3.40	3.98	3.45	4.78	5.42	6.46	5.55
S_2	3.29	3.70	4.31	3.76	5.48	6.27	7.31	6.35
S_3	3.31	3.72	4.35	3.79	5.51	6.32	7.38	6.40
S_4	2.90	3.30	3.87	3.35	4.67	5.20	6.29	5.39
S_5	3.01	3.44	4.06	3.50	4.89	5.55	6.52	5.65
S_6	2.99	3.43	4.03	3.48	4.82	5.46	6.50	5.59
S_7	3.33	3.78	4.41	3.84	5.73	6.41	7.48	6.54
S_8	2.97	3.43	4.01	3.47	4.90	5.42	6.44	5.59
S_9	3.28	3.70	4.30	3.76	5.52	6.27	7.28	6.36
S_{10}	2.96	3.32	3.88	3.39	4.77	5.44	6.36	5.52
Mean of levels	3.10	3.52	4.12		5.11	5.78	6.80	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.04	0.12			0.12	0.33
S			0.08	0.22			0.21	0.60
L × S			0.13	NS			0.37	NS
NPK only	2.57				3.64			
NPK + FYM	3.27				5.28			

L= Level S= Source DAP = Days after palnting NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Table 42: Chlorophyll (SPAD meter reading) content of capsicum leaves at different intervals as influenced by sources and levels of humic acid

Humic acid sources	20 DAP				40 DAP				60 DAP			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	22.72	24.40	26.30	24.47	31.15	32.42	33.97	32.51	39.95	40.81	41.84	40.87
S_2	25.31	26.50	28.47	26.76	33.32	35.20	36.84	35.12	41.68	42.68	43.83	42.73
S_3	25.32	26.71	28.76	26.93	33.40	35.43	36.91	35.25	41.95	42.84	43.98	42.92
S_4	22.87	24.03	25.68	24.19	31.07	32.05	33.81	32.31	39.94	40.67	41.83	40.81
S_5	23.28	24.63	26.73	24.88	31.41	33.26	35.33	33.33	40.23	41.19	42.35	41.26
S_6	22.95	24.56	26.48	24.67	31.29	32.60	34.65	32.85	40.00	41.11	42.13	41.08
S_7	25.85	27.08	28.94	27.29	33.65	35.48	37.58	35.57	42.05	43.05	44.40	43.17
S_8	23.22	24.51	26.51	24.75	31.18	32.41	34.39	32.66	39.95	40.64	41.85	40.81
S_9	25.27	26.42	28.41	26.70	33.28	35.16	37.32	35.25	41.63	42.66	43.78	42.69
S_{10}	23.09	24.32	26.20	24.54	31.15	32.12	34.46	32.58	39.92	40.66	41.90	40.83
Mean of levels	23.99	25.32	27.25		32.09	33.61	35.53		40.73	41.63	42.79	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.32	0.90			0.34	0.95			0.25	0.71
S			0.58	1.65			0.62	1.74			0.45	1.29
L × S			1.01	NS			1.07	NS			0.79	NS
NPK only	21.45				28.46				34.43			
NPK + FYM	25.64				33.27				41.90			

L= Level S= Source DAP = Days after palnting NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Humic acid extracted from different types of organic wastes influenced chlorophyll (SPAD meter reading) content significantly recording higher value of 43.17 in S_7 (poultry manure) followed by 42.92 in S_3 (pressmud), 42.73 in S_2 (coffee pulp) and 42.69 in S_9 (urban waste) at 60 DAP. Similar was the trend at 20 and 40 DAP. However lower chlorophyll (SPAD meter reading) content was recorded at 20, 40 and 60 DAP and was 24.19, 32.31 and 40.81, respectively due to HA application extracted from bio fuel waste (S_4).

Humic acid extracted from other sources like S_1 (coco peat), S_4 (biofuel waste), S_5 (distillery biocompost), S_6 (sewage sludge), S_8 (vermicompost) and S_{10} (FYM) significantly differed with S_7 (poultry manure), S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban waste) with respect to chlorophyll content on application of humic acid at levels varying from 30 to 90 kg ha^{-1}.

4.4.2 Dry matter yield

The data on the effect of graded levels and sources of humic acid application on shoot and root dry weight (g pot^{-1}) of capsicum are presented in Table 43, Fig. 7 and Plate 4.

Increase in the levels of humic acid application resulted in significant increase in both shoot and root dry weight of capsicum and maximum shoot and root dry weight of 43.33 and 8.08 g pot^{-1}, respectively was recorded with addition of humic acid @ 90 kg ha^{-1} and minimum shoot and root dry weight of 25.11 and 4.34 g pot^{-1}, respectively was recorded with humic acid application @ 30 kg ha^{-1}. Treatments which received NPK alone recorded 20.14 and 3.74 g pot^{-1} of shoot and root dry weight. Application of NPK + FYM was found to be on par with application of humic acid @ 30 kg ha^{-1} in terms of shoot (27.57 g pot^{-1}) and root (4.72 g pot^{-1}) dry weight.

Significant difference in dry matter yield was noticed with application of different of humic acid extracted from different organic wastes. Significantly higher shoot (38.02 g pot^{-1}) and root dry weight (6.66 g pot^{-1}) was recorded in S_7 (poultry manure) followed by shoot and root dry weight of 37.24 and 6.56 g pot^{-1} in S_3 (pressmud), 36.96 and 6.50 g pot^{-1} in S_2 (coffee pulp) and 36.84 and 6.50 g pot^{-1} in S_9 (urban compost). Lower shoot and root dry weight of 31.63 and 5.65 g pot^{-1} was recorded in S_4 (biofuel waste).

The interaction effect between different sources and levels of humic acid application was non-significant (Table 43).

The combination of fertilizers and humic acid had a significant effect on growth parameters in the present study. All the growth parameters recorded were significantly higher with application of higher levels of humic acid. The increase in growth characteristics of capsicum in response to HA application was due to the presence of growth promoting substances like Indole acetic acid (IAA), gibberellins and auxin in its structure which are directly involved in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis, and various enzymatic reactions (Ulukan, 2008). Higher ion exchange capacity of HA might have increased the availability of nutrients

Table 43: Shoot and root dry matter yield (g pot^{-1}) of capsicum at harvest (60 DAS) as influenced by sources and levels of humic acid

Humic acid sources	Shoot dry weight (g pot^{-1})				Root dry weight (g pot^{-1})			
	L_1	L_2	L_3	Mean sources	L_1	L_2	L_3	Mean sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	23.72	32.91	41.18	32.60	4.13	5.52	7.73	5.79
S_2	27.16	37.45	46.28	36.96	4.67	6.27	8.57	6.50
S_3	27.26	37.76	46.70	37.24	4.71	6.34	8.64	6.56
S_4	22.97	32.13	39.79	31.63	4.02	5.43	7.50	5.65
S_5	24.00	33.82	42.06	33.29	4.15	5.71	7.87	5.91
S_6	23.73	32.94	41.27	32.65	4.11	5.53	7.79	5.81
S_7	27.66	38.39	48.01	38.02	4.76	6.40	8.83	6.66
S_8	23.89	32.63	41.28	32.60	4.14	5.51	7.73	5.79
S_9	27.11	37.07	46.32	36.84	4.65	6.25	8.58	6.50
S_{10}	23.60	32.48	40.40	32.16	4.09	5.43	7.61	5.71
Mean level	25.11	34.76	43.33		4.34	5.84	8.08	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.57	1.62			0.09	0.27
S			1.04	2.95			0.17	0.48
L × S			1.81	NS			0.30	NS
NPK only	20.14				3.74			
NPK + FYM	27.57				4.72			

L= Level S= Source NS = Non significant

S_1= Coco peat S_6= Sewage sludge
S_2= Coffee pulp S_7= Poultry manure
S_3= Pressmud S_8= Vermicompost
S_4= Biofuel waste S_9= Urban compost
S_5= Distillery biocompost S_{10}= Farmyard manure

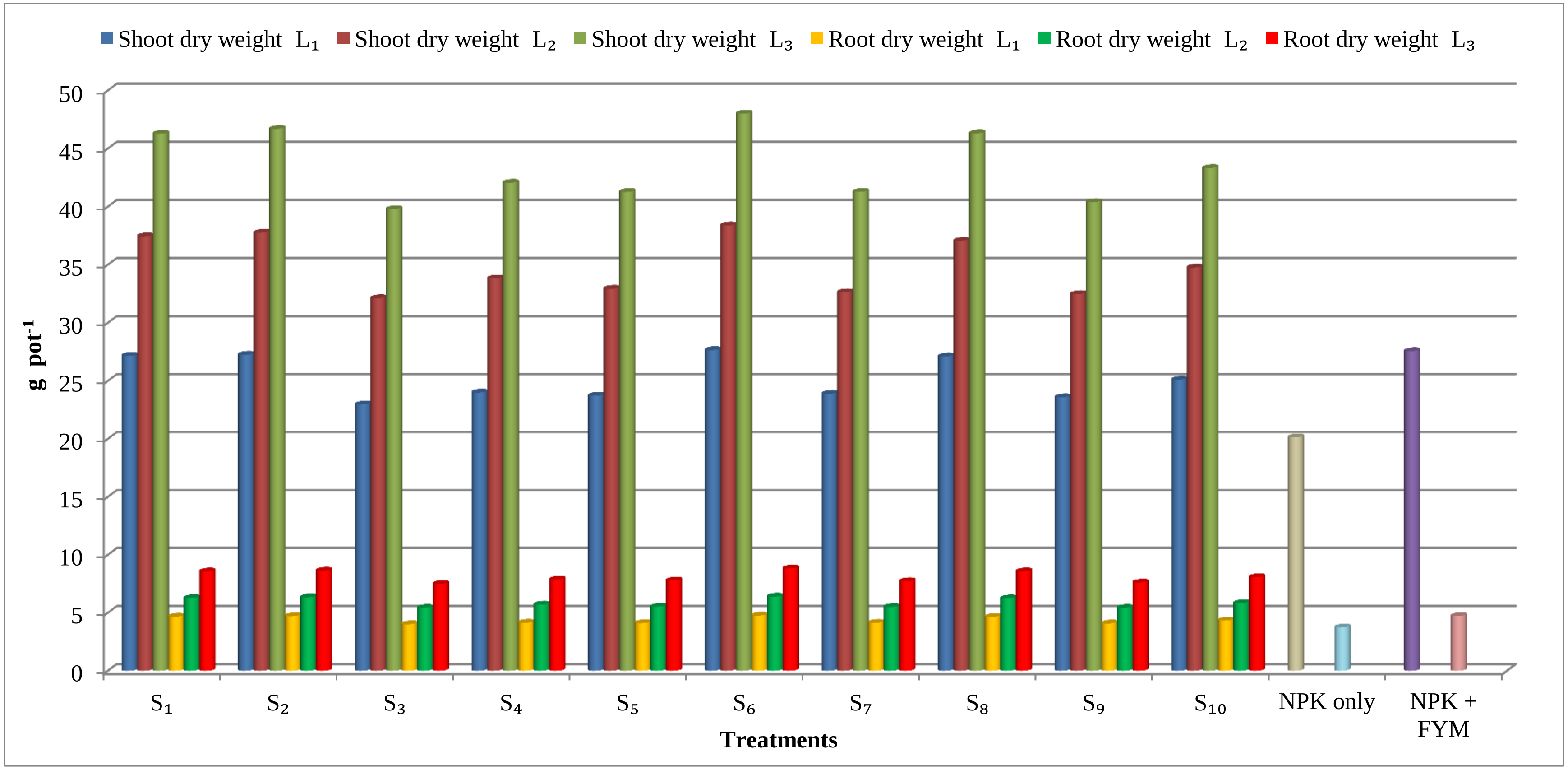

Fig. 7: Shoot and root dry weight (g pot^{-1}) of capsicum as influenced by different sources and levels of humic acid extracted from different organic wastes

LEGEND

S_1- Coco peat
S_2 - Coffee pulp
S_3- Pressmud
S_4 - Biofuel waste
S_5 - Biodistillery compost

S_6- Sewage sludge
S_7- Poultry manure
S_8 -Vermi compost
S_9 - Urban compost
S_{10}- FYM

L_1- 30 kg ha^{-1}
L_2- 60 kg ha^{-1}
L_3- 90 kg ha^{-1}

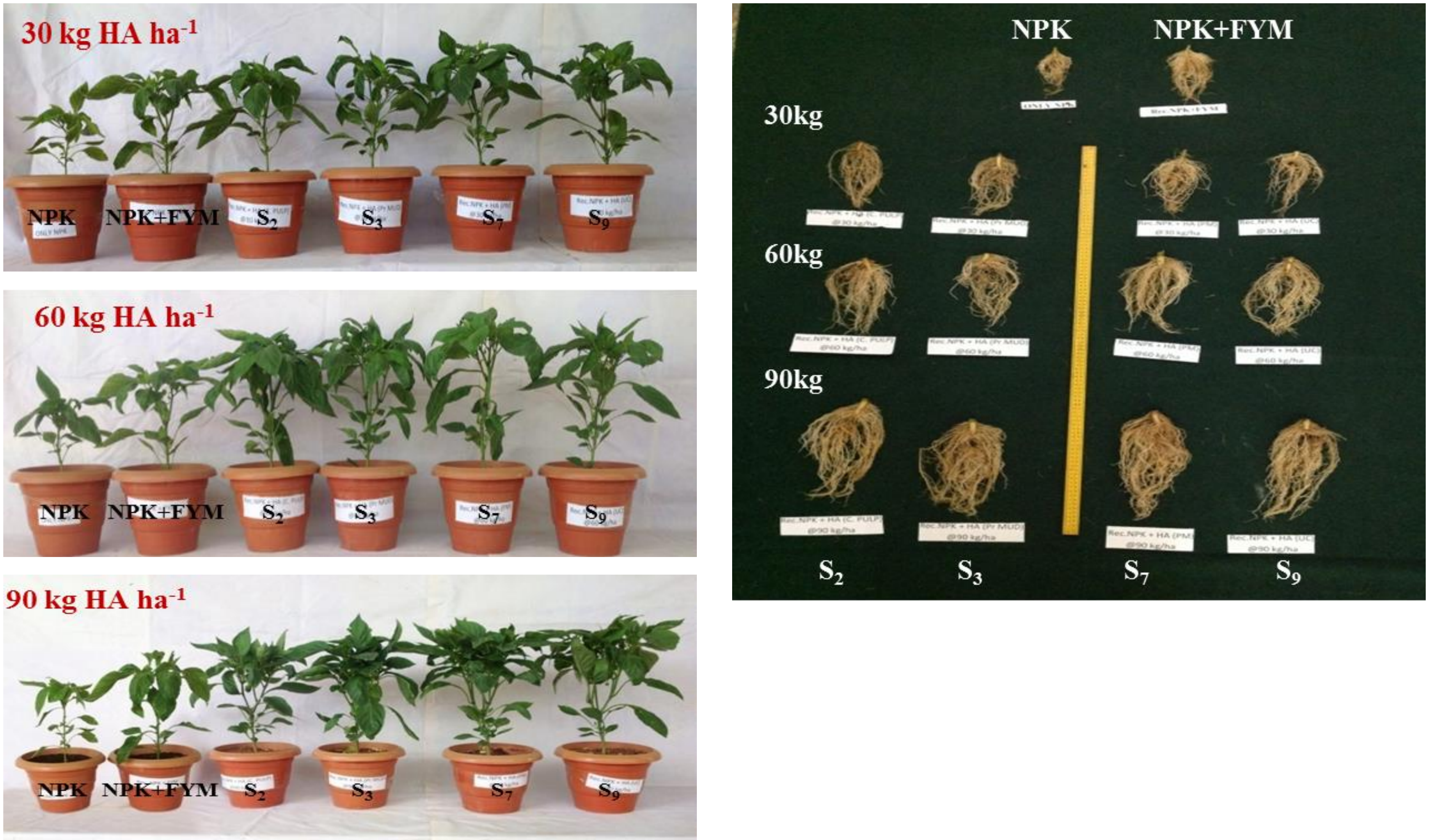

Plate 4: Above ground biomass and root biomass of capsicum as influenced by different levels and sources of humic acid

leading to an increase in the volume of roots. Similar findings were reported by Nikbakht *et al.* (2008), Shahrayri *et al.* (2011), Tahir *et al.* (2011) and Saruhan *et al.* (2011). It was reported that (Sezer Sahin *et al.*, 2014) dry matter yield of tomato increased with increase in levels of HA upto120 mg kg^{-1}, significant increase in shoot and root fresh weight of okra by the application of lignite humic acid along with recommended fertilizer was observed by Kirn *et al.* (2010). In the present study, Humic acid extracted from poultry manure, pressmud, coffee pulp and urban compost recorded higher growth parameters due to higher nutrient composition and presence of different functional groups of humic molecules which form complexes with metals (Livens, 1991). The functional group encourages movement of cations in soils and serves as natural chelate in soils.

4.4.3 Nutrient content of capsicum plant at harvest

The data on content of nitrogen, phosphorous and potassium in shoot and root of capsicum are presented in Table 44 and 45.

The data on content of nitrogen, phosphorus and potassium in shoot (Table 44) and root (Table 45) of capsicum varied significantly with varied levels of humic acid application.

The nutrient content of shoot and root increased with graded levels of HA application. The nitrogen content in shoot was higher (2.63 %) with application of HA @ 90 kg $ha-^{1}$ compared to that in roots (0.90 %). Similarly application of NPK alone recorded lower N content (1.57 % and 0.65 % in shoot and root, respectively) and it was 2.20 and 0.86 per cent in shoot and root in treatment which received NPK + FYM.

With respect to different sources, application of HA extracted from poultry manure (S_7) recorded significantly higher content of nitrogen in shoot (2.52 %) and root (0.93 %) followed by, S_3 (pressmud) (2.50 % and 0.92 %, respectively), S_2 (2.49 and 0.91 %, respectively) and S_9 (2.48 % and 0.97 %, respectively). However, lower N content in shoot (2.03 %) and root and (0.75 %) was recorded due to biofuel waste (S_4). The interaction effect between different sources and levels of HA application was non significant.

Higher content of phosphorus was recorded in shoot (0.51 %) and root (0.26 %) with HA application @ 90 kg ha^{-1}. However the P content was low in treatment NPK alone (0.31 % and 0.12 % in shoot and root, respectively). While the values were 0.48 per cent in shoot and 0.21 per cent in root in treatment receiving NPK + FYM and was found to be on par with application of HA @ 30 kg ha^{-1}.

Among different sources, the phosphorus content both in shoot and root showed similar trend as that of nitrogen, with higher content of phosphorus in shoot (0.54 %) and root (0.27 %) due to S_7 (poultry manure) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost).

Table 44: Nitrogen, phosphorus and potassium content (%) of capsicum shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	1.76	2.09	2.48	2.11	0.35	0.41	0.46	0.41	2.45	2.63	2.88	2.65
S_2	2.17	2.43	2.86	2.49	0.46	0.51	0.56	0.51	2.80	3.04	3.26	3.03
S_3	2.19	2.44	2.87	2.50	0.47	0.52	0.58	0.52	2.82	3.05	3.27	3.04
S_4	1.74	2.02	2.34	2.03	0.35	0.40	0.42	0.39	2.37	2.53	2.82	2.57
S_5	1.78	2.16	2.56	2.17	0.36	0.41	0.48	0.42	2.48	2.69	2.97	2.71
S_6	1.77	2.17	2.53	2.16	0.36	0.42	0.47	0.42	2.46	2.66	2.93	2.68
S_7	2.20	2.47	2.88	2.52	0.48	0.54	0.59	0.54	2.83	3.09	3.30	3.07
S_8	1.78	2.14	2.53	2.15	0.36	0.41	0.47	0.41	2.44	2.64	2.91	2.67
S_9	2.17	2.42	2.86	2.48	0.46	0.51	0.57	0.51	2.79	3.04	3.23	3.02
S_{10}	1.75	2.03	2.39	2.06	0.35	0.40	0.45	0.40	2.43	2.61	2.87	2.64
Mean of levels	1.93	2.24	2.63		0.40	0.45	0.51		2.59	2.80	3.05	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.04	0.12			0.013	0.036			0.04	0.13
S			0.08	0.23			0.023	0.069			0.08	0.24
L × S			0.14	NS			0.04	NS			0.14	NS
NPK only	1.57				0.31				1.93			
NPK + FYM	2.20				0.48				2.83			

L= Level S= Source NS = Non significant

S_1 = Coco peat
S_2 = Coffee pulp
S_3 = Pressmud
S_4 = Biofuel waste
S_5 = Distillery biocompost
S_6 = Sewage sludge
S_7 = Poultry manure
S_8 = Vermicompost
S_9 = Urban compost
S_{10} = Farmyard manure

Table 45: Nitrogen, phosphorus and potassium content (%) of capsicum root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	L_1 30 (kg ha^{-1})	L_2 60	L_3 90	Mean of sources	L_1 30 (kg ha^{-1})	L_2 60	L_3 90	Mean of sources	L_1 30 (kg ha^{-1})	L_2 60	L_3 90	Mean of sources
S_1	0.71	0.78	0.84	0.77	0.16	0.19	0.23	0.19	0.88	0.94	1.02	0.95
S_2	0.84	0.91	0.96	0.91	0.22	0.26	0.29	0.25	0.98	1.07	1.14	1.06
S_3	0.85	0.93	0.98	0.92	0.22	0.26	0.29	0.26	0.99	1.08	1.14	1.07
S_4	0.68	0.76	0.81	0.75	0.14	0.17	0.22	0.18	0.86	0.93	1.00	0.93
S_5	0.72	0.79	0.87	0.80	0.17	0.21	0.24	0.20	0.90	0.97	1.06	0.97
S_6	0.72	0.79	0.86	0.79	0.17	0.20	0.24	0.20	0.89	0.96	1.04	0.96
S_7	0.86	0.95	1.00	0.93	0.23	0.27	0.31	0.27	0.99	1.09	1.16	1.08
S_8	0.70	0.78	0.85	0.78	0.16	0.19	0.23	0.19	0.89	0.96	1.03	0.96
S_9	0.84	0.91	0.97	0.91	0.22	0.26	0.29	0.26	0.98	1.06	1.14	1.06
S_{10}	0.70	0.76	0.84	0.77	0.15	0.20	0.23	0.19	0.87	0.97	1.02	0.95
Mean of levels	0.76	0.84	0.90		0.18	0.22	0.26		0.92	1.00	1.08	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.016	0.045			0.008	0.022			0.013	0.037
S			0.029	0.083			0.013	0.039			0.022	0.066
L × S			0.051	NS			0.024	NS			0.041	NS
NPK only	0.65				0.12				0.81			
NPK + FYM	0.86				0.21				0.98			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

The interaction effect between different sources and levels of HA application was non significant.

The potassium content in shoot and root of capsicum followed the same trend as that of nitrogen and phosphorus. Higher potassium content was observed in shoot (3.05 %) and was low in root (1.08 %). The pots receiving NPK alone recorded lower K content in shoot (1.93 %) and root (0.81 %). The K content of plants due to NPK + FYM treatment recorded 2.83 and 0.98 per cent in shoot and root compared to HA treated pots and was on par with application of HA @ 30 kg ha^{-1}.

The concentration of potassium in capsicum shoot (3.07 %) and root (1.08 %) was significantly higher in S_7 (poultry manure), followed by S_3 (3.04 and 1.07 %, respectively), S_2 (3.03 and 1.06 %, respectively) and S_9 (3.02 and 1.06 %, respectively) in shoot and root respectively. Lower potassium content in shoot and root (2.57 and 0.93 %, respectively) was in S_4 (biofuel waste). However the interaction effect between the levels and sources of HA application was non significant.

The concentration of calcium, magnesium and sulphur in shoot and root of capsicum varied significantly due to different sources and levels of HA application (Table 46 and 47).

Higher content of Ca in shoot and root (0.71 and 0.30 %, respectively), Mg (0.30 and 0.14 %, respectively) and sulphur 0.59 and 0.26 %, respectively) was observed with application of HA @ 90 kg ha^{-1}. Lower content of Ca, Mg and S was observed with HA application @ 30 kg ha^{-1}. The NPK alone treatment recorded lower Ca content of (0.46 and 0.20 %, in shoot and root, respectively), magnesium content of 0.21 and 0.09 per cent, respectively and sulphur content of 0.35 and 0.16 per cent, respectively. The concentration of Ca, Mg, and S was relatively higher in NPK + FYM treated pots than NPK alone pots. The NPK + FYM treatment was on par with application of HA @ 30 kg ha-^{1}.

Significantly higher concentration of Ca, Mg and S (0.70, 0.31 and 0.62 %, respectively) in shoot and (0.30, 0.15 and 0.26 %, respectively) in root was recorded in pots receiving humic acid extracted from poultry manure (S_7) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost) and lower concentration of Ca, Mg and S (0.57, 0.25 and 0.45 %, respectively in shoot and 0.24, 0.11 and 0.21 %, respectively in root) was recorded in S_4 (biofuel waste). The interaction effect between different sources and levels of HA application was non significant.

The concentration of micronutrients (iron, manganese and zinc) in shoot and root of capsicum is presented in Table 48 and 49.

Iron, manganese and zinc content of capsicum shoot and root varied significantly with different levels and sources of humic acid application. Higher concentration of Fe (620.41 and 268.0 mg kg^{-1}, respectively), Mn (187.96 and 66.24 mg kg^{-1}, respectively)

Table 46: Calcium, magnesium and sulphur content (%) of capsicum shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Calcium				Magnesium				Sulphur			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.52	0.58	0.65	0.58	0.24	0.26	0.28	0.26	0.42	0.48	0.54	0.48
S_2	0.62	0.68	0.77	0.69	0.27	0.30	0.32	0.30	0.54	0.60	0.66	0.60
S_3	0.63	0.68	0.78	0.69	0.28	0.30	0.32	0.30	0.54	0.60	0.68	0.60
S_4	0.50	0.56	0.63	0.57	0.23	0.25	0.28	0.25	0.40	0.45	0.50	0.45
S_5	0.53	0.59	0.69	0.60	0.24	0.26	0.29	0.27	0.43	0.48	0.55	0.49
S_6	0.54	0.60	0.70	0.61	0.24	0.26	0.29	0.26	0.44	0.49	0.55	0.49
S_7	0.63	0.69	0.79	0.70	0.29	0.31	0.32	0.31	0.55	0.61	0.69	0.62
S_8	0.53	0.60	0.67	0.60	0.24	0.26	0.29	0.26	0.42	0.48	0.54	0.48
S_9	0.62	0.67	0.78	0.69	0.27	0.30	0.32	0.30	0.54	0.59	0.66	0.60
S_{10}	0.51	0.57	0.65	0.57	0.24	0.26	0.28	0.26	0.41	0.46	0.52	0.46
Mean of levels	0.56	0.62	0.71		0.25	0.27	0.30		0.47	0.52	0.59	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.012	0.034			0.005	0.013			0.015	0.041
S			0.022	0.063			0.008	0.023			0.027	0.076
L × S			0.039	NS			0.014	NS			0.046	NS
NPK only	0.46				0.21				0.35			
NPK + FYM	0.64				0.28				0.52			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

Table 47: Calcium, magnesium and sulphur content (%) of capsicum root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Calcium				Magnesium				Sulphur			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.21	0.25	0.28	0.25	0.10	0.12	0.13	0.12	0.19	0.22	0.24	0.22
S_2	0.25	0.29	0.33	0.29	0.12	0.14	0.16	0.14	0.23	0.26	0.28	0.25
S_3	0.25	0.29	0.33	0.29	0.12	0.14	0.16	0.14	0.23	0.26	0.28	0.26
S_4	0.20	0.24	0.27	0.24	0.10	0.12	0.13	0.11	0.18	0.20	0.24	0.21
S_5	0.21	0.25	0.29	0.25	0.10	0.12	0.14	0.12	0.20	0.22	0.24	0.22
S_6	0.21	0.25	0.29	0.25	0.10	0.12	0.13	0.12	0.20	0.23	0.25	0.23
S_7	0.26	0.30	0.34	0.30	0.13	0.15	0.17	0.15	0.24	0.27	0.29	0.26
S_8	0.21	0.26	0.29	0.25	0.10	0.12	0.13	0.12	0.19	0.23	0.25	0.22
S_9	0.25	0.29	0.33	0.29	0.12	0.14	0.16	0.14	0.23	0.26	0.28	0.26
S_{10}	0.21	0.24	0.27	0.24	0.10	0.12	0.13	0.12	0.18	0.21	0.24	0.21
Mean of levels	0.23	0.27	0.30		0.11	0.13	0.14		0.21	0.24	0.26	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.006	0.017			0.003	0.008			0.004	0.014
S			0.011	0.031			0.005	0.014			0.008	0.024
L × S			0.019	NS			0.009	NS			0.015	NS
NPK only	0.20				0.09				0.16			
NPK + FYM	0.27				0.12				0.23			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 48: Iron, manganese and zinc content (mg kg^{-1}) of capsicum shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Iron				Manganese				Zinc			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	530.50	553.64	589.84	558.00	146.52	158.70	179.24	161.49	67.51	71.23	77.57	72.10
S_2	587.50	614.14	655.57	619.07	167.47	184.30	201.64	184.47	77.39	81.83	88.22	82.48
S_3	587.97	617.28	659.37	621.54	168.40	186.94	202.26	185.87	77.71	82.50	88.86	83.02
S_4	524.96	550.85	583.25	553.02	143.35	157.47	173.28	158.03	65.32	69.18	73.10	69.20
S_5	534.40	562.86	607.83	568.36	147.40	162.36	180.63	163.47	68.07	74.30	80.50	74.29
S_6	536.73	566.60	610.59	571.31	148.20	164.99	182.74	165.31	67.98	73.49	79.62	73.70
S_7	590.06	624.80	667.87	627.58	168.73	186.63	203.71	186.36	78.27	83.00	89.20	83.49
S_8	531.57	559.68	594.50	561.92	145.49	160.82	180.33	162.21	67.57	72.42	79.19	73.06
S_9	586.93	611.19	650.48	616.20	167.93	183.63	200.48	184.01	77.23	81.76	87.68	82.22
S_{10}	529.77	550.56	584.83	555.05	144.52	158.26	175.28	159.35	67.07	70.64	75.66	71.12
Mean of levels	554.04	581.16	620.41		154.80	170.41	187.96		71.41	76.03	81.96	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			6.93	19.59			2.69	7.60			1.25	3.54
S			12.65	35.77			4.90	13.87			2.29	6.47
L × S			21.90	NS			8.50	NS			3.96	NS
NPK only	504.71				136.80				61.79			
NPK + FYM	585.60				172.54				80.77			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 49: Iron, manganese and zinc content (mg kg^{-1}) of capsicum root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Iron				Manganese				Zinc			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	220.78	234.79	252.36	235.98	57.33	60.33	63.06	60.24	25.87	27.52	29.06	27.49
S_2	251.47	270.97	288.85	270.43	63.51	67.06	70.21	66.93	28.90	30.61	32.30	30.60
S_3	254.10	274.99	289.44	272.84	63.75	67.23	70.69	67.23	29.23	30.86	32.49	30.86
S_4	212.97	228.69	246.00	229.22	55.67	59.21	61.73	58.87	25.21	26.71	28.41	26.78
S_5	227.43	242.89	262.06	244.13	58.92	61.95	65.03	61.97	26.26	28.13	29.95	28.12
S_6	223.37	240.25	256.04	239.89	58.96	61.58	64.31	61.62	26.07	27.63	29.58	27.76
S_7	258.82	278.66	292.09	276.52	64.60	68.26	72.12	68.33	29.63	31.50	32.91	31.35
S_8	220.50	238.66	252.92	237.36	57.50	60.51	63.42	60.48	25.95	27.69	29.29	27.64
S_9	250.13	269.52	286.21	268.62	63.33	67.13	69.66	66.71	28.81	30.56	32.05	30.47
S_{10}	217.78	241.61	254.01	237.80	57.06	59.70	62.16	59.64	25.76	27.50	28.82	27.36
Mean of levels	233.73	252.10	268.00		60.06	63.30	66.24		27.17	28.87	30.49	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			4.00	11.31			0.79	2.25			0.38	1.09
S			7.30	20.65			1.45	4.10			0.70	1.99
L × S			12.64	NS			2.51	NS			1.22	NS
NPK only	201.37				54.34				24.23			
NPK + FYM	259.03				62.59				28.87			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

and Zn (81.96 and 30.49 mg kg^{-1}, respectively) was observed with application of HA @ 90 kg ha^{-1} and lower concentration with application of HA @ 30 kg ha^{-1}.

Among the sources significantly higher concentration of Fe was recorded in shoot and root (627.58 and 276.52 mg kg^{-1}, respectively), Mn (186.36 and 68.33 mg kg^{-1}, respectively) and Zn (83.49 and 31.35 mg kg^{-1}, respectively) was observed inS_7 (poultry manure) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost).

The copper and boron concentration in shoot and root of capsicum as influenced by different sources and levels of HA application is presented in Table 50 and 51.

Higher content of copper and boron (24.93 and 10.54 mg kg^{-1} and 14.13 and 5.01 mg kg^{-1} in shoot and root of capsicum, respectively) was observed with application of HA @ 90 kg ha^{-1} while lower content of copper and boron was in HA treatment receiving @ 30 kg ha^{-1}. In case of application of NPK alone and NPK + FYM the concentration of Cu (17.05 and 7.43 mg kg^{-1}, respectively) and B (9.86 and 3.73 mg kg^{-1}, respectively) was lower in shoot and root. On the other hand the concentration of copper and boron in capsicum shoot and root in treatment receiving NPK + FYM recorded Cu (23.39 and 10.32 mg kg^{-1}, respectively) and B (13.63 and 4.85 mg kg^{-1}, respectively) and was on par with application of HA @ 30 kg ha^{-1}.

Among the humic acid sources significantly higher concentration Cu and B in shoot and root (25.76 and 14.71 mg kg^{-1} and 10.79 and 14.71 and 5.13 mg kg^{-1}, respectively) was in poultry manure (S_7) followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9) respectively.

HA extracted from distillery bio compost (S_5), sewage sludge (S_6), coco peat (S_1), vermicompost (S_8), FYM (S_{10}) and biofuel waste (S_4) significantly differed compared to poultry manure (S_7), pressmud (S_3), coffee pulp (S_2) and urban compost (S_9) with respect to micronutrient content, there was no significant interaction effect between different sources and levels of HA application.

4.4.4 Nutrient uptake by capsicum plant

The uptake of nitrogen, phosphorus and potassium by capsicum varied significantly due to different sources and levels of HA application (Table 52).

The uptake of major nutrients by capsicum varied significantly due to different sources and levels of HA application. Humic acid application @ 90 kg ha^{-1} resulted in increase in uptake of N (1.22 g pot^{-1}), P (0.24 g pot^{-1}) and K (1.41 g pot^{-1}) by capsicum plant compared to that of HA application @ 30 kg ha^{-1} with N (0.52 g pot^{-1}), P (0.11 g pot^{-1}) and K (0.70 g pot^{-1}).

However uptake of major nutrients @ 60 kg ha^{-1}showed significant difference with that of HA application @ 90 kg ha^{-1}. Among NPK alone and NPK + FYM treatments, the uptake of NPK (0.36g pot^{-1}, 0.07 g pot^{-1} and K 0.42 g pot^{-1}, respectively)

Table 50: Copper and boron content (mg kg^{-1}) of capsicum shoot at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Copper				Boron			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	19.69	21.43	23.08	21.40	10.69	11.95	13.12	11.92
S_2	23.06	25.24	27.50	25.27	13.42	14.33	15.76	14.50
S_3	23.35	25.58	27.65	25.53	13.57	14.39	15.79	14.58
S_4	19.04	20.47	21.87	20.46	10.91	11.75	12.98	11.88
S_5	20.02	21.94	23.97	21.98	11.17	12.71	13.84	12.57
S_6	19.96	21.92	23.73	21.87	11.03	12.57	13.52	12.38
S_7	23.57	25.96	27.76	25.76	13.62	14.58	15.93	14.71
S_8	19.87	21.70	23.57	21.71	10.87	12.10	13.41	12.13
S_9	23.05	25.12	27.39	25.19	13.38	14.37	15.62	14.46
S_{10}	19.65	20.73	22.82	21.07	10.39	11.71	13.08	11.73
Mean of levels	21.13	23.01	24.93		11.90	13.05	14.31	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.48	1.37			0.29	0.81
S			0.88	2.50			0.52	1.48
L × S			1.53	NS			0.90	NS
NPK only	17.05				9.86			
NPK + FYM	23.39				13.63			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 51: Copper and boron content (mg kg^{-1}) of capsicum root at harvest (60 DAS) as influenced by different sources and levels of humic acid

Humic acid sources	Copper				Boron			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	8.69	9.25	9.96	9.30	4.11	4.41	4.75	4.42
S_2	9.94	10.72	11.33	10.66	4.69	5.11	5.40	5.07
S_3	9.96	10.81	11.41	10.73	4.73	5.15	5.44	5.11
S_4	8.48	9.11	9.64	9.08	4.01	4.26	4.47	4.25
S_5	8.79	9.73	10.25	9.59	4.19	4.64	4.93	4.59
S_6	8.75	9.63	10.22	9.53	4.16	4.59	4.87	4.54
S_7	10.03	10.87	11.45	10.79	4.75	5.18	5.46	5.13
S_8	8.75	9.49	10.17	9.47	4.11	4.52	4.85	4.49
S_9	9.92	10.76	11.31	10.66	4.68	5.13	5.39	5.07
S_{10}	8.58	9.09	9.70	9.12	4.09	4.29	4.58	4.32
Mean of levels	9.19	9.95	10.54		4.35	4.73	5.01	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.16	0.45			0.08	0.22
S			0.29	0.83			0.15	0.41
L × S			0.51	NS			0.25	NS
NPK only	7.43				3.73			
NPK + FYM	10.32				4.85			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 52: Nitrogen, phosphorus and potassium uptake (g pot^{-1}) by capsicum (shoot + root) at harvest as influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.45	0.73	1.09	0.75	0.09	0.15	0.21	0.15	0.62	0.92	1.27	0.93
S_2	0.63	0.97	1.41	1.00	0.14	0.21	0.29	0.21	0.81	1.20	1.61	1.21
S_3	0.64	0.98	1.42	1.01	0.14	0.21	0.30	0.22	0.82	1.22	1.63	1.22
S_4	0.43	0.69	0.99	0.70	0.09	0.14	0.18	0.14	0.58	0.86	1.20	0.88
S_5	0.46	0.78	1.14	0.79	0.09	0.15	0.22	0.15	0.62	0.97	1.33	0.97
S_6	0.45	0.76	1.11	0.77	0.09	0.15	0.21	0.15	0.62	0.93	1.29	0.95
S_7	0.65	1.01	1.47	1.04	0.14	0.22	0.31	0.23	0.83	1.25	1.69	1.26
S_8	0.45	0.74	1.11	0.77	0.09	0.14	0.21	0.15	0.62	0.92	1.28	0.94
S_9	0.63	0.95	1.41	1.00	0.14	0.21	0.29	0.21	0.81	1.19	1.60	1.20
S_{10}	0.44	0.70	1.03	0.73	0.09	0.14	0.20	0.14	0.61	0.90	1.24	0.92
Mean of levels	0.52	0.83	1.22		0.11	0.17	0.24		0.70	1.04	1.41	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.03	0.09			0.01	0.02			0.03	0.10
S			0.06	0.16			0.01	0.04			0.06	0.18
L × S			0.10	NS			0.03	NS			0.11	NS
NPK only	0.36				0.07				0.42			
NPK + FYM	0.64				0.14				0.81			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

was low in NPK treatments. While NPK + FYM recorded uptake of 0.64, 0.14 and K 0.81 g pot^{-1} of NPK, respectively and was on par with HA applied @ 30 kg ha^{-1}.

The uptake of nitrogen, phosphorus and potassium by capsicum was higher in S_7 (poultry manure): 1.04, 0.23 and 1.26 g pot^{-1}, respectively followed by S_3 (pressmud):1.01, 0.22 and 1.22 g pot^{-1}, respectively, S_2 (coffee pulp): 1.00, 0.21 and 1.21 g pot^{-1}, respectively and S_9 (urban compost): 1.00, 0.21 and 1.20 g pot^{-1}, respectively. However, significant difference was also found with other sources of humic acid viz., S_5 (distillery biocompost): 0.79, 0.15 and 0.97 g pot^{-1}, S_6 (sewage sludge): 0.77, 0.15 and 0.95 g pot^{-1}, S_8 (vermicompost): 0.77 and 0.15, 0.94 g pot^{-1}, S_1 (coco peat): 0.75, 0.15 and 0.93 g pot^{-1}, respectively, S_{10} (FYM):0.73, 0.14 and 0.92 g pot^{-1}, respectively. Lower uptake (0.7, 0.14, 0.88 g pot^{-1}, respectively) of major nutrient was in S_4 (biofuel waste) and was found to be significantly different with S_7 (poultry manure) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost) respectively.There was no significant interaction effect between different sources and levels of HA application.

The uptake of calcium, magnesium and sulphur by capsicum varied significantly due to different sources and levels of HA (Table 53).

The uptake of secondary nutrients by capsicum increased with increase in levels of HA application and significant difference was observed with different sources and levels of HA application.

Higher calcium (0.33 g pot^{-1}), magnesium (0.14 g pot^{-1}) and sulphur (0.36 g pot^{-1}) uptake by the capsicum was recorded with application of HA @ 90 kg ha^{-1} compared to lower Ca, mg, S uptake of 0.16, 0.07 and 0.26 g pot^{-1} with application of HA @ 30 kg ha^{-1}.

The NPK alone treatment recorded lower uptake compared to NPK + FYM recorded appreciably higher N P and K values and was on par with treatment receiving HA @ 30 kg ha^{-1}.

Higher uptake of Ca, Mg and S was recorded in S_7 (poultry manure) 0.30, 0.13 and 0.41 g pot^{-1}, respectively followed by Ca (0.29 g pot^{-1}), Mg (0.12 g pot^{-1}) and S (0.39 g pot^{-1}) in S_3 (pressmud), (0.28, 0.12 and 0.39 g pot^{-1}, respectively) of Ca, Mg and S in S_2 (coffee pulp) and 0.28 g pot^{-1} of Ca, 0.12 g pot^{-1} of mg and 0.38 g pot^{-1} of S in S_9 (urban compost). However lower uptake of Ca, Mg, S (0.20, 0.09 and 0.24 g pot^{-1}, respectively) was observed in S_4 (biofuel waste) when compared to other sources.

The data on uptake of iron, manganese and zinc by capsicum varied significantly due to different sources and levels of HA application (Table 54).

The uptake of Fe, Mn and Zn by capsicum was significantly higher with humic acid application @ 90 kg ha^{-1} compared to 60 and 30 kg ha^{-1}. Higher uptake of iron 29.34 mg pot^{-1}, manganese 8.78 mg pot^{-1} and zinc 3.84 mg pot^{-1} was recorded at 90 kg ha^{-1} and significantly different with application of HA @ 60 kg ha^{-1} and 30 kg ha^{-1} respectively

Table 53: Calcium, magnesium and sulphur uptake (g pot^{-1}) by capsicum (shoot + root) at harvest as influenced by different sources and levels of humic acid

Humic acid sources	Calcium				Magnesium				Sulphur			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.13	0.21	0.29	0.21	0.06	0.09	0.13	0.09	0.11	0.17	0.24	0.17
S_2	0.19	0.27	0.39	0.28	0.08	0.12	0.16	0.12	0.16	0.24	0.33	0.24
S_3	0.20	0.27	0.39	0.29	0.08	0.12	0.16	0.12	0.16	0.24	0.34	0.25
S_4	0.12	0.19	0.27	0.20	0.06	0.09	0.12	0.09	0.10	0.16	0.22	0.16
S_5	0.14	0.21	0.31	0.22	0.06	0.10	0.13	0.10	0.11	0.18	0.25	0.18
S_6	0.14	0.21	0.31	0.22	0.06	0.09	0.13	0.09	0.11	0.17	0.25	0.18
S_7	0.21	0.28	0.41	0.30	0.09	0.13	0.17	0.13	0.16	0.25	0.36	0.26
S_8	0.13	0.21	0.30	0.21	0.06	0.09	0.13	0.09	0.11	0.17	0.24	0.17
S_9	0.19	0.27	0.39	0.28	0.08	0.12	0.16	0.12	0.16	0.23	0.33	0.24
S_{10}	0.13	0.20	0.28	0.20	0.06	0.09	0.12	0.09	0.10	0.16	0.23	0.16
Mean of levels	0.16	0.23	0.33		0.07	0.10	0.14		0.13	0.20	0.28	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.009	0.025			0.003	0.010			0.01	0.03
S			0.016	0.046			0.006	0.018			0.02	0.05
L × S			0.03	NS			0.01	NS			0.03	NS
NPK only	0.10				0.04				0.08			
NPK + FYM	0.18				0.081				0.15			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 54: Iron, manganese and zinc uptake (mg pot^{-1}) by capsicum (shoot + root) at harvest as influence by different sources and levels of humic acid

Humic acid sources	Iron				Manganese				Zinc			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	13.42	19.40	26.13	19.65	3.69	5.52	7.83	5.68	1.70	2.48	3.40	2.53
S_2	17.32	24.76	33.05	25.04	4.89	7.34	10.00	7.41	2.26	3.26	4.39	3.31
S_3	17.25	25.31	33.01	25.19	4.89	7.56	9.96	7.47	2.26	3.35	4.39	3.33
S_4	13.12	19.24	25.47	19.28	3.58	5.47	7.48	5.51	1.63	2.41	3.18	2.41
S_5	14.00	20.41	28.12	20.85	3.84	5.82	8.26	5.97	1.77	2.66	3.69	2.71
S_6	13.58	20.12	27.21	20.30	3.76	5.87	8.11	5.92	1.73	2.62	3.55	2.63
S_7	17.69	25.80	34.44	25.98	5.01	7.61	10.35	7.66	2.32	3.39	4.55	3.42
S_8	13.69	20.28	26.36	20.11	3.73	5.78	7.89	5.80	1.73	2.61	3.48	2.61
S_9	17.16	24.43	32.87	24.82	4.86	7.25	9.97	7.36	2.25	3.23	4.38	3.29
S_{10}	13.21	19.50	26.77	19.83	3.59	5.55	7.92	5.69	1.67	2.48	3.43	2.53
Mean of levels	15.04	21.92	29.34		4.19	6.38	8.78		1.93	2.85	3.84	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.61	1.71			0.20	0.55			0.09	0.25
S			1.11	3.13			0.36	1.01			0.16	0.46
L × S			1.92	NS			0.62	NS			0.28	NS
NPK only	11.07				3.00				1.35			
NPK + FYM	17.39				5.06				2.37			

L= Level S= Source NS = Non significant

$S_{1=}$	Coco peat	$S_{6=}$	Sewage sludge
$S_{2=}$	Coffee pulp	$S_{7=}$	Poultry manure
$S_{3=}$	Pressmud	$S_{8=}$	Vermicompost
$S_{4=}$	Biofuel waste	$S_{9=}$	Urban compost
$S_{5=}$	Distillery biocompost	$S_{10=}$	Farmyard manure

with 21.02 and 15.04 mg pot^{-1} of iron, 6.38 and 4.19 mg pot^{-1} of manganese and 2.85 and 1.93 mg pot^{-1} of zinc. The pot which received NPK alone and NPK + FYM recorded uptake of Fe (11.07 and 17.39 mg pot^{-1}, respectively), Mn (3.00 and 5.06 mg pot^{-1}, respectively) and Zn (1.35 and 2.37 mg pot^{-1}, respectively) and was found on par with HA applied @ 30 kg ha^{-1}.

The uptake of Fe, Mn and Zn recorded significantly higher values with S_7 (poultry manure) at 25.98 mg pot^{-1}of Fe, 7.66 mg pot^{-1} of Mn and 3.42 mg pot^{-1} , respectively of Zn followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost). However lower uptake of Fe (19.28 mg pot^{-1}), Mn (5.51 mg pot^{-1}) and Zn (2.41 mg pot^{-1}) was recorded due to S_4 (biofuel waste). The interaction effect non significant between different sources and levels of HA application.

The uptake of copper and boron by capsicum varied significantly due to different sources and levels of HA application (Table 55).

Higher uptake of copper (1.18 mg pot^{-1}) and boron (0.67 mg pot^{-1}) by capsicum, respectively was observed with higher level of HA application @ 90 kg ha^{-1}. Lower content of copper and boron was recorded due to HA application @ 30 kg ha^{-1}. With respect to application of NPK + FYM the uptake of copper has 0.69 mg pot^{-1} and boron 0.4 mg pot^{-1} and was on par with application of HA @ 30 kg ha^{-1}

Among the different humic acid sources, significantly higher uptake of copper and boron was recorded in S_7 poultry manure (1.07 and 0.60 mg pot^{-1}, respectively), followed by S_3 pressmud (1.04 and 0.58 mg pot^{-1}), S_2 coffee pulp (1.02 and 0.58 mg pot^{-1}, respectively) and S_9 (urban compost 1.02 and 0.58 mg pot^{-1}, respectively). With respect to other sources distillery biocompost (S_5), sewage sludge (S_6), vermicompost (S_8), coco peat (S_1), FYM (S_{10}) and biofuel waste (S_4) differed significantly compared to S_7 (poultry manure), S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost).

Application of humic acid has influenced the plant growth directly through ion uptake and provision of growth regulators. A considerable increase in the nutrient content and uptake of nitrogen was observed by (Satish Kumar, 1997) and (Thenmozhi, 2001). Organic substances increase the activity of microorganisms capable of producing urease activity (Balasubramanian *et al.*, 1972). Urease activity was highest under combined application of urea and organic materials (Zantua and Bremner, 1975). Hence, the application of both urea and HA in the present study might have induced urease activity and persistence of the same in the soils by inhibiting the rapid hydrolysis of urea to ammonium carbonate. Increase in the content and uptake of P with increasing levels of HA application was supported by Mishra and Srivastava (1988). Humic acid influenced the root growth which inturn helped in better assimilation of P. The other reasons for increased P availability was due to reduced fixation of P as reported by Hashimoto (1965) and also due to the formation of humophosphate complexes (Logvinova, 1939) which increased the P uptake by capsicum. The increase in K uptake with HA application could be related to the influence of HA on the release of fixed K from clay minerals to soil

Table 55: Copper and boron uptake (mg pot^{-1}) by capsicum (shoot + root) at harvest as influenced by different sources and levels of humic acid

Humic acid sources	Copper				Boron			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	0.50	0.75	1.02	0.76	0.27	0.41	0.57	0.42
S_2	0.68	1.01	1.38	1.02	0.39	0.57	0.78	0.58
S_3	0.69	1.05	1.38	1.04	0.39	0.58	0.78	0.58
S_4	0.48	0.72	0.96	0.72	0.27	0.41	0.56	0.41
S_5	0.52	0.79	1.11	0.81	0.29	0.45	0.63	0.46
S_6	0.51	0.79	1.07	0.79	0.28	0.45	0.60	0.44
S_7	0.70	1.07	1.43	1.07	0.40	0.59	0.81	0.60
S_8	0.51	0.79	1.05	0.78	0.28	0.44	0.59	0.43
S_9	0.68	1.00	1.38	1.02	0.39	0.57	0.78	0.58
S_{10}	0.49	0.73	1.04	0.76	0.26	0.41	0.59	0.42
Mean of levels	0.58	0.87	1.18		0.32	0.49	0.67	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.032	0.09			0.018	0.05
S			0.058	0.16			0.033	0.09
L × S			0.100	NS			0.056	NS
NPK only	0.38				0.22			
NPK + FYM	0.69				0.40			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

labile pool (Tan, 1978). According to Samson and Viser (1989) application of humic acid increased the permeability of bio membranes for electrolytes and thereby accounted for increased K uptake. The significant increase in the Ca, Mg and S uptake in present study may be attributed to application of humic acid which helps in formation of complex compound with Ca and Mg which plays a major role in the transport of these nutrients to the tissue and thereby promotes plant growth (Tisdale *et al.*, 1997).

There was significant response to the addition of humic acid in enhancing micronutrients content and uptake by capsicum with respect to both levels and sources. The increase in the content and uptake of micronutrients might be due to increased root activity. In addition, the formation of soluble humus chelates in soil favoured increased micronutrients uptake (Fortun and Polo, 1982). Nikbakht *et al.* (2008) reported that humic acid significantly improved macro (N, P, K, Ca and Mg) and micro (Mn, Fe and Zn) nutrients contents of leaves in gerbera (*Gerbera jamesonii* L.) plants.

4.4.5 Effect of different sources and levels of humic acid application on properties of soil after harvest of capsicum

The data on the changes in pH, EC, OC and CEC of soil after harvest of capsicum has been presented in Table 56.

There was no significant difference in soil pH after harvest of capsicum, however there was slight increase in pH of soil at different levels of humic acid application compared to initial value (6.61). Application of humic acid @ 90 kg ha^{-1} resulted in increase in pH (6.74) while with application of humic acid @ 30 kg ha^{-1} the pH was 6.70. With respect to NPK alone, there was decrease in pH (6.52) compared to initial value (6.61). There was slight increase in pH of soil in the treatment receiving RDF + FYM. The interaction effect found between different sources and levels of humic acid application was non-significant. Among different sources of humic acid the rise in pH was high in S_7 (poultry manure: 6.75) followed by (S_3: 6.73) and (S_2: 6.72).

The data on electrical conductivity of soil with application of graded levels and sources of HA showed slight increase in electrical conductivity over the initial value of 0.49 dS m^{-1} and was found to be non significant with levels and sources of humic and application. There was slight increase in pH and EC of soil due to application of HA compared to initial values which might be due to their buffering action where in HA helps to resist the change in pH and also due to deactivation of Fe^{3+} and Al^{3+} through chelating agent and subsequent release of basic cation upon its decomposition (Suresh Lal and Mathur, 1989) and accumulation of salts added through organic material.

The organic carbon content of soil differed significantly due to graded levels of humic acid application over the initial organic carbon content of 0.81 percent. Higher organic carbon content (0.91 %) was recorded with application of humic acid @ 90 kg ha^{-1} and lower value (0.87 %) was with humic acid application @ 30 kg ha^{-1}. In NPK alone treatment there was reduction in organic carbon content (0.79 %) of soil over the initial value (0.81 %) whereas in NPK + FYM treatment it was higher (0.90 %). Increase in organic carbon content of soil maybe due to the fact that humic acid being an

Table 56: Effect of different sources and levels of humic acid on pH, EC, OC and CEC of soil after harvest of capsicum

Humic acid sources	pH (1:2.5)				EC (dS m^{-1}) (1:2.5)				OC (%)				CEC (cmol (p^+) kg^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	6.69	6.71	6.72	6.71	0.52	0.53	0.53	0.53	0.88	0.91	0.94	0.91	15.51	15.74	16.05	15.77
S_2	6.71	6.72	6.74	6.72	0.53	0.54	0.54	0.54	0.88	0.91	0.92	0.90	15.90	16.15	16.47	16.17
S_3	6.72	6.73	6.74	6.73	0.52	0.53	0.54	0.53	0.85	0.89	0.91	0.89	15.91	16.19	16.51	16.20
S_4	6.68	6.70	6.72	6.70	0.51	0.52	0.55	0.53	0.90	0.93	0.96	0.93	15.40	15.59	15.99	15.66
S_5	6.70	6.71	6.72	6.71	0.54	0.56	0.56	0.55	0.88	0.89	0.92	0.90	15.59	15.84	16.11	15.85
S_6	6.70	6.71	6.73	6.71	0.53	0.54	0.55	0.54	0.85	0.85	0.89	0.86	15.54	15.78	16.06	15.79
S_7	6.73	6.76	6.78	6.75	0.53	0.54	0.56	0.54	0.86	0.89	0.91	0.88	16.10	16.38	16.68	16.39
S_8	6.68	6.72	6.74	6.72	0.52	0.53	0.54	0.53	0.85	0.86	0.88	0.86	15.53	15.77	16.17	15.82
S_9	6.70	6.72	6.76	6.73	0.53	0.55	0.56	0.55	0.86	0.89	0.90	0.88	15.88	16.13	16.41	16.14
S_{10}	6.68	6.70	6.71	6.70	0.51	0.52	0.53	0.52	0.85	0.87	0.87	0.86	15.50	15.72	16.19	15.81
Mean of levels	6.70	6.72	6.74		0.53	0.54	0.55		0.87	0.89	0.91		15.69	15.93	16.26	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.02	NS			0.007	NS			0.005	0.015			0.05	0.15
S			0.03	NS			0.013	NS			0.010	0.027			0.09	0.27
L × S			0.06	NS			0.022	NS			0.016	NS			0.16	NS
NPK only	6.52				0.52				0.79				14.46			
NPK + FYM	6.70				0.53				0.90				16.13			
Initial	**6.61**				**0.49**				**0.81**				**14.8**			

L= Level S= Source NS = Non significant

$S_{1=}$ Coco peat
$S_{2=}$ Coffee pulp
$S_{3=}$ Pressmud
$S_{4=}$ Biofuel waste
$S_{5=}$ Distillery biocompost
$S_{6=}$ Sewage sludge
$S_{7=}$ Poultry manure
$S_{8=}$ Vermicompost
$S_{9=}$ Urban compost
$S_{10=}$ Farmyard manure

organically rich material along with recommended dose of fertilizer resulted increasing the organic carbon content which might be due to higher microbial activity (Deepa, 2001).

Among different sources of humic acid, application of humic acid extracted from S_4 (biofuel waste) resulted in significant increase in the organic carbon (0.93 %) content of soil followed by S_1 (coco peat), S_2 (coffee pulp) S_3 (pressmud) and S_7 (poultry manure) with OC values of 0.91, 0.90, 0.89 and 0.88 per cent, respectively. However the interaction effect was non-significant between different sources and levels of humic acid application.

The cation exchange capacity of soil increased significantly with increasing levels of humic acid application compared to initial value (14.8 cmol (p^+) kg^{-1}).

Higher cation exchange capacity value (16.26 cmol (p+) kg^{-1}) was recorded with application of HA @ 90 kg ha^{-1}. While it was lower (15.69 cmol (p+) kg^{-1}) with application of HA @ 30 kg ha^{-1}. With respect to application of NPK alone there was decrease in cation exchange capacity of soil (14.46 cmol (p+) kg^{-1}) over initial value (14.8). The treatment NPK + FYM recorded higher value (18.85 cmol (p+) kg^{-1}) and was on par with application of HA @ 30 kg ha^{-1}.

Among different sources of HA, application of HA extracted from poultry manure (S_7) resulted in significant increase in CEC value of 16.39 cmol (p+) kg^{-1} followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost). However addition of humic acid extracted from distillery biocompost (S_5), sewage sludge (S_6), vermicompost (S_8), coco peat (S_1) FYM (S_{10}) and biofuel waste (S_4) differed significantly compared to addition of HA from S_7 (poultry manure), S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost). The CEC increased with increasing levels of HA application. The functional group present in humic acid influenced negative charge and thereby contributed to the CEC of the soil.

The data on available major nutrients viz., nitrogen, phosphorus and potassium content of soil after harvest of capsicum are presented in Table 57 and Fig. 8, 9 and 10.

The data on available nitrogen content of soil after the harvest of capsicum showed significant increase with graded levels of HA application over initial content of (293.68 kg ha^{-1}).

Higher available nitrogen content of 319.75 kg ha^{-1} and lower nitrogen content 308.89 kg ha^{-1} was recorded with application of HA @ 90 and 30 kg ha^{-1} respectively. Application of NPK alone resulted in decrease in N content (282.23 kg ha^{-1}) while NPK + FYM recorded slightly higher N content (319.97 kg ha^{-1}).

The application of humic acid from different sources viz., poultry manure (S_7) recorded higher N status (324.34 kg ha^{-1}) followed by 322.13 kg ha^{-1} in S_3 (pressmud), 321.11 kg ha^{-1} in S_2 (coffee pulp) and 320.72 kg ha^{-1} in S_9 (urban compost) while

Table 57: Effect of different sources and levels of humic acid on available nitrogen, phosphorus and potassium content of soil after harvest of capsicum

Humic acid sources	Available-N (kg ha^{-1})				Available-P_2O_5 (kg ha^{-1})				Available-K_2O (kg ha^{-1})			
	L_1 30	L_2 60	L_3 90 (kg ha^{-1})	Mean of sources	L_1 30	L_2 60	L_3 90 (kg ha^{-1})	Mean of sources	L_1 30	L_2 60	L_3 90 (kg ha^{-1})	Mean of sources
S_1	304.47	309.87	314.49	309.61	93.95	96.87	103.36	98.06	291.32	296.34	301.49	296.38
S_2	315.33	321.17	326.83	321.11	99.52	103.86	111.64	105.01	301.83	306.07	311.24	306.38
S_3	316.17	322.13	328.08	322.13	99.75	104.45	112.48	105.56	302.84	306.77	312.15	307.25
S_4	302.40	307.53	310.54	306.82	92.84	94.43	101.73	96.33	289.52	294.15	300.07	294.58
S_5	306.23	311.47	317.13	311.61	94.75	99.27	106.32	100.11	292.60	297.57	302.67	297.61
S_6	304.87	310.00	315.87	310.24	94.17	98.37	105.18	99.24	291.68	296.97	301.41	296.69
S_7	318.47	324.47	330.08	324.34	99.97	105.30	114.49	106.59	303.78	307.84	313.27	308.30
S_8	303.73	309.42	314.45	309.20	94.20	97.95	104.36	98.84	291.42	297.12	300.71	296.42
S_9	314.97	320.77	326.42	320.72	99.23	103.74	111.17	104.72	300.46	305.63	311.17	305.75
S_{10}	302.23	307.90	313.58	307.91	93.07	95.90	102.40	97.12	290.01	294.86	300.23	295.03
Mean of levels	308.89	314.47	319.75		96.14	100.01	107.31		295.55	300.33	305.44	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			1.46	4.14			0.84	2.39			1.27	3.59
S			2.67	7.55			1.54	4.36			2.32	6.56
L × S			4.62	NS			2.67	NS			4.01	NS
NPK only	282.23				88.53				279.53			
NPK + FYM	319.97				102.30				299.99			
Initial	**293.68**				**91.53**				**284.70**			

L= Level S= Source NS = Non significant

S_1 = Coco peat
S_2 = Coffee pulp
S_3 = Pressmud
S_4 = Biofuel waste
S_5 = Distillery biocompost
S_6 = Sewage sludge
S_7 = Poultry manure
S_8 = Vermicompost
S_9 = Urban compost
S_{10} = Farmyard manure

lower nitrogen status (306.82 kg ha^{-1}) was in S_4 (biofuel waste). The interaction effect was non significant between different sources and levels of HA application.

The available phosphorus content of soil varied significantly due to graded levels of HA application. Higher phosphorus content of 107.31 kg ha^{-1} was recorded with application of HA @ 90 kg^{-1}. A significant difference was observed among different levels @ 30, 60 and 90 kg ha^{-1}.

Humic acid extracted from S_7 (poultry manure) showed significant increase in available phosphorus content (106.59 kg ha^{-1}) of soil followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost). The other sources S_5 (distillery biocompost), S_6 (sewage sludge), S_8 (vermicompost), S_1 (coco peat), S_{10} (FYM) and S_4 (biofuel waste) showed significant difference compared to S_7 (poultry manure), S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost).

The available potassium content of soil varied significantly due to increase in graded levels of HA application. Higher potassium content (305.44 kg ha^{-1}) was recorded with HA application @ 90 kg ha^{-1} while lower potassium content (295.55 kg ha^{-1}) was recorded with HA application @ 30 kg ha^{-1}. Application of NPK alone resulted in decrease in the available K content (279.53 kg $ha^{-1)}$ of soil compared to initial value of 284.70 kg ha^{-1}. However NPK + FYM treatment showed an increase over initial value and was 299.99 kg ha^{-1}.

The effect of different sources of HA application showed similar trend as that of nitrogen and phosphorus with higher potassium status of 308.30 kg ha^{-1} recorded with S_7 (poultry manure) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost) and the values were 307.25, 306.38 and 305.75 kg ha^{-1}, respectively while application of HA extracted from others sources showed significant difference in the potassium content of soil but the values recorded were much lower.

The increase in the available major nutrients status of soil may be attributed to the solubilising effect caused by humic acid coupled with the release from exchangeable sites by other cations (Khan *et al.,* 1997).The increase in the available N status of soil due to humic acid application may be due to increased microbial activity and release of nutrients through interaction of humic acid with soil particles. The high available P content in humic acid applied soils was due to the tendency of metal humate to extract more native sources leading to increased availability of P in the soil (Mary *et al*., 2002). Humic acid stimulates fixation and release of K in soils by dissolving the K-bearing minerals or blocking interlayers and helps in reducing fixation of potassium.

Changes in available secondary nutrients content of soil viz., exchangeable calcium, magnesium and available sulphur content of soil after harvest of capsicum is presented in Table 58.

The exchangeable Ca, Mg and available S status of soil after harvest of capsicum indicated significant increase with increase in the levels of HA application over initial

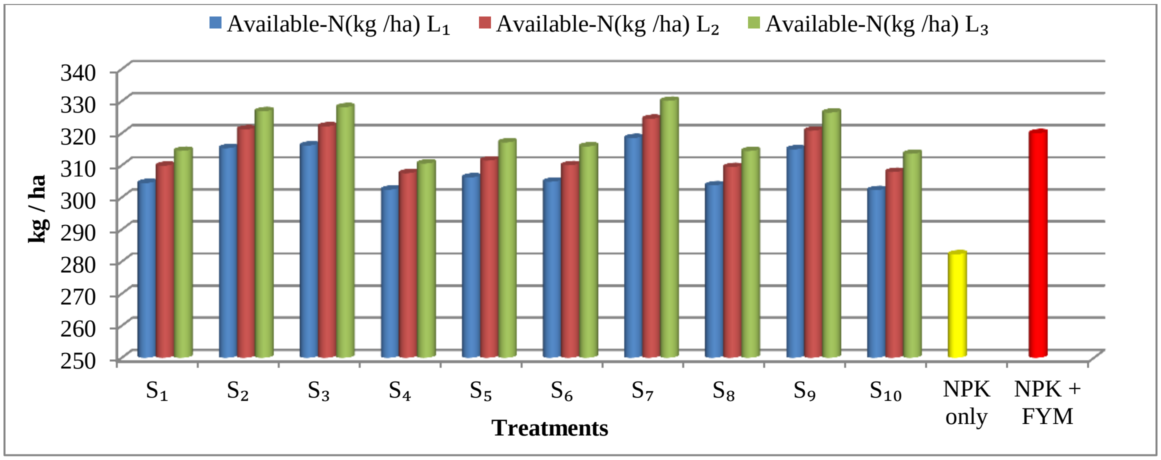

Fig. 8: Available nitrogen content of soil after harvest of capsicum as influenced by different sources and levels of humic acid

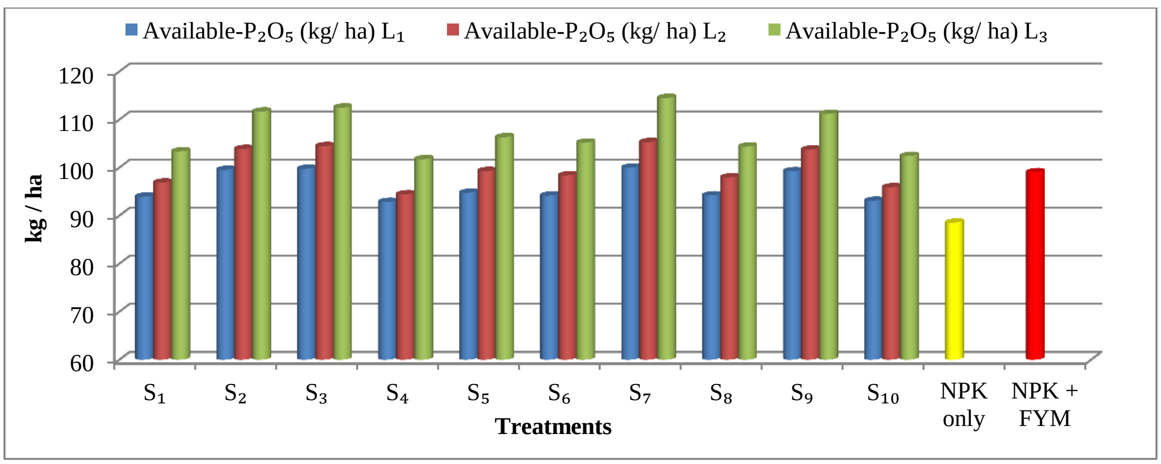

Fig. 9: Available phosphorus content of soil after harvest of capsicum as influenced by different sources and levels of humic acid

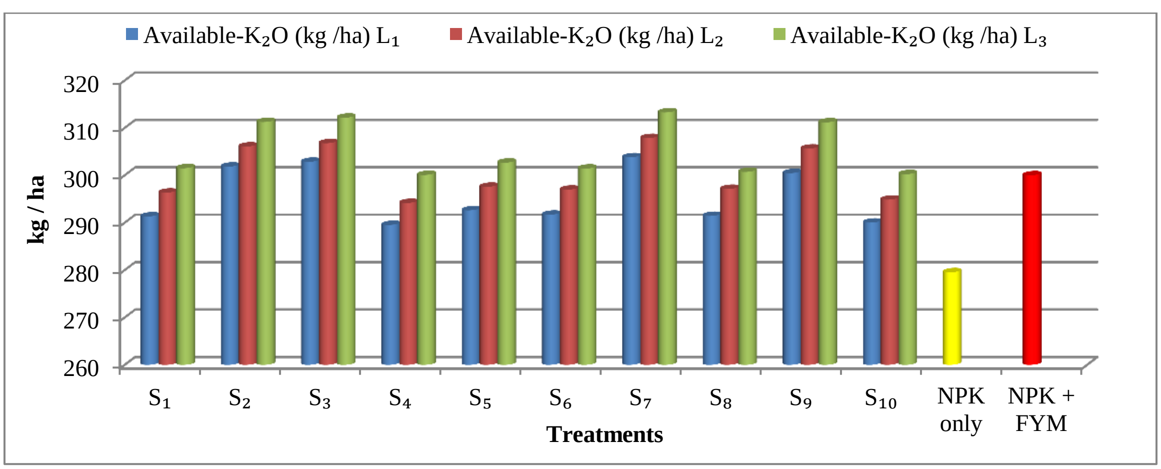

Fig. 10: Available potassium content of soil after harvest of capsicum as influenced by different sources and levels of humic acid

Table 58: Effect of different sources and levels of humic acid on exchangeable calcium, magnesium and available sulphur content of soil after harvest of capsicum

Humic acid sources	Exch. Ca [c mol (p+) kg^{-1}]				Exch. Mg [c mol (p+) kg^{-1}]				Avail-S (mg kg^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	6.04	6.10	6.14	6.09	2.42	2.47	2.49	2.46	18.32	18.88	19.40	18.87
S_2	6.17	6.24	6.30	6.23	2.48	2.54	2.58	2.53	19.28	20.08	20.77	20.04
S_3	6.18	6.25	6.32	6.25	2.49	2.54	2.59	2.54	19.34	20.17	20.92	20.15
S_4	6.03	6.08	6.11	6.07	2.41	2.45	2.47	2.44	18.29	18.82	19.28	18.80
S_5	6.06	6.13	6.19	6.13	2.42	2.48	2.50	2.47	18.35	18.93	19.53	18.93
S_6	6.05	6.12	6.17	6.11	2.43	2.50	2.52	2.48	18.42	19.11	19.66	19.06
S_7	6.20	6.26	6.35	6.27	2.50	2.55	2.60	2.55	19.80	20.33	21.02	20.38
S_8	6.04	6.11	6.15	6.10	2.42	2.47	2.50	2.46	18.37	19.04	19.53	18.98
S_9	6.17	6.23	6.29	6.23	2.48	2.54	2.58	2.53	19.21	20.03	20.56	19.93
S_{10}	6.03	6.09	6.13	6.08	2.42	2.46	2.47	2.45	18.36	18.92	19.26	18.85
Mean of levels	6.09	6.16	6.22		2.44	2.50	2.53		18.77	19.43	19.99	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.017	0.048			0.008	0.024			0.14	0.39
S			0.031	0.087			0.015	0.044			0.25	0.71
L × S			0.05	NS			0.03	NS			0.43	NS
NPK only	5.85				2.34				15.91			
NPK + FYM	6.15				2.48				18.85			
Initial	**5.98**				**2.36**				**16.29**			

L= Level   S= Source   NS = Non significant

$S_{1=}$ Coco peat $S_{6=}$ Sewage sludge
$S_{2=}$ Coffee pulp $S_{7=}$ Poultry manure
$S_{3=}$ Pressmud $S_{8=}$ Vermicompost
$S_{4=}$ Biofuel waste $S_{9=}$ Urban compost
$S_{5=}$ Distillery biocompost $S_{10=}$ Farmyard manure

values. Application of HA @ 90 kg ha^{-1} recorded higher Ca, Mg and available S content of 6.22 cmol (p+) kg^{-1}, 2.53 cmol (p+) kg^{-1} and 19.99 mg kg^{-1}, respectively and was found to be significantly higher compared to humic acid application of 60 and 30 kg ha^{-1}. With respect to NPK alone, there was decrease in Ca (5.85 cmol (p+) kg^{-1}), Mg (2.34 cmol (p+) kg^{-1}) and S (15.91 mg kg^{-1}) , respectively) over initial value of 5.98 cmol (p+) kg^{-1}), 2.36 cmol (p+) kg^{-1} and 16.29 mg kg^{-1} of Ca, Mg and S, respectively.

Among different sources of HA application, S_7 (poultry manure) showed significantly higher exchangeable Ca (6.27 cmol (p+) kg^{-1}), exchangeable Mg (2.55 cmol (p+) kg^{-1}) and available sulphur (20.38 mg kg^{-1}), followed by S_3 (pressmud) S_2 (coffee pulp) and S_9 (urban compost). Lower exchangeable Ca (6.07 cmol (p+) kg^{-1}), exchangeable mg (2.44 cmol (p+) kg^{-1}) and available S (18.80 mg kg^{-1}) was in S_4 (biofuel waste).

Humic acid affects plant growth both through direct and indirect action, the indirect effects comprised of organic matter mineralisation, hormonal activity, transport and availability of micro and some macro nutrients as reported by (Saruhan *et al*., 2011).

The data on DTPA extractable iron, manganese and zinc content of soil after harvest of capsicum is been presented in Table 59 and DTPA extractable copper and hot water extractable boron is presented in Table 60.

There was significant increase in iron, manganese, zinc, copper and boron content of soil due to various levels and sources of HA application over initial values.

Application of HA @ 90 kg ha^{-1} recorded significantly higher Fe (16.36 mg kg^{-1}), Mn (28.79 mg kg^{-1}), Cu (2.89 mg kg^{-1}), Zn (1.69 mg kg^{-1}), and boron (0.57 mg kg^{-1}) compared to 60 and 30 kg ha^{-1} with 15.74 and 15.21 mg kg^{-1} , respectively of Fe, 27.98 and 27.26 mg kg^{-1}, respectively of Mn, 1.59 and 1.51 mg kg^{-1}, respectively of Zn, 2.79 and 2.72 mg kg^{-1} , respectively of Cu and 0.54 and 0.52 mg kg^{-1}, respectively of boron. Application of NPK alone recorded lower values (12.57 mg kg^{-1} Fe), (23.26 mg kg^{-1} Mn), (1.26 mg kg^{-1} of Zn), (2.30 mg kg^{-1} of Cu) and (0.44 mg kg^{-1} of B) and pots which received with NPK + FYM recorded increase in Fe (15.27 mg kg^{-1}), Mn (28.47 mg kg^{-1}), Zn (1.62 mg kg^{-1}), Cu (2.82 mg kg^{-1}) and B (0.52 mg kg^{-1}) over initial value.

Significant difference was found with respect to micronutrients content of soil due to sources and recorded higher content in S_7 (poultry manure) 16.57 mg kg^{-1} of Fe, 29.54 mg kg^{-1} of Mn, 1.76 mg kg^{-1} of Zn, 2.94 mg kg^{-1} of Cu and 0.59 mg kg^{-1} of B followed by S_3 (pressmud), S_2 (coffee pulp), and S_9 (urban compost). While application of HA extracted from other sources recorded significantly lower values of micronutrients over S_7 (poultry manure), S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost).

The results of the present study revealed an increase in the available micronutrients status of soil due to levels and sources of humic acid application. This may be due to the ability of humic substances to chelate compounds and these micronutrients which chelated with humic substances were released to soil when required

Table 59: Effect of different sources and levels of humic acid on DTPA extractable iron, manganese and zinc content of soil after harvest of capsicum

Humic acid sources	DTPA-Fe (mg kg^{-1})				DTPA-Mn (mg kg^{-1})				DTPA-Zn (mg kg^{-1})			
	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources	L_1 30	L_2 60	L_3 90	Mean of sources
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	14.84	15.29	15.87	15.33	26.38	27.19	27.93	27.17	1.44	1.50	1.60	1.51
S_2	15.61	16.27	16.99	16.29	28.31	28.92	29.91	29.05	1.62	1.71	1.82	1.72
S_3	15.67	16.34	17.12	16.37	28.41	29.04	30.13	29.20	1.63	1.72	1.84	1.73
S_4	14.81	15.25	15.77	15.28	26.33	27.11	27.76	27.07	1.38	1.46	1.55	1.46
S_5	14.86	15.33	15.97	15.39	26.42	27.25	28.12	27.26	1.44	1.52	1.61	1.52
S_6	14.92	15.48	16.08	15.49	26.52	27.51	28.30	27.45	1.45	1.54	1.65	1.55
S_7	16.04	16.46	17.19	16.57	29.08	29.27	30.26	29.54	1.66	1.75	1.86	1.76
S_8	14.88	15.43	15.97	15.43	26.45	27.42	28.12	27.33	1.44	1.51	1.63	1.52
S_9	15.56	16.22	16.82	16.20	28.22	28.84	29.61	28.89	1.61	1.71	1.80	1.71
S_{10}	14.87	15.32	15.76	15.32	26.44	27.24	27.73	27.14	1.40	1.49	1.54	1.47
Mean of levels	15.21	15.74	16.36		27.26	27.98	28.79		1.51	1.59	1.69	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.11	0.32			0.22	0.61			0.025	0.07
S			0.20	0.58			0.40	1.12			0.046	0.13
L × S			0.35	NS			0.69	NS			0.080	NS
NPK only	12.57				23.26					1.26		
NPK + FYM	15.27				28.47					1.62		
Initial	**13.55**				**25.02**				**1.33**			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

Table 60: Effect of different sources and levels of humic acid on copper and boron content of soil after harvest of capsicum

Humic acid sources	DTPA-Cu (mg kg^{-1})				Hot water-B (mg kg^{-1})			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	2.65	2.72	2.80	2.72	0.50	0.52	0.54	0.52
S_2	2.80	2.86	3.00	2.89	0.54	0.56	0.60	0.57
S_3	2.81	2.88	3.03	2.90	0.54	0.57	0.60	0.57
S_4	2.63	2.71	2.79	2.71	0.50	0.52	0.55	0.52
S_5	2.66	2.73	2.82	2.73	0.51	0.52	0.53	0.52
S_6	2.67	2.75	2.84	2.75	0.51	0.53	0.55	0.53
S_7	2.88	2.90	3.04	2.94	0.55	0.58	0.63	0.59
S_8	2.65	2.74	2.82	2.74	0.50	0.52	0.54	0.52
S_9	2.79	2.86	3.00	2.88	0.54	0.56	0.60	0.57
S_{10}	2.64	2.72	2.78	2.72	0.50	0.53	0.54	0.53
Mean of levels	2.72	2.79	2.89		0.52	0.54	0.57	
			S.Em.±	CD (p=0.05)			S.Em.±	CD (p=0.05)
L			0.02	0.06			0.006	0.017
S			0.04	0.10			0.011	0.031
L × S			0.06	NS			0.019	NS
NPK only	2.30				0.44			
NPK + FYM	2.82				0.52			
Initial	**2.59**				**0.46**			

L= Level S= Source NS = Non significant

S_1= Coco peat
S_2= Coffee pulp
S_3= Pressmud
S_4= Biofuel waste
S_5= Distillery biocompost
S_6= Sewage sludge
S_7= Poultry manure
S_8= Vermicompost
S_9= Urban compost
S_{10}= Farmyard manure

by plants. Sharif *et al*. (2006) reported that there was increase in buildup of micronutrients (zinc, iron, manganese, and copper) concentrations after harvest of capsicum and their accumulations by capsicum plants increased significantly over control with the application of HA.

From the results of the pot experiment conducted with maize as a test crop it was found that application of HA @ 90 kg ha^{-1} resulted in higher biomass yield and nutrient uptake and was on par with application of HA @ 60 kg ha^{-1}.

Similarly, in case of capsicum application of HA @ 90 kg ha^{-1} was found to be superior and resulted in higher biomass yield and nutrient uptake. With respect to sources of HA, poultry manure was superior followed by HA of pressmud and coffee pulp. Thus, HA extracted from three different sources viz., poultry manure, pressmud, coffee pulp at two levels 60 and 90 kg ha^{-1} were evaluated in a field experiment with capsicum as the test crop.

4.5 Field experiment I

A field experiment was conducted to evaluate the efficiency of selected best sources and levels of HA as determined from pot experiment. The field experiment was conducted to study the growth, yield of capsicum and changes in soil properties (Plate 5).

The experiment was carried out in a farmer's field at Harohalli village, Devanahalli taluk during k*harif 2015*. The soil of the experiment plot was sandy clay loam in texture (Table 61). The sand content was (61.90 %), the bulk density 1.42 Mg m^{-3}. The maximum water capacity was 36.5 per cent. With respect to chemical properties, the soil was slightly acidic in reaction pH (6.72) with low electrical conductivity (0.55 dS m^{-1}). The organic carbon content was high (0.78 %). Among major nutrients, available nitrogen was medium (301.8 kg ha^{-1}), available phosphorus was high (108.10 kg ha^{-1}) and potassium medium (294.30 kg ha^{-1}). Among secondary nutrients the exchangeable Ca and Mg were sufficient recording of 5.70 cmol (p+) kg^{-1}, 2.05 cmol (p+) kg^{-1} and available sulphur of soil was medium (12.34 mg kg^{-1}). The DTPA extractable micronutrients (Fe, Mn, Zn and Cu) were higher (12.47, 33.22, 2.92 and 4.76 mg kg^{-1}, respectively). The hot water soluble boron content of soil was 0.58 mg kg^{-1}.The cation exchange capacity was 13.20 cmol (p+) kg^{-1}.

4.5.1 Growth parameters of capsicum

The data on plant height, number of branches plant^{-1} and SPAD meter reading (chlorophyll content) of capsicum as influenced by different sources and levels of humic acid application at different growth stages (30, 60, 90, 120, DAP and at harvest) are presented in Table 62 and Plate 6.

At different growth stages plant height, number of branches plant^{-1} and chlorophyll (SPAD meter reading) content differed significantly with HA application @ 60 and 90 kg ha^{-1}. Higher plant height (109.81 cm), number of branches (14.19) and SPAD meter reading (41.83) was recorded at harvest with HA application @ 90 kg ha^{-1}

Table 61: Initial properties of soil of experimental plot collected from farmer's field

Parameters		Contents
Physical properties		
Particle size distribution	Sand (%)	61.90
	Silt (%)	10.98
	Clay (%)	27.01
	Texture	Sandy clay loam
Bulk density (Mg m^{-3})		1.42
Maximum water holding capacity (%)		36.5
Chemical properties		
pH (1:2.5)		6.72
EC (dS m^{-1}) (1:2.5)		0.55
OC (%)		0.78
CEC (cmol (p+) kg^{-1})		13.20
Available nitrogen (kg ha^{-1})		301.8
Available phosphorus (kg ha^{-1})		108.10
Available potassium (kg ha^{-1})		294.30
Exchangeable calcium (cmol (p+) kg^{-1})		5.70
Exchangeable magnesium (cmol (p+) kg^{-1})		2.05
Available sulphur (mg kg^{-1})		12.34
Exchangeable sodium (cmol (p+) kg^{-1})		0.42
DTPA-iron (mg kg^{-1})		12.47
DTPA-manganese (mg kg^{-1})		33.22
DTPA-copper (mg kg^{-1})		4.76
DTPA-zinc (mg kg^{-1})		2.92
Boron (mg kg^{-1})		0.58

Plate 5: General view of field experiment I

Table 62: Plant height, number of branches and SPAD meter reading of capsicum at different intervals as influenced by sources and levels of humic acid

	Plant Height (cm)					No. of Branches					SPAD meter reading				
	30 DAP	60 DAP	90 DAP	120 DAP	At harvest	30 DAP	60 DAP	90 DAP	120 DAP	At harvest	30 DAP	60 DAP	90 DAP	120 DAP	At harvest
Levels (L)															
L_1	34.10	58.79	87.45	103.57	105.82	4.94	9.95	10.96	12.85	13.23	26.81	39.82	43.98	46.72	38.57
L_2	38.18	64.41	92.22	108.02	109.81	5.23	10.42	12.03	14.09	14.19	27.97	41.83	47.45	49.44	41.83
S.Em.±	0.66	0.73	0.79	0.78	0.66	0.04	0.08	0.08	0.11	0.09	0.24	0.33	0.54	0.51	0.41
CD (p=0.05)	2.07	2.31	2.50	2.44	2.09	0.13	0.25	0.26	0.34	0.28	0.75	1.05	1.71	1.60	1.31
Sources (S)															
S_1	35.80	60.98	89.00	105.18	107.06	5.05	10.09	11.38	13.27	13.63	26.88	40.37	45.48	47.54	39.73
S_2	36.17	61.50	89.64	105.67	107.26	5.09	10.19	11.52	13.45	13.69	27.50	40.75	45.62	47.76	40.15
S_3	36.45	62.32	90.88	106.55	109.11	5.12	10.29	11.57	13.69	13.82	27.79	41.35	46.04	48.92	40.71
S.Em.±	0.81	0.90	0.97	0.95	0.81	0.05	0.10	0.10	0.13	0.11	0.29	0.41	0.66	0.62	0.51
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment combinations with control															
T_1	27.16	45.28	76.70	85.70	87.67	3.49	6.97	8.05	9.39	9.65	21.27	29.21	34.27	37.97	34.91
T_2	30.35	51.07	81.64	97.43	98.23	4.26	8.53	10.07	11.80	12.13	24.22	34.12	40.41	43.78	36.70
T_3	33.91	58.35	86.62	103.16	105.07	4.91	9.82	10.92	12.73	13.12	26.39	39.29	43.79	46.26	38.17
T_4	37.68	63.60	91.37	107.19	109.06	5.18	10.36	11.84	13.82	14.14	27.37	41.45	47.18	48.82	41.29
T_5	34.11	58.69	87.15	103.63	105.51	4.98	9.96	10.95	12.77	13.18	26.98	39.82	43.93	46.52	38.30
T_6	38.23	64.30	92.12	107.71	109.01	5.21	10.42	12.09	14.14	14.20	28.02	41.68	47.31	49.01	41.99
T_7	34.29	59.31	88.57	103.92	106.88	4.94	10.08	11.00	13.07	13.40	27.06	40.33	44.22	47.37	39.22
T_8	38.61	65.33	93.18	109.17	111.35	5.30	10.49	12.14	14.24	14.32	28.51	42.36	47.86	50.48	42.20
S.Em.±	1.12	1.09	1.42	1.21	1.01	0.07	0.14	0.26	0.26	0.30	0.43	0.58	0.92	0.78	0.71
CD (p=0.05)	3.41	3.29	4.32	3.68	3.06	0.21	0.43	0.80	0.80	0.92	1.29	1.76	2.79	2.36	2.16

L_1=60 kg Humic acid, L_2=90 Kg Humic acid: $S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure DAP- Days after planting NS = Non significant

$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

and lower plant height (34.10 cm), number of branches (4.94) and SPAD meter reading (26.81) was recorded at 30 DAP of capsicum.

Among different sources of HA viz., S_1 (coffee pulp), S_2 (pressmud) and S_3 (poultry manure) the plant height, number of branches plant^{-1} and SPAD meter reading did not differ significantly.

Among different treatment combinations in comparison with control, the plant height, number of branches and chlorophyll (SPAD meter reading) content differed significantly. Higher plant height (111.35 cm), number of branches (14.32) at harvest and chlorophyll (SPAD meter reading) content (50.48) at 120 DAP recorded in T_8 (RDF + 90 kg humic acid extracted from poultry manure) followed by plant height of (109.06 cm), number of branches (14.20) and SPAD meter reading (49.01) in T_6 (RDF + 90 kg humic acid extracted from pressmud) and plant height (109.01 cm), number of branches (14.14) and chlorophyll (SPAD meter reading) content at 120 DAP (48.82) in T_4 (RDF + 90 kg humic acid extracted from coffee pulp). There was significant difference in plant height, number of branches and chlorophyll (SPAD meter reading) content between T_2 (RDF + FYM) and application of HA at both 60 and 90 kg ha^{-1}, irrespective of the sources.

The increase in growth parameters in the present study might be due to higher nitrogen content in humic acid used for the study. Since, N is one of the essential nutrients for growth and development of plants, an increase in the supply of nitrogen might have accelerated the activation of enzymes involved in the photosynthesis, carbohydrate metabolism, protein synthesis, and production of growth promoting substances, better cell division and cell elongation. Nitrogen being a constituent of chlorophyll increases the photosynthetic efficiency of crop and resulted in higher growth and development of capsicum. In the treatment that received recommended dose of NPK + FYM the availability of nutrients was affected by many factors, low or deficient content of nutrients in the FYM or application of partially decomposed FYM might have resulted in lesser supply of nutrients to crops, resulting in lower growth and development of capsicum when compared to humic acid treated plots. Similar trend was observed with plant height due to application of RDF + 12.5 kg ha^{-1} of HA as soil application over RDF +FYM treated plots in sunflower (Harshad Thakur *et al*., 2013).

Serenella *et al*. (2002) found that humic substances have a direct action on plant growth by influencing metabolic process such as nucleic acid synthesis, ion uptake and regulation of hormone levels. Ismail and Kamal (2015) reported that the application of HA to potato favorably influenced the plant height and leaf area. Similarly, Arancon *et al*. (2006) observed that humic acids from organic wastes (food-waste vermi compost) produced a significant increase in plant growth compared to commercially produced humic acid. Increase in chlorophyll content was found to be due to higher content of nitrogen in the humic acid used for the study. These results are in agreement with Selim *et al*. (2012) who observed that application of HA @120 kg ha^{-1} recorded higher chlorophyll content in potato crop. Nardi *et al*. (2002) reported that application of humic acid caused an enhancement in the synthesis of the chlorophyll in leaves. Similar findings were observed by Abeer *et al*. (2015).

Plate 6: Growth performance of capsicum as influenced by control and sources of HA @ 90 kg ha^{-1}

4.5.2 Yield and yield parameters

The crop growth and productivity are influenced by many factors both externally and internally. Nutrient management is one such important factor which largely decides the yield of the crop. The economic yield of a plant is an outcome of a series of integrated interactions between various biological events which takes place during its development in accordance with the availability of light, temperature and supply of water and nutrients (Donald, 1962). The information on per cent fruit set, number of fruits per plant, weight of fruits and fruit yield per hectare differed significantly due to application of humic acid extracted from poultry manure, pressmud and coffee pulp at different levels (Table 63 and Fig. 11).

Application of HA @ 90 kg ha^{-1} recorded significantly higher per cent fruit set (78.63), number of fruits $plant^{-1}$ (25.10), fruit yield per plant (2.69 kg $plant^{-1}$), total yield (54.81 t ha^{-1}) and dry matter yield (3.63 t ha^{-1}) while it was lower with HA application @ 60 kg ha^{-1}.

The different sources of HA viz., S_1 (coffee pulp), S_2 (pressmud) and S_3 (poultry manure) did not show significant difference with respect to per cent fruit set, number of fruits $plant^{-1}$, fruit yield (kg $plant^{-1}$), total yield (t ha^{-1}) and dry matter yield (t ha^{-1}).

Among different treatment combinations significantly higher per cent fruit set (79.53), number of fruits $plant^{-1}$ (25.35) fruit yield (2.81 kg $plant^{-1}$), total fruit yield (55.41 t ha^{-1}) and dry matter yield (3.66 t ha^{-1}) in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) with per cent fruit set (78.63), number of fruits $plant^{-1}$ (25.03), fruit yield (2.68 kg ha^{-1}), total yield (54.68 t ha^{-1}) and dry matter yield (3.62 t ha^{-1}). The per cent fruit set, number of fruits per plant, fruit yield per plant, total fruit yield and dry matter yield was 77.73, 24.93, 2.59 kg $plant^{-1}$, 54.34 t ha^{-1} and 3.61 t ha^{-1}in T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). The T_2 treatment (RDF + FYM) differed significantly compared to application of HA @ 60 and 90 kg ha^{-1}. However lower per cent fruit set (60.83), number of fruit $plant^{-1}$ (15.96), fruit yield per plant (1.48 kg $plant^{-1}$), total fruit yield (42.32 t ha^{-1}) and dry matter yield (2.68 t ha^{-1}) were observed in (T_1) RDF alone.

Increased yield and yield parameters due to combined use of chemical fertilizers + humic acid was responsible for improvement in the availability of plant nutrients and balanced supply of nutrients. Increase in yield parameters may be attributed to efficient translocation of photosynthates and availability of adequate amount of nutrients. (Harshad Thakur *et al*., 2013). These results are in agreement with those of Selim *et al.*, (2012) who reported that increasing humic acid application rates up to 120 kg ha^{-1} enhanced the plant growth parameters of potato- tuber production, biochemical indicators i.e., chlorophyll, ascorbic acid, nitrate, starch, total soluble solids and protein contents. Similar findings were observed in case of tomato by ErtanYildirim (2007).

Hai and Mir (1998) reported 8 to 20 per cent increase in wheat, 14 per cent in rice, 8 per cent in vegetables and 44 per cent in radish yield with application of HA at various agricultural research organizations in different ecological zones of Pakistan.

Table 63: Per cent fruit set, number of fruits $plant^{-1}$, fruit yield, total yield and dry matter yield of capsicum as influenced by different sources and levels of humic acid

	Per cent fruit set	Number of fruits $plant^{-1}$	Fruit yield (kg $plant^{-1}$)	Total yield (t ha^{-1})	Dry matter yield (t ha^{-1})
Levels (L)					
L_1	72.58	22.34	2.32	51.61	3.24
L_2	78.63	25.10	2.69	54.81	3.63
S.Em.±	0.65	0.12	0.05	0.35	0.03
CD (p=0.05)	2.06	0.38	0.14	1.10	0.11
Sources (S)					
S_1	74.85	23.51	2.39	52.58	3.39
S_2	75.55	23.59	2.50	53.21	3.44
S_3	76.42	24.06	2.63	53.83	3.48
S.Em.±	0.80	0.15	0.06	0.43	0.04
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	60.83	15.96	1.48	42.32	2.68
T_2	68.23	20.52	1.92	48.27	2.96
T_3	71.97	22.09	2.20	50.83	3.18
T_4	77.73	24.93	2.59	54.34	3.61
T_5	72.47	22.14	2.32	51.74	3.26
T_6	78.63	25.03	2.68	54.68	3.62
T_7	73.30	22.78	2.46	52.26	3.29
T_8	79.53	25.35	2.81	55.41	3.66
S.Em.±	1.09	0.36	0.07	0.76	0.05
CD (p=0.05)	3.29	1.08	0.22	2.31	0.16

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

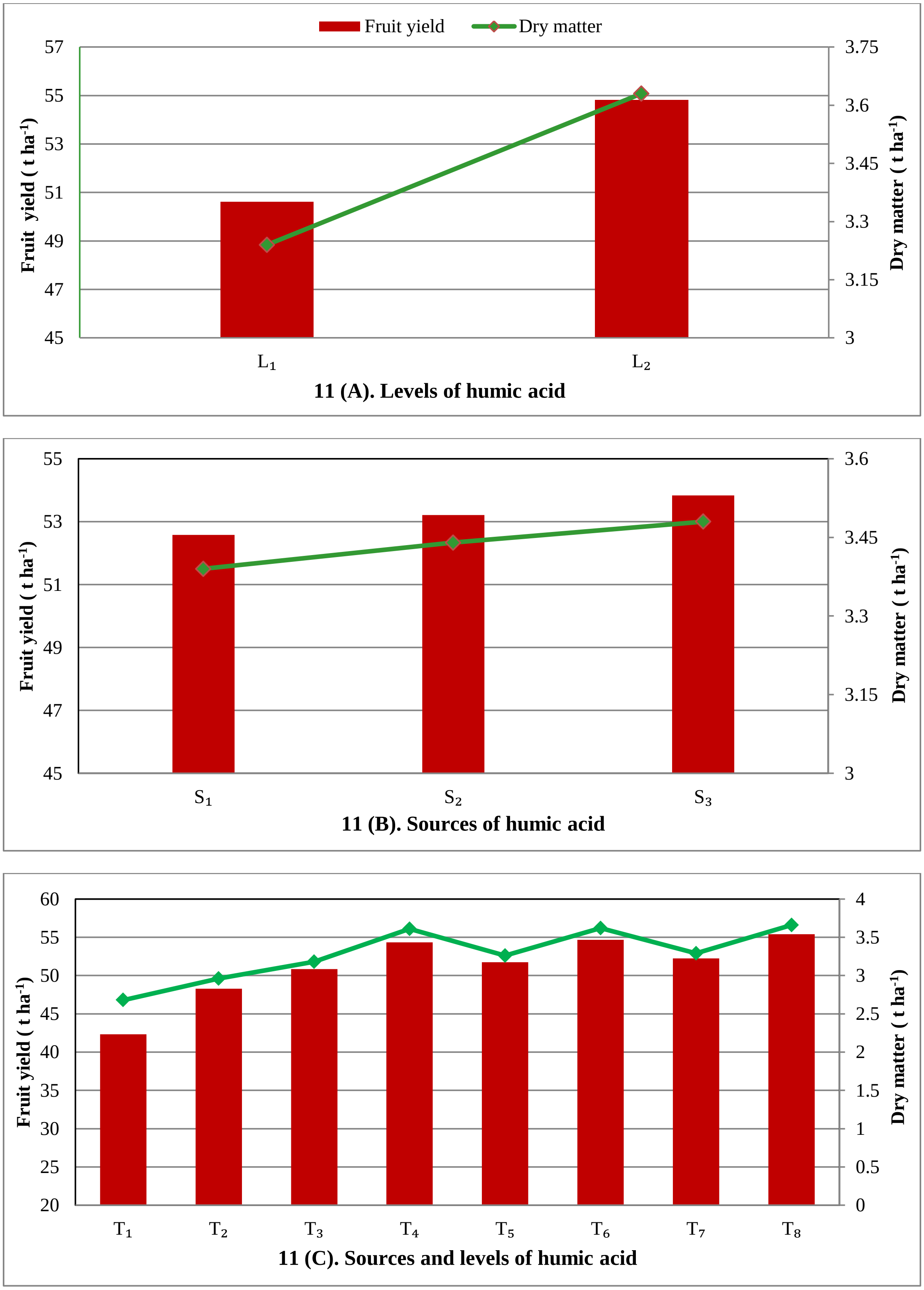

Fig. 11: Fruit yield and dry matter yield of capsicum as influenced by different sources and levels of humic acid

Verlinden *et al*. (2009) studied the effect of humic substances on yield and nutrient uptake by grass, maize, potato and spinach. The results showed that application of humic substances had an overall positive effect on dry matter yield of crops and its effect was statistically significant. Tuber production of potato showed high response to the application of humic substances while its effect on maize yield was limited.

In the present study humic acid extracted from poultry manure, pressmud and coffee pulp resulted in higher yield and yield attributes. This might be due to the presence of higher amount of carboxylic and phenolic hydroxyl groups and these sources having less aromatic nature which might have increased the nutrient absorption and translocation, increase in physiological processes thus resulting in better growth and development of crop and also increased water holding capacity, nutrient availability, hormonal activity or microbial growth and an increased organic matter mineralization (Tan and Nopamornbodi, 1979). More specifically, humic acids also act as growth regulator, regulate hormones, improve plant growth and enhance stress tolerance (Delfine *et al*., 2005). FYM treated plot recorded significantly lower yield in FYM + fertilizer treated plot might be due to the fact that FYM is bulky in nature and takes more time for release of nutrients. Similar findings were observed by Harshad Thakur *et al*. (2013) who reported that application of RDF + FYM @ 5t ha^{-1} recorded significantly lower dry matter yield, seed and stalk yield of sunflower over application of RDF + 12.5 kg ha^{-1} of HA as soil application.

Fruit parameters

The data pertaining to the parameters such as fruit length, breadth and pericarp thickness measured at different pickings is presented in Table 64 and Plate 7.

Higher level of HA application (90 kg ha^{-1}) recorded significantly higher fruit length, breadth and pericarp thickness recorded maximum at 90 DAP (10.08, 8.85 and 0.68 cm, respectively) compared to HA @ 60 kg ha^{-1} (9.57, 8.45 and 0.60 cm, respectively). At harvest the fruit length, breadth and pericarp thickness were reduced at both the levels.

The different sources of HA did not show any significant difference with respect to fruit parameters.

Among different sources and levels of HA application along with two controls, recommended dose of NPK (T_1) and RDF + FYM (T_2) differed significantly and recorded higher fruit length (10.13 cm), fruit breadth (8.90 cm) and pericarp thickness (0.69 cm) respectively were recorded at 90 DAP in T_8 which received RDF + 90 kg HA extracted from poultry manure followed by T_6 (RDF + 90 kg HA extracted from pressmud) and T_4 (RDF + 90 kg HA extracted from coffee pulp). Significantly lower values were recorded in T_1 (RDF) and T_2 (RDF + FYM). Shahmaleki *et al*. (2014) stated that the increase in fruit parameters is due to increased production and accumulation of carbohydrates. Humic acid application favoured vegetative growth leading to enhanced photosynthetic rate, better nutrient uptake from the soil and increased accumulation and translocation of metabolites/nutrients resulting in larger fruit number and size, due to

Table 64: Fruit length, fruit breadth and fruit thickness of capsicum as influenced by different sources and levels of humic acid

	Fruit length (cm)			Fruit breadth (cm)			Fruit thickness (cm)		
	60 DAP	**90 DAP**	**At harvest**	**60 DAP**	**90 DAP**	**At harvest**	**60 DAP**	**90 DAP**	**At harvest**
Levels (L)									
L_1	8.83	9.57	8.23	8.14	8.45	7.28	0.56	0.60	0.52
L_2	9.35	10.08	8.64	8.45	8.85	7.83	0.64	0.68	0.59
S.Em.±	0.06	0.03	0.04	0.06	0.07	0.03	0.00	0.01	0.00
CD (p=0.05)	0.20	0.08	0.13	0.18	0.22	0.11	0.01	0.04	0.01
Sources (S)									
S_1	8.97	9.70	8.32	8.22	8.63	7.51	0.60	0.63	0.54
S_2	9.09	9.84	8.45	8.30	8.66	7.54	0.60	0.65	0.56
S_3	9.21	9.94	8.55	8.38	8.67	7.61	0.61	0.65	0.56
S.Em.±	0.08	0.03	0.05	0.07	0.08	0.04	0.00	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment combinations with control									
T_1	7.64	7.97	6.99	7.42	7.58	6.87	0.44	0.47	0.41
T_2	8.22	8.97	7.76	7.66	7.88	7.07	0.49	0.53	0.47
T_3	8.70	9.36	8.14	8.08	8.43	7.26	0.55	0.59	0.50
T_4	9.25	10.03	8.49	8.36	8.83	7.77	0.64	0.67	0.58
T_5	8.81	9.59	8.23	8.15	8.48	7.27	0.56	0.61	0.52
T_6	9.36	10.08	8.66	8.44	8.84	7.81	0.64	0.68	0.59
T_7	8.98	9.75	8.32	8.19	8.44	7.31	0.57	0.61	0.52
T_8	9.43	10.13	8.77	8.56	8.90	7.90	0.65	0.69	0.60
S.Em.±	0.11	0.05	0.09	0.09	0.11	0.05	0.01	0.02	0.01
CD (p=0.05)	0.33	0.16	0.28	0.26	0.32	0.16	0.02	0.05	0.02

L_1=60 kg Humic acid, L_2=90 Kg Humic acid: $S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure DAP- Days after planting NS = Non significant

$T_{1:}$ Recommended dose of fertilizer (RDF)

T_2: RDF + FYM

$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp

$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp

$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud

$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud

$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure

$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Plate 7: Fruit size of capsicum as influenced by control and sources of HA @ 90 kg ha^{-1}

increase in retention of flower and fruits. The different sources of organic wastes used for humic acid extraction contained sufficient amount of boron which is an essential trace element for plants and is involved in many enzymatic reactions and also enhanced the movement of sugar borate complex from leaves to fruit which ultimately increases fruit yield (Pandita *et al.*, 1976). Similar results were reported by Denre *et al*. (2014).

Quality parameters of capsicum fruits

The data on TSS (°Brix), ascorbic acid (mg 100 g^{-1}) in Fig. 12, weight of ten fruits at 2^{nd}, 5^{th} and 8^{th} picking as influenced by different sources and levels of HA application are presented in Table 65.

Application of humic acid at 90 kg ha^{-1} along with recommended dose of fertilizers recorded significantly higher TSS (6.36 °Brix), ascorbic acid content (143.97 mg 100 g^{-1}) at 5^{th} picking and weight of ten fruits (1516.32, 1542.37 and 1274.87 g, respectively) at 2^{nd}, 5^{th} and 8^{th} picking respectively.

With respect to different sources, there was no significant difference in TSS (°Brix), ascorbic acid content of fruits at 5^{th} picking and weight of ten fruit, at 2^{nd}, 5th and 8^{th} picking.

With respect to different treatments, HA extracted from different sources and application at different levels differed significantly. Higher TSS (6.57 °Brix), ascorbic acid (144.23 mg 100 g^{-1}) at 5^{th} picking and ten fruit weight (1568.23 g) at 5^{th} picking was observed in T_8 (RDF + HA 90 kg extracted from poultry manure) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) with (6.26 °Brix) TSS, (143.59 mg 100g^{-1}) ascorbic acid and (1534.71 g) of ten fruit weight and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with values of (6.24 °Brix) TSS, (144.09 mg 100g^{-1}) Ascorbic acid and (1524.17 g) of 10 fruit weight. Among the two controls, RDF + FYM recorded higher TSS (5.37 °Brix), ascorbic acid (135.23 mg 100 g^{-1}) and ten fruit weight (1318.50 g) and it differed significantly with application of humic acid at 60 and 90 kg ha^{-1} irrespective of sources. Similar results were reported by Shahmaleki *et al*. (2014) for tomato, Ferrara *et al*. (2010) for grapes and ErtanYildirim *et al*. (2006) who reported that the increase in quality parameters was mainly due to increased carbohydrates production during photosynthesis and increased activity of carbonic anhydrase, fructose-1, 6-bisphosphate and aldolase enzymes. Aminifard *et al*. (2012) found that HA applied at 250 mg kg^{-1} resulted in higher total soluble solids content (11.25 °Brix) compared to control.

4.5.3 Nutrient content in haulm (stem and leaves) of capsicum

The major and secondary nutrients content in haulm (stem and leaves) of capsicum plants are presented in Table 66.

Nitrigen, phosphorus and potassium content in haulm

Application of HA at 90 kg ha^{-1} resulted in significant increase in N (2.70 %), P (0.49 %) and K (3.18 %) content. However, lower concentration of N (2.34 %), P (0.44 %) and K (2.95 %) was with application of HA @ 60 kg ha^{-1}.

Table 65: Quality parameters and 10 fruits weight (g) at different growth stages of capsicum as influenced by different sources and levels of humic acid

	TSS (°Brix)	Ascorbic acid mg 100 g^{-1}	10 fruits weight (g)		
			At 2nd picking	At 5th picking	At 8th picking
Levels (L)					
L_1	5.84	140.17	1402.21	1426.59	1212.80
L_2	6.36	143.97	1516.32	1542.37	1274.87
S.Em.±	0.07	0.27	13.33	17.18	9.33
CD (p=0.05)	0.21	0.86	41.99	54.13	29.40
Sources (S)					
S_1	6.01	141.59	1447.41	1463.10	1218.40
S_2	6.03	142.23	1458.84	1479.39	1247.08
S_3	6.26	142.40	1471.54	1510.95	1266.02
S.Em.±	0.08	0.34	16.32	21.04	11.43
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	4.66	125.19	1081.73	1129.33	998.18
T_2	5.37	135.23	1301.67	1318.50	1099.39
T_3	5.78	139.09	1390.89	1402.04	1193.73
T_4	6.24	144.09	1503.92	1524.17	1243.07
T_5	5.80	140.86	1403.45	1424.07	1213.95
T_6	6.26	143.59	1514.24	1534.71	1280.22
T_7	5.94	140.56	1412.28	1453.66	1230.73
T_8	6.57	144.23	1530.79	1568.23	1301.31
S.Em.±	0.12	0.68	24.72	25.33	14.05
CD (p=0.05)	0.35	2.06	74.97	76.82	42.63

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

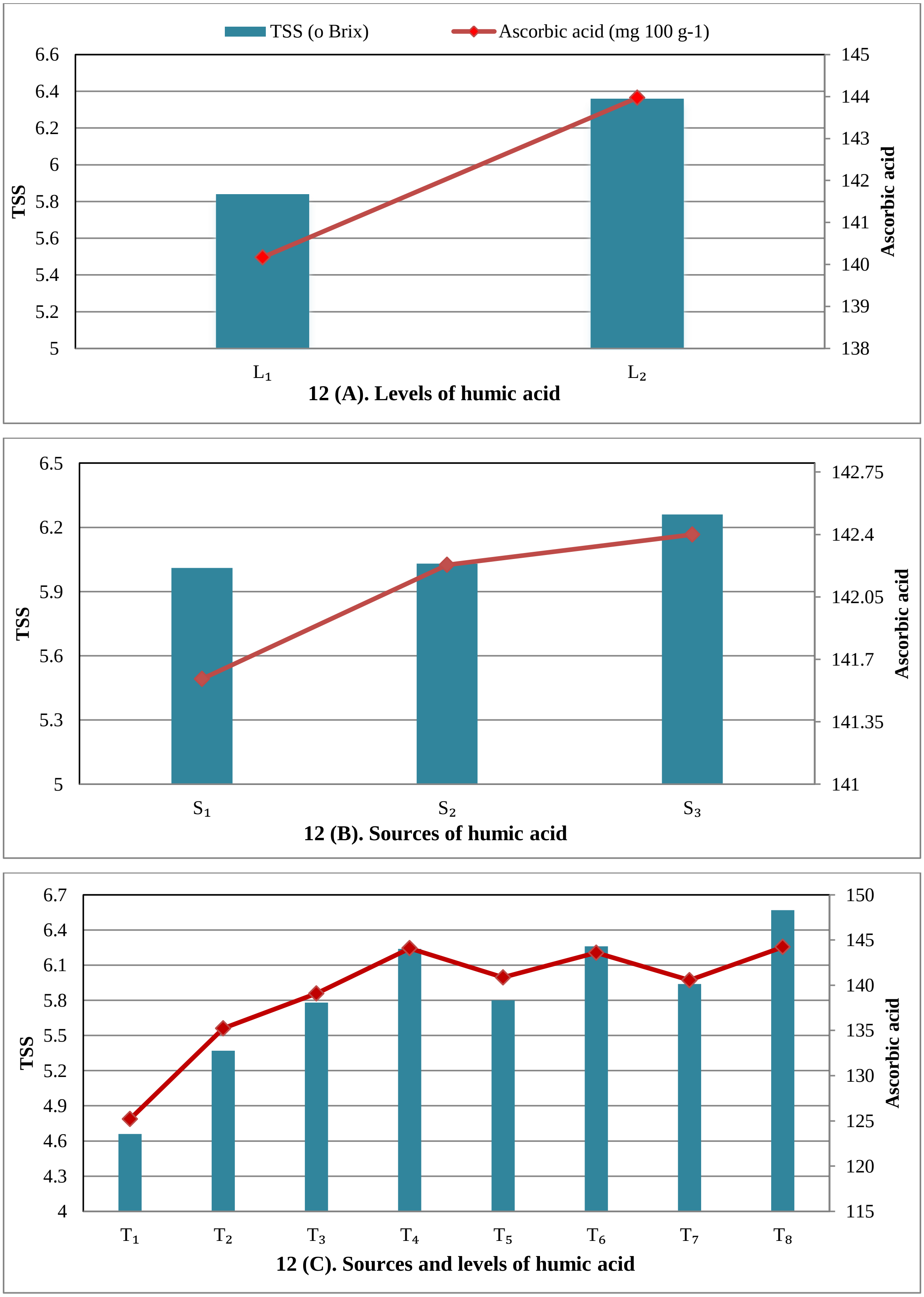

Fig. 12: TSS and Ascorbic acid content of capsicum as influenced by different sources and levels of humic acid

Table 66: Major and secondary nutrient content in haulm (stem and leaves) in capsicum as influenced by different sources and levels of humic acid

	N	P	K	Ca	Mg	S
	(%)					
Levels (L)						
L_1	2.34	0.44	2.95	0.64	0.29	0.52
L_2	2.70	0.49	3.18	0.71	0.36	0.58
S.Em.±	0.01	0.00	0.01	0.01	0.01	0.01
CD (p=0.05)	0.05	0.01	0.04	0.04	0.03	0.03
Sources (S)						
S_1	2.51	0.45	3.05	0.66	0.31	0.54
S_2	2.52	0.46	3.06	0.67	0.32	0.55
S_3	2.54	0.47	3.08	0.69	0.33	0.57
S.Em.±	0.02	0.00	0.01	0.02	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	1.82	0.30	2.57	0.42	0.19	0.40
T_2	2.19	0.39	2.81	0.54	0.25	0.44
T_3	2.33	0.43	2.93	0.62	0.28	0.52
T_4	2.69	0.47	3.17	0.70	0.35	0.57
T_5	2.34	0.44	2.95	0.63	0.28	0.52
T_6	2.71	0.49	3.17	0.71	0.36	0.58
T_7	2.36	0.45	2.96	0.65	0.30	0.54
T_8	2.72	0.50	3.20	0.73	0.36	0.60
S.Em.±	0.03	0.01	0.02	0.02	0.01	0.02
CD (p=0.05)	0.08	0.02	0.06	0.07	0.04	0.05

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

The different sources of HA did not show significant difference with respect to concentration of N, P and K in haulm of capsicum.

Among different treatment combinations along with control higher concentration of N (2.72 %), P (0.50 %) and K (3.20 %) was recorded in T_8 (RDF + HA 90 kg ha^{-1}extracted from poultry manure) followed by N, P and K content of 2.71, 0.49 and 3.17 per cent, respectively in T_6 treatment (RDF + HA 90 kg ha^{-1} extracted from pressmud) and in T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with concentration of (2.69 %) N, (0.47 %) and (3.17 %) K in haulm of capsicum. With respect to T_1 and T_2 significantly higher concentration of nutrients was observed in T_2 (2.19, 0.39 and 2.81 % of N, P, K, respectively), treatment which received RDF along with FYM compared to RDF alone. The treatment RDF + FYM varied significantly compared to HA application @ 60 and 90 kg ha^{-1}.

Calcium, magnesium and sulphur content in haulm

Higher level of HA application (L_2: 90 kg ha^{-1}) recorded significant increase in Ca (0.71 %), Mg (0.36 %) and S (0.58 %) content compared to that of L_1: receiving HA @ 60 kg ha^{-1} with values of 0.64 per cent Ca, 0.29 per cent Mg and 0.52 per cent S.

The different sources of HA did not show significant difference in secondary nutrients content in haulm.

With respect to different sources and levels of HA application along with control differed significantly. Higher content of Ca (0.73 %), Mg (0.36 %) and S (0.60 %) was recorded in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1}extracted from coffee pulp). With respect to T_1 (RDF) and T_2 (RDF + FYM) significantly higher concentration of secondary nutrients viz., Ca (0.54 %), Mg (0.25 %) and S (0.44 %) was in T_2 (RDF + FYM) compared to T_1 (RDF alone).

Iron, manganese, zinc, copper and boron concentration in capsicum haulm

The concentration of micro nutrients in capsicum haulm as influenced by different sources and levels of HA application presented in Table 67.

The concentration of iron (650 mg kg^{-1}), manganese (191.58 mg kg^{-1}), zinc (84.34 mg kg^{-1}), copper (26.19 mg kg^{-1}) and boron (15.30 mg kg^{-1}) was higher in L_2 (HA @ 90 kg ha^{-1}) and it was lower in L_1 (HA @ 60 kg ha^{-1}).

There was no significant difference with respect to concentration of iron, manganese, zinc, copper and boron with different sources of HA.

Among different treatment combinations along with controls application HA at varied levels differed significantly and recorded higher concentration of 656.57 mg kg^{-1} iron, 194.57 mg kg^{-1} manganese, 85.30 mg kg^{-1} zinc, 26.80 mg kg^{-1} copper and 15.63 mg kg^{-1} boron concentration in capsicum haulm in T_8 (RDF + HA 90 kg ha^{-1} extracted from

Table 67: Micronutrient contents in haulm (stem and leaves) in capsicum as influenced by different sources and levels of humic acid

	Fe	Mn	Zn	Cu	B
	(mg kg^{-1})				
Levels (L)					
L_1	611.47	177.04	77.12	23.62	13.80
L_2	650.00	191.58	84.34	26.19	15.30
S.Em.±	2.86	2.28	0.71	0.39	0.19
CD (p=0.05)	9.02	7.20	2.23	1.23	0.60
Sources (S)					
S_1	626.13	181.45	79.68	24.29	14.34
S_2	630.29	184.10	80.73	25.02	14.60
S_3	635.78	187.38	81.79	25.41	14.71
S.Em.±	3.50	2.80	0.86	0.48	0.23
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	563.83	130.90	56.33	15.31	8.97
T_2	580.37	156.33	72.80	21.38	11.62
T_3	607.97	174.67	76.45	23.35	13.75
T_4	644.30	188.23	82.90	25.23	14.92
T_5	611.43	176.27	76.63	23.50	13.87
T_6	649.14	191.93	84.82	26.53	15.33
T_7	615.00	180.20	78.27	24.01	13.79
T_8	656.57	194.57	85.30	26.80	15.63
S.Em.±	4.59	5.32	1.96	0.68	0.34
CD (p=0.05)	13.93	16.12	5.94	2.06	1.04

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

poultry manure) followed by T_6 (RDF + HA 90 kg ha^{-1}extracted from pressmud) with iron (649.14 mg kg^{-1}), manganese (191.93 mg kg^{-1}), zinc (84.82 mg kg^{-1}), copper (26.53 mg kg^{-1}) and boron (15.33 mg kg^{-1}) and T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with iron (644.30 mg kg^{-1}), manganese (188.23 mg kg^{-1}), zinc (82.90 mg kg^{-1}), copper (25.23 mg kg^{-1}) and boron (14.92 mg kg^{-1}) . Among the two controls, T_1 (RDF) and T_2 (RDF + FYM) treatment, application of RDF + FYM recorded (580.37 mg kg^{-1}, 156.33 mg kg^{-1}, 72.80 mg kg^{-1}, 21.38 mg kg^{-1} and 11.62 mg kg^{-1} , Fe, Mn, Zn, Cu and B, respectively), and differed significantly with different levels of HA application.

4.5.4 Nutrient content of capsicum fruit

The data pertaining to major and secondary nutrient content in capsicum fruit are presented in Table 68.

Major nutrients content of capsicum fruit.

Application of HA @ 90 kg ha^{-1} resulted in significant increase in N (2.79 %), P (0.54 %) and K (3.29 %) concentration while lower concentration of N (2.47 %), P (0.47 %) and K (3.04 %) was with application of HA @ 60 kg ha^{-1}.

There was no significant difference with respect to N, P and K concentration in capsicum fruit with different sources of HA application.

Among different treatments with respect to sources and levels of HA, RDF alone and RDF+FYM application revealed significantly higher concentration of N (2.80 %), P (0.55 %) and K (3.31 %) in T_8 (RDF+ HA 90 kg ha^{-1} extracted from poultry manure) followed by N, P and K content of (2.78, 0.54 and 3.29 per cent, respectively) in T_6 treatment (RDF + HA 90 kg ha^{-1} extracted from pressmud) and in T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with concentration of (2.77 %) N, (0.52 %) P and (3.27 %) K in capsicum fruit. Significantly higher concentration of (2.33, 0.41 and 2.90 % of N, P and K, respectively) major nutrients was observed in T_2.Which received RDF along with FYM and varied significantly with HA application @ 60 and 90 kg ha^{-1}.

Secondary nutrients content of capsicum fruit

Higher level of HA application @ 90 kg ha^{-1} (L_2) recorded significantly higher Ca, Mg and S content (0.77, 0.40 and 0.59 %, respectively) and HA application @ 60 kg ha^{-1} recorded lower values with Ca (0.68 %), Mg (0.33 %) and S (0.53 %).

The different sources of HA did not show significant difference in secondary nutrient content of capsicum fruit.

The results of different treatment combination on secondary nutrients content were found to be similar to that of major nutrients. Significantly higher content of Ca (0.79 %), Mg (0.41 %) and S (0.61 %) was recorded in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) followed by Ca, Mg and S content of 0.77, 0.40 and 0.59 per cent, respectively in T_6 (RDF + HA 90 kg ha^{-1}extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with content of Ca (0.76 %), Mg (0.40 %)

Table 68: Major and secondary nutrient content in fruit in capsicum as influenced by different sources and levels of humic acid

	N	P	K	Ca	Mg	S
	(%)					
Levels (L)						
L_1	2.47	0.47	3.04	0.68	0.33	0.53
L_2	2.79	0.54	3.29	0.77	0.40	0.59
S.Em.±	0.02	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)	0.07	0.02	0.04	0.05	0.02	0.02
Sources (S)						
S_1	2.62	0.49	3.15	0.72	0.36	0.55
S_2	2.63	0.50	3.17	0.72	0.37	0.56
S_3	2.64	0.52	3.18	0.75	0.38	0.57
S.Em.±	0.03	0.01	0.02	0.02	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	1.98	0.31	2.51	0.48	0.21	0.40
T_2	2.33	0.41	2.90	0.62	0.28	0.44
T_3	2.46	0.46	3.02	0.67	0.32	0.51
T_4	2.77	0.52	3.27	0.76	0.40	0.58
T_5	2.47	0.47	3.04	0.68	0.33	0.53
T_6	2.78	0.54	3.29	0.77	0.40	0.59
T_7	2.48	0.49	3.05	0.70	0.35	0.54
T_8	2.80	0.55	3.31	0.79	0.41	0.61
S.Em.±	0.04	0.01	0.03	0.02	0.01	0.01
CD (p=0.05)	0.12	0.03	0.09	0.07	0.03	0.03

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

and S (0.58 %). Significantly higher concentration of secondary nutrients viz., Ca (0.62 %), Mg (0.28 %) and S(0.44 %) was in T_2 compared to that of Ca (0.48 %), Mg (0.21 %) and S (0.40 %) in T_1 (RDF alone) which varied significantly with HA application @ 60 and 90 kg ha^{-1} irrespective of sources.

Concentration of iron, manganese, zinc, copper and boron in capsicum fruit

The concentration of micro nutrients in capsicum fruit as influenced by different sources and levels of HA application are presented in Table 69.

Application of HA @ 90 kg ha^{-1} (L_2) resulted in significantly higher concentration of iron (674.24 mg kg^{-1}), manganese (196.63 mg kg^{-1}), zinc (89.71 mg g^{-1}), copper (33.38 mg kg^{-1}) and boron (16.22 mg kg^{-1}) and was lower in L_1 (HA @ 60 kg ha^{-1}).

There was no significant difference with respect to concentration of iron, manganese, zinc, copper and boron when HA extracted from different sources was applied.

Different treatment combinations along with control showed significantly higher concentration of iron (677.93 mg kg^{-1}), manganese (198.67 mg kg^{-1}), zinc (91.33 mg kg^{-1}), copper (33.97 mg kg^{-1}) and boron (16.39 mg kg^{-1}) in T_8 (RDF + HA 90 kg ha^{-1} extraction from poultry manure) followed by (674.73 mg kg^{-1}) iron, (196.13 mg kg^{-1}) manganese, (89.45 mg kg^{-1}) zinc, (33.77 mg kg^{-1}) copper and (16.10 mg kg^{-1}) boron in T_6 treatment (RDF + HA 90 kg ha^{-1} extracted from pressmud) and in T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) treatment. Application of RDF + FYM resulted in higher concentration of (609.93 mg kg^{-1}) Fe, (167.97 mg kg^{-1}) Mn, (81.90 mg kg^{-1}) Zn, (25.30 mg kg^{-1}) Cu and (12.55 mg kg^{-1}) B, respectively (T_1) compared to RDF alone and these two treatments differed significantly with sources and levels HA application.

4.5.5 Nutrient uptake by haulm (stem and leaves) of capsicum

The major and secondary nutrients uptake by haulm (stem and leaves) of capsicum as influenced by different sources and levels of HA application is presented in Table 70.

Uptake of nitrogen, phosphorus and potassium by haulm of capsicum

The N, P and K uptake significantly increased with increase in levels of HA application. Higher N (89.12 kg ha^{-1}), P (17.43 kg ha^{-1}) and K (104.8 kg ha^{-1}) uptake was recorded in L_2 (HA @ 90 kg ha^{-1}) while lower N (69.07 kg ha^{-1}), P (13.97 kg ha^{-1}) and K (86.92 kg ha^{-1}) was recorded in L_1 (HA @ 60 kg ha^{-1}) (Fig. 13).

There were no significant differences in the uptake of N, P and K by capsicum fruit with different sources of HA application.

With respect to treatment combinations application of HA at varied levels and sources along with controls was found to be significant. Higher uptake of major nutrients

Table 69: Micronutrients content in fruit in capsicum as influenced by different sources and levels of humic acid

	Fe	Mn	Zn	Cu	B
	mg kg^{-1}				
Levels (L)					
L_1	631.50	186.09	83.20	29.27	14.29
L_2	674.24	196.63	89.71	33.38	16.22
S.Em.±	1.75	2.13	0.73	0.66	0.13
CD (p=0.05)	5.50	NS	2.30	2.07	0.42
Sources (S)					
S_1	649.98	189.73	85.43	30.50	15.16
S_2	653.08	191.08	86.27	31.67	15.20
S_3	655.55	193.27	87.67	31.80	15.40
S.Em.±	2.14	2.61	0.90	0.81	0.16
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	580.87	137.30	59.47	16.23	9.09
T_2	609.93	167.97	81.90	25.30	12.55
T_3	629.89	184.37	82.52	28.60	14.16
T_4	670.07	195.10	88.33	32.40	16.15
T_5	631.43	186.03	83.09	29.57	14.30
T_6	674.73	196.13	89.45	33.77	16.10
T_7	633.17	187.87	84.00	29.63	14.41
T_8	677.93	198.67	91.33	33.97	16.39
S.Em.±	3.92	3.33	1.46	1.04	0.23
CD (p=0.05)	11.88	10.09	4.44	3.16	0.70

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant

$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure

$T_{1:}$ Recommended dose of fertilizer (RDF)

T_2: RDF + FYM

$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp

$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp

$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud

$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud

$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure

$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Table 70: Major and secondary nutrient uptake by haulm (stem and leaves) in capsicum as influenced by different sources and levels of humic acid

	N	P	K	Ca	Mg	S
	kg ha^{-1}					
Levels (L)						
L_1	69.07	13.97	86.92	18.75	8.42	15.46
L_2	89.12	17.43	104.88	23.58	11.75	19.25
S.Em.±	0.71	0.32	0.75	0.55	0.27	0.37
CD (p=0.05)	2.23	1.00	2.35	1.73	0.84	1.17
Sources (S)						
S_1	77.77	15.06	94.46	20.51	9.74	16.76
S_2	79.03	15.72	95.63	21.11	10.00	17.29
S_3	80.49	16.32	97.62	21.88	10.52	18.00
S.Em.±	0.87	0.39	0.91	0.67	0.33	0.45
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	46.40	8.01	65.30	10.60	4.92	10.09
T_2	59.14	11.25	75.76	14.56	6.76	11.86
T_3	67.29	13.30	84.72	17.88	7.97	14.93
T_4	88.26	16.83	104.20	23.13	11.50	18.59
T_5	69.31	14.04	87.38	18.78	8.32	15.41
T_6	88.74	17.40	103.88	23.43	11.68	19.18
T_7	70.60	14.58	88.66	19.57	8.97	16.03
T_8	90.38	18.06	106.57	24.18	12.08	19.97
S.Em.±	1.16	0.49	1.18	0.86	0.41	0.57
CD (p=0.05)	3.53	1.50	3.58	2.59	1.26	1.71

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

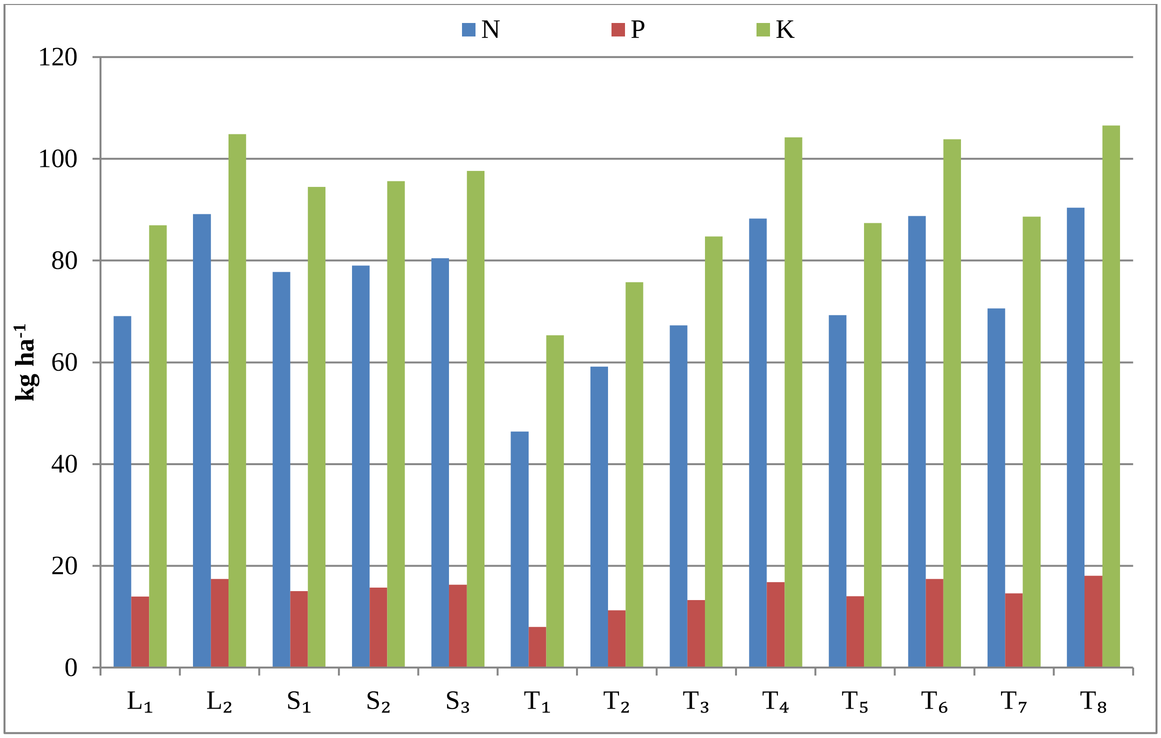

Fig. 13: N, P and K uptake by capsicum haulm (stem and leaves) as influenced by different levels and sources of humic acid

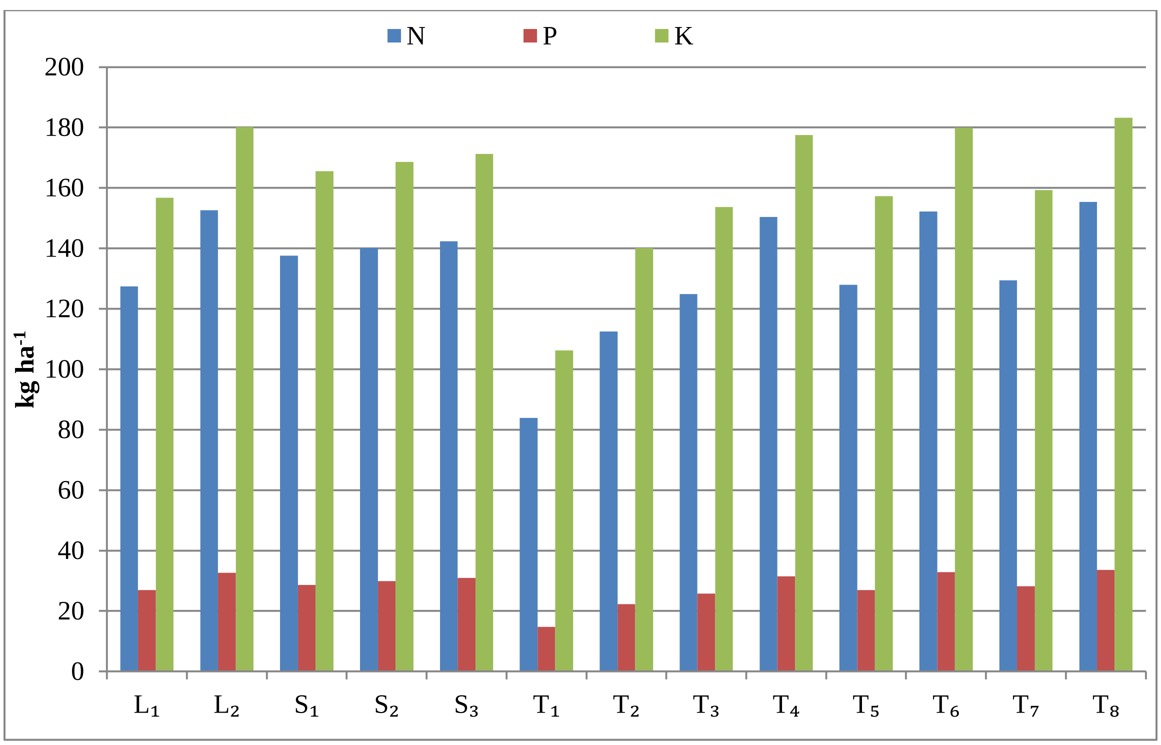

Fig. 14: N, P and K uptake by capsicum fruit as influenced by different levels and sources of humic acid application

was observed in T_8 (RDF + HA 90 kg ha^{-1} extraction from poultry manure) with uptake of N (90.38 kg ha^{-1}), P (18.06 kg ha^{-1}) and K (106.57 kg ha^{-1}) followed by T_6 treatment (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) However, T_1 which received RDF alone recorded lower uptake of N (46.40 kg ha^{-1}), P (8.01 kg ha^{-1}) and K (65.30 kg ha^{-1}). Whereas higher uptake of N (59.14 kg ha^{-1}), P (11.25 kg ha^{-1}) and K (75.76 kg ha^{-1}) was in T_2 (RDF + FYM) and found to be vary significantly with treatment receiving HA @ 60 and 90 kg ha^{-1}.

Uptake of calcium, magnisium and sulphur by haulm (stem and leaves) of capsicum

The uptake of Ca, Mg and S by haulm (stem and leaves) of capsicum differed significantly with different sources and levels of HA application (Table 70).

Higher level of HA application @ 90 kg ha^{-1} resulted in significant increase in uptake of Ca (23.58 kg ha^{-1}), Mg (11.75 kg ha^{-1}) and S (19.25 kg ha^{-1}) with respect to different sources of HA, there was no significant difference in uptake of Ca, Mg and S uptake.

The different treatment combinations along with control showed similar trend as that of major nutrient with Ca uptake (24.18 kg ha^{-1}), Mg (12.08 kg ha^{-1}) and S (19.97 kg ha^{-1}) uptake in T_8 (RDF + HA extracted from poultry manure) with uptake of Ca (23.43 kg ha^{-1}), Mg (11.68 kg ha^{-1}) and S (19.18 kg ha^{-1}) in T_6 treatment (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with respect to T_1 (RDF) and T_2 (RDF + FYM) higher uptake of secondary nutrients Ca (14.56 kg ha^{-1}), Mg (6.76 kg ha^{-1}) and S (11.86 kg ha^{-1}) was in T_2, which varied significantly with HA application @ 60 and 90 kg ha^{-1}.

Uptake of iron, manganese, zinc, copper and boron by haulm (stem and leaves) of capsicum

The micronutrients uptake by haulm (stem and leaves) of capsicum as influenced by different sources and levels of HA application is presented in Table 71.

Micronutrients uptake increased significantly with increase in the levels of HA application. Higher uptake of Fe (2143.27 g ha^{-1}), Mn (631.78 g ha^{-1}), Zn (278.05 g ha^{-1}), Cu (86.33 g ha^{-1}) and B (50.45 g ha^{-1}) was in L_2 (HA @ 90 kg ha^{-1}), where as uptake was lower in L_1 (HA @ 60 kg ha^{-1}).

Different treatment combination with sources and levels of HA showed similar results as that of the uptake of major and secondary nutrients. T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) recorded higher uptake of Fe (2183.46 g ha^{-1}), Mn (647.09 g ha^{-1}), Zn (283.69 g ha^{-1}), Cu (89.06 g ha^{-1}) and B (51.99 g ha^{-1}) followed by T_6 which received RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). With respect to control T_1 (RDF) and T_2 (RDF + FYM), significantly higher uptake of Fe (1564.64 mg kg^{-1}), Mn (421.44 g ha^{-1}), Zn (196.30 g ha^{-1}), Cu (57.67 g ha^{-1}) and B (31.32 g ha^{-1}) was in T_2 treatment and was significantly higher compared to HA application @ 60 and 90 kg ha^{-1}.

Table 71: Micronutrients uptake by haulm (stem and leaves) in capsicum as influenced by different sources and levels of humic acid

	Fe	Mn	Zn	Cu	B
	g ha^{-1}				
Levels (L)					
L_1	1804.60	522.54	227.59	69.69	40.74
L_2	2143.27	631.78	278.05	86.33	50.45
S.Em.±	18.40	8.44	2.92	1.17	0.84
CD (p=0.05)	57.99	26.59	9.19	3.69	2.64
Sources (S)					
S_1	1938.18	561.51	246.88	75.21	44.40
S_2	1970.81	576.52	252.52	78.33	45.73
S_3	2012.81	593.45	259.07	80.49	46.65
S.Em.±	22.54	10.33	3.57	1.44	1.03
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	1434.64	333.03	143.41	38.95	22.82
T_2	1564.64	421.44	196.30	57.67	31.32
T_3	1758.00	504.81	221.13	67.48	39.76
T_4	2118.36	618.22	272.64	82.95	49.04
T_5	1813.62	523.00	227.19	69.67	41.14
T_6	2127.99	630.03	277.84	86.99	50.31
T_7	1842.17	539.81	234.45	71.92	41.32
T_8	2183.46	647.09	283.69	89.06	51.99
S.Em.±	28.13	17.06	6.46	2.06	1.33
CD (p=0.05)	85.32	51.74	19.59	6.23	4.03

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

4.5.6 Nutrients uptake by capsicum fruit

The major and secondary nutrients uptake by capsicum fruit as influenced by different sources and levels of HA application are presented in Table 72.

The N, P and K uptake by capsicum fruit showed similar trend as that of nutrient uptake by haulm (leaves and stem). Higher N (152.65 kg ha^{-1}), P (32.63 kg ha^{-1}) and K (180.20 kg ha^{-1}) uptake was recorded in L_2 (HA @ 90 kg ha^{-1}) while lower uptake was recorded in L_1 (HA @ 60 kg ha^{-1}) (Fig. 14).

The three different sources of HA application did not show significant difference in the uptake of major nutrients by capsicum fruit.

The different treatments along with control showed significant difference. Higher uptake of N (155.34 kg ha^{-1}), P (33.62 kg ha^{-1}) and K (183.19 kg ha^{-1}) was observed in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) followed by T_6 treatment (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). Among two controls, application of RDF along with FYM (T_2) resulted in significantly higher uptake of N (112.47 kg ha^{-1}), P (22.22 kg ha^{-1}) and K (140.12 kg ha^{-1}) than T_1 (RDF alone).

The Ca, Mg and S uptake by capsicum fruit differed significantly due to application of different sources and levels of HA.

The Ca, Mg and S uptake by capsicum fruit increased with levels of HA application. Higher Ca (42.31 kg ha^{-1}), Mg (22.14 kg ha^{-1}) and S (32.52 kg ha^{-1}) uptake was in L_2 (HA @ 90 kg ha^{-1}). Application of different sources of HA did not record significant difference in the uptake of secondary nutrients.

With respect to different treatment combinations with sources and levels of HA application showed significantly higher uptake of Ca, Mg and S (43.95, 22.70 and 33.73 kg ha^{-1}, respectively) in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) followed by T_6 treatment (RDF + 90 kg ha^{-1} HA extracted from pressmud) and T_4 treatment (RDF + HA 90 kg ha^{-1} extracted from coffee pulp).The treatments T_1 (RDF) and T_2 (RDF + FYM) showed similar trend in the uptake of Ca, Mg and S as that major nutrients uptake.

The data on micronutrients uptake by capsicum fruit as influenced by different sources and levels of HA application are presented in Table 73.

The uptake of micronutrient increased with increase in the levels of HA application. HA @ 90 kg ha^{-1} recorded higher uptake compared to application @ 60 kg ha^{-1}. The different sources of HA did not differ significantly with uptake of micro nutrients.

Among different treatment combinations, application of RDF along with 90 kg ha^{-1} of HA extracted from poultry manure (T_8) was superior compared to other treatment

Table 72: Major and secondary nutrients uptake by capsicum fruits as influenced by different sources and levels of humic acid

	N	P	K	Ca	Mg	S
	kg ha^{-1}					
Levels (L)						
L_1	127.41	26.95	156.72	35.27	17.16	27.20
L_2	152.65	32.63	180.20	42.31	22.14	32.52
S.Em.±	3.88	0.71	3.40	1.13	0.66	0.41
CD (p=0.05)	12.22	2.25	10.72	3.56	2.07	1.28
Sources (S)						
S_1	137.62	28.60	165.58	37.72	18.97	28.69
S_2	140.10	29.86	168.59	38.49	19.47	29.91
S_3	142.37	30.91	171.22	40.18	20.51	30.96
S.Em.±	4.75	0.87	4.17	1.38	0.80	0.50
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	83.87	14.73	106.21	20.14	8.76	16.80
T_2	112.47	22.22	140.12	29.92	13.39	21.27
T_3	124.86	25.75	153.66	34.22	16.25	25.94
T_4	150.38	31.45	177.49	41.21	21.69	31.45
T_5	127.97	26.89	157.26	35.20	16.91	27.46
T_6	152.24	32.83	179.92	41.78	22.03	32.37
T_7	129.39	28.21	159.25	36.40	18.32	28.20
T_8	155.34	33.62	183.19	43.95	22.70	33.73
S.Em.±	6.11	1.13	5.65	1.70	1.06	0.68
CD (p=0.05)	18.52	3.44	17.13	5.17	3.22	2.06

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Table 73: Micronutrients uptake by capsicum fruits as influenced by different sources and levels of humic acid

	Fe	Mn	Zn	Cu	B
	g ha^{-1}				
Levels (L)					
L_1	3258.94	950.40	430.39	151.08	73.74
L_2	3692.45	1076.99	491.42	182.70	88.81
S.Em.±	69.65	19.24	7.56	3.14	1.87
CD (p=0.05)	219.48	60.62	23.82	9.89	5.88
Sources (S)					
S_1	3417.51	997.70	449.17	160.56	79.78
S_2	3477.37	1002.98	459.65	168.63	80.99
S_3	3532.19	1040.42	473.89	171.48	83.04
S.Em.±	85.31	23.56	9.26	3.84	2.29
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	2457.63	580.67	251.43	68.69	38.47
T_2	2944.88	810.90	395.53	122.01	60.57
T_3	3201.51	937.33	419.36	145.43	71.97
T_4	3633.52	1058.07	478.99	175.69	87.58
T_5	3266.88	933.45	429.98	152.95	74.00
T_6	3687.87	1072.51	489.33	184.31	87.99
T_7	3308.42	980.43	441.83	154.85	75.23
T_8	3755.96	1100.40	505.94	188.11	90.85
S.Em.±	108.70	29.85	13.93	5.34	3.04
CD (p=0.05)	329.70	90.53	42.26	16.19	9.21

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
S_1= Coffee pulp, S_2= Pressmud, S_3= Poultry manure
T_1: Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
T_3: RDF + 60 kg Humic acid extracted from Coffee pulp
T_4: RDF + 90 kg Humic acid extracted from Coffee pulp
T_5: RDF + 60 kg Humic acid extracted from Pressmud
T_6: RDF + 90 kg Humic acid extracted from Pressmud
T_7: RDF + 60 kg Humic acid extracted from Poultry manure
T_8: RDF + 90 kg Humic acid extracted from Poultry manure

combinations and recorded higher uptake of Fe (3755.97 g ha^{-1}), Mn (1100.40 g ha^{-1}), Zn (505.94 g ha^{-1}), Cu (188.11 g ha^{-1}) and B (90.84 g ha^{-1}) followed by T_6 and T_4. Among T_1 (RDF alone) and T_2 (RDF + FYM), the treatment T_2 resulted in significantly higher uptake of Fe (2944.88 g ha^{-1}), Mn (810.90 g ha^{-1}), Zn (395.53 g ha^{-1}), Cu (122.01 g ha^{-1}) and B (60.57 g ha^{-1}).

In the present study, application of humic acid derived from different organic wastes significantly enhanced the nutrient content and uptake of macro and micronutrients in capsicum which might be due to enhanced photosynthetic activity and increased production and accumulation of carbohydrates. The above findings are in conformity with other workers (Ayuso *et al*., 1996; Atiyeh *et al*., 2002; Arancon *et al*., 2006; Eyheraguibel *et al*., 2008) who reported positive effects of humic substances derived from organic materials on various plant species. With application of HA at optimal level the roots were highly branched and this might have resulted in increased surface area, which facilitated efficient nutrient absorption (Mallikarjuna Rao *et al*., 1987). The mechanism of root interception of soil nutrients is one of the ways by which plant absorb nutrients. This was made possible due to profuse root growth (Tisdale *et al*., 1997). The improved root growth of capsicum in the presence of HA observed would have induced the large uptake of nutrients. Humic acid had a definite role on the protein and nucleic acid synthesis, which indirectly indicated the increased uptake of various nutrient elements essentially N, K and Ca (Guminski, 1968). In the presence of humates, the plants could use phospohumate fertilizers fully as the humic molecules and the phosphate anion compete for exchange sites. Anion exchange phenomenon could be another reason for increasing P availability and higher P uptake (Deb and Datta, 1967).

According to Fortun and Polo (1982) HA increased the uptake of micronutrients due to increased root activity and formation of soluble humus chelates in soil would have increased micronutrients uptake. The role of humic substances is mainly related to the enhancement of nutrients uptake. Humic substances increase soil cation exchange capacity (ability to hold and release cations such as K^+, Ca^{2+} or NH_4^+), and can also form aqueous complexes with micronutrients (Aiken *et al*., 1985). These effects were associated with increasing nutrients concentration in capsicum.

Many researchers reported that soil or foliar application of humic acid significantly increased the major and secondary nutrients (N, P, K, Ca, Mg) and micronutrients (Fe, Cu, Zn ,Mn) contents of different crops i.e., in gerbera by Nikbakht *et al*.(2008) and Haghighi *et al*.(2014) in maize by Celik *et al*. (2011); in wheat by Taha *et al*. (2006); in cucumber by El-nemer *et al*. (2012); in tomato by Asri *et al.*(2015).

4.5.7 Changes in soil properties after harvest of capsicum

Physical properties

The changes in BD (Mg m^{-3}) and MWHC (%) of soil after the harvest of capsicum due to different sources and levels of HA treatments are presented in Table 74.

A decrease in bulk density (1.32 Mg m^{-3}) and increase of MWHC (40.71 %) of soil was recorded in L_2 (HA @ 90 kg ha^{-1}), whereas it was (1.37 Mg m^{-3}) and (38.40 %),

Table 74: Effect of different sources and levels of humic acid application on BD, MWHC, pH, EC, OC and CEC of soil after harvest of capsicum

	BD ($Mg\ m^{-3}$)	MWHC (%)	pH (1:2.5)	EC ($dS\ m^{-1}$) (1:2.5)	OC (%)	CEC ($cmol\ (P^+)\ kg^{-1}$)
Levels (L)						
L_1	1.37	38.40	6.80	0.60	0.86	14.73
L_2	1.32	40.71	6.85	0.64	0.94	15.17
S.Em.±	0.00	0.25	0.03	0.03	0.01	0.07
CD (p=0.05)	0.01	0.78	NS	NS	0.02	0.23
Sources (S)						
S_1	1.35	39.26	6.80	0.60	0.91	14.86
S_2	1.35	39.61	6.82	0.62	0.90	14.97
S_3	1.35	39.80	6.85	0.64	0.89	15.04
S.Em.±	0.00	0.30	0.03	0.03	0.01	0.09
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	1.45	36.27	6.66	0.57	0.75	12.97
T_2	1.36	41.00	6.79	0.59	0.88	14.23
T_3	1.38	38.07	6.78	0.61	0.86	14.62
T_4	1.32	40.45	6.82	0.63	0.95	15.10
T_5	1.37	38.45	6.80	0.60	0.86	14.75
T_6	1.32	40.78	6.85	0.65	0.94	15.18
T_7	1.37	38.69	6.83	0.62	0.85	14.83
T_8	1.32	40.91	6.88	0.65	0.94	15.24
S.Em.±	0.01	0.42	0.08	0.04	0.02	0.16
CD (p=0.05)	0.03	1.28	NS	NS	0.05	0.47
Initial	**1.42**	**36.5**	**6.72**	**0.55**	**0.78**	**12.34**

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant

$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure

$T_{1:}$ Recommended dose of fertilizer (RDF)

T_2: RDF + FYM

$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp

$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp

$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud

$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud

$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure

$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

respectively in L_1 (HA @ 60 kg ha^{-1}). Application of different sources of HA did not show significant difference in bulk density and maximum water holding capacity of soil.

Significant difference was observed between different sources and levels HA and also treatments without HA application in respect of BD (Mg m^{-3}) and MWHC (%). Lower BD (1.31 Mg m^{-3}) and higher MWHC (40.91 %) was recorded due to T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) followed by T_6 and T_4 treatments. However, application of RDF alone (T_1) resulted in increase in BD (1.45 Mg m^{-3}) and decrease in MWHC (36.27 %) compared to other treatment combinations.

Results from the present study indicate that bulk density and water holding capacity were positively affected by the application of HA at varied levels. The decrease in bulk density was mainly due to increase in the organic carbon content of soil and improvement in soil aggregate stability (Ijaz Ahmad *et al*., 2015).The advantage of humic substances is due to its chemical structures that make it more resistant to microbial attacks. Reports show that humic substances extracted from farmyard manure improved and prolonged aggregate stability more than application of bulky farmyard manure (Piccolo *et al*., 1997). Thus, the use of humic acid in soil as an organic source can improve the physical condition of soil by increasing the aggregate stability of soil and reducing the compactness of soil which resulted in decrease in bulk density of soil and hence improved the water infiltration (Barzegar *et al.*, 2002; Mahmoud *et al*., 2011). Similar findings were observed by Piccola *et al*. (1996) who stated that addition of highly humified organic substances such as coal- derived humic acid can improve the structural and water retention properties of degraded arable soils.

Chemical properties

The changes in pH, electrical conductivity, organic carbon content and CEC of soil after the harvest of capsicum are presented in Table 74.

There was no significant variation in pH and electrical conductivity of soil at different levels of HA application (60 and 90 kg ha^{-1}). However the organic carbon and CEC showed significant increase with graded levels of humic acid application and higher values of organic carbon (0.94 %) and CEC (15.17 cmol (p^+) kg^{-1}) were recorded at 90 kg ha^{-1}.

Application of different sources of HA did not show significant difference in pH, EC, organic carbon and CEC of soil.

With respect to different treatment combinations along with control, HA application with varied levels and sources was non significant with respect to pH and EC and differed significantly with OC and CEC of soil. The treatment T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) recorded value of pH 6.88, EC of 0.65 dSm^{-1} and CEC value of 15.24 cmol (p+) kg^{-1} followed by T_6 and T_4. Higher organic carbon content was recorded in T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with 0.95 per cent followed by T_6 and T_8. However, application of RDF alone (T_1) resulted in lower values of pH (6.65), EC (0.54 dS m^{-1}), OC (0.75 %) and CEC (12.97 cmol (p+) kg^{-1}).

In the present study the soil pH and electrical conductivity did not vary significantly due to application of humic acid along with RDF. With respect to levels and sources of humic acid there was slight increase in pH and EC over initial value. The slight increase in pH of the soil may be due the mineralization of carbon and the subsequent production of hydroxyl ions by ligand exchange as well as the introduction of basic cations, such as K^+, Ca^{2+} and Mg^{2+} (Mkhabela and Warman, 2005). The treatment receiving NPK only (T_1) recorded lower pH. Increase in the electrical conductivity of soil may be due to accumulation of salts added through the different sources of humic acid. There was significant increase in organic carbon content of soil with varied levels of HA application, this may be because carbon is a major component of humic acid is carbon in nature (Kulikova *et al.*, 2005) hence it improved soil organic carbon status. Vallini *et al.* (1993) recorded increase in organic carbon content of soil due to humic acid addition, because of the refractory nature of chemical structure which makes it resistant to microbial attack. Similar findings were observed by Ijaz Ahmad *et al.* (2015).

The profound increase in CEC due to HA application in the present study highlighted the beneficial effect of HA on CEC. There was steady increase in CEC with increased levels of HA application up to 90 kg ha^{-1}. Humic acid consists functional groups that form source of negative charges, which helps in part to the dissociation of hydrogen ions from carboxyl groups and also probably in part to their dissociation from phenolic hydroxyls. Similar findings were observed by Lax (1991).

The data pertaining to changes in available nitrogen, phosphorus, potassium, calcium, magnesium and sulphur content of soil after the harvest of capsicum due to different sources and levels of HA application are presented in Table 75.

After harvest of capsicum, significantly higher available nitrogen (333.48 kg ha^{-1}), phosphorus (124.30 kg ha^{-1}) and potassium (318.16 kg ha^{-1}) content was recorded and increased with increase in levels of HA application i.e. at L_2 (HA @ 90 kg ha^{-1}) (Fig. 14). Similar was the trend with respect to calcium (6.50 cmol (p+) kg^{-1}), magnesium (2.33 cmol (p+) kg^{-1}) and sulphur (16.14 mg kg^{-1}) content of soil. Lower build up of major and secondary nutrients status of soil was in L_1 (HA @ 60 kg ha^{-1}).

There was no significant difference in buildup of major and secondary nutrients content in soil due to application of different sources of humic acid. However, there was significant difference was observed between different sources and levels of HA application along with control, higher content of available nitrogen (334.22 kg ha^{-1}), phosphorus (125.23 kg ha^{-1}) and potassium (319.19 kg ha^{-1}) was recorded in T_8 (RDF + 90 kg ha^{-1} HA extracted from poultry manure).

Similar was the trend with Ca, Mg and S status of soil recording (6.52, 2.34 cmol (p+) kg^{-1} and 16.27 mg kg^{-1}, respectively) in treatment RDF + HA 90 kg ha^{-1} extracted from poultry manure followed by T_6 which received RDF + HA 90 kg ha^{-1} extracted from pressmud and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). The major nutrients was low in RDF alone treatment with nitrogen content (282.62 kg ha^{-1}), phosphorus (102.25 kg ha^{-1}), potassium content of soil 286.31 kg ha^{-1}. The calcium (5.54) and

Table 75: Effect of different sources and levels of humic acid application on available major and secondary nutrients content of soil after harvest of capsicum

	Available-N (kg ha^{-1})	Available-P_2O_5 (kg ha^{-1})	Available-K_2O (kg ha^{-1})	Exch. Ca [cmol (p+) kg^{-1}]	Exch. Mg [cmol (p+) kg^{-1}]	Avail-S (mg kg^{-1})
Levels (L)						
L_1	325.53	118.63	309.71	6.29	2.25	14.48
L_2	333.48	124.30	318.16	6.50	2.33	16.14
S.Em.±	0.41	0.74	0.77	0.02	0.01	0.10
CD (p=0.05)	1.30	2.35	2.42	0.06	0.03	0.31
Sources (S)						
S_1	328.82	120.45	313.11	6.37	2.28	15.20
S_2	329.45	121.52	313.57	6.40	2.29	15.25
S_3	330.25	122.44	315.13	6.41	2.31	15.48
S.Em.±	0.51	0.91	0.94	0.02	0.01	0.12
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	282.62	102.25	286.31	5.54	1.97	11.52
T_2	316.77	112.75	301.04	6.17	2.13	13.57
T_3	324.91	117.87	308.81	6.26	2.24	14.33
T_4	332.73	123.02	317.40	6.48	2.32	16.07
T_5	325.40	118.37	309.25	6.29	2.25	14.40
T_6	333.50	124.66	317.88	6.50	2.32	16.10
T_7	326.28	119.65	311.07	6.31	2.27	14.70
T_8	334.22	125.23	319.19	6.52	2.34	16.27
S.Em.±	1.89	1.39	1.37	0.03	0.03	0.21
CD (p=0.05)	5.74	4.21	4.15	0.10	0.10	0.63
Initial	**301.8**	**108.10**	**294.30**	**5.70**	**2.05**	**12.34**

L_1=60 kg Humic acid, L_2=90 Kg Humic acid, S_1= Coffee pulp, S_2= Pressmud, S_3= Poultry manure NS = Non significant

T_1: Recommended dose of fertilizer (RDF)

T_2: RDF + FYM

T_3: RDF + 60 kg Humic acid extracted from Coffee pulp

T_4: RDF + 90 kg Humic acid extracted from Coffee pulp

T_5: RDF + 60 kg Humic acid extracted from Pressmud

T_6: RDF + 90 kg Humic acid extracted from Pressmud

T_7: RDF + 60 kg Humic acid extracted from Poultry manure

T_8: RDF + 90 kg Humic acid extracted from Poultry manure

magnesium (1.97) cmol (p+) kg^{-1} and sulphur (11.52 mg kg^{-1}) content of soil was also low in T_1 receiving RDF alone.

The data on the effect of different sources and levels of HA application on micronutrients viz., Fe, Mn, Zn, Cu and B content of soil after the harvest of capsicum are presented in Table 76.

Higher DTPA extractable iron, manganese, zinc, copper and boron content of soil was observed in L_2 HA @ 90 kg ha^{-1} (20.76, 38.16, 3.24, 5.23 and 0.74 mg kg^{-1}, respectively) where as it was lower due to L_1 HA @ 60 kg ha^{-1}. There was no significant difference in the micronutrient content of soil after the harvest of capsicum due to different sources of HA application.

With respect to different treatment combinations along the control micronutrients concentration differed significantly. Treatment receiving RDF along with 90 kg $ha^{-1}$of HA extracted from poultry manure showed higher concentration of Fe (21.53 mg kg^{-1}), Mn (38.58 mg kg^{-1}), Zn (3.27 mg kg^{-1}), Cu (5.26 mg kg^{-1}) and B (0.76 mg kg^{-1}). With respect to T_1 (RDF alone) and T_2 (RDF + FYM), the results were similar as that of major and secondary nutrients content of soil and the values were Fe 11.45 mg kg^{-1}, Mn 30.71 mg kg^{-1}, Zn 2.36 mg kg^{-1}, Cu 4.51mg kg^{-1} and B 0.53 mg kg^{-1} in treatment receiving RDF alone (T_1).

The maintenance of soil organic matter in present day situation is the most important challenge of modern agriculture. The humic substances are important fraction of soil organic matter and their transformation along with interactions are important because they provide useful information on the role of humic substances on nutrient availability in soil. The effect of humic acid on soil fertility could be better expressed when there are sufficient nutrients. From the present study it was clear that there was significant build up of major, secondary and micronutrients in soil due to Ha application.

The high content of OC and CEC confers upon the soil, the capacity to hold the essential plant nutrients in sufficient amounts so as to meet the nutrient demand by crops. The increase in the nutrients status of soil in the present study may be attributed to indirect effect of stimulating microorganisms and release of native nutrients or through other interactions of HA with soil particles. The combined application of HA and NPK fertilizers, resulted in the increased nutrient availability from all the sources, there would have been complementary effect of HA on NPK fertilizers so that, their combination was found to produce marked effect on NPK availability. One of the possible reasons for increasing the available nitrogen content of soil might be due to inhibition of urease activity by HA (Vaughan and Ord, 1991), which led to reduced losses of N by volatilization and also helps in prevention of P fixation in the soil by formation of humophospho complexes (Raina and Goswami, 1988) thereby increase the available P content in soils. The release of fixed K by humic acid (Tan, 1978) may explain its increased availability. Sarwar *et al.* (2012) revealed that soil application of humic acid @ 50 mg kg^{-1} along with 100 per cent recommended dose of P fertilizer significantly

Table 76: Effect of different sources and levels of humic acid application on available micronutrient contents of soil after harvest of capsicum

	DTPA-Fe	DTPA-Mn	DTPA-Zn	DTPA-Cu	Hot water-B
	(mg kg^{-1})				
Levels (L)					
L_1	17.96	35.98	3.16	5.16	0.69
L_2	20.76	38.16	3.24	5.23	0.74
S.Em.±	0.34	0.42	0.01	0.01	0.01
CD (p=0.05)	1.09	1.31	0.05	0.04	0.02
Sources (S)					
S_1	18.67	36.43	3.18	5.17	0.70
S_2	19.45	37.15	3.20	5.19	0.72
S_3	19.95	37.64	3.23	5.22	0.73
S.Em.±	0.42	0.51	0.02	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	11.45	30.71	2.36	4.51	0.53
T_2	15.33	34.07	3.04	5.01	0.66
T_3	17.47	35.13	3.15	5.15	0.68
T_4	19.88	37.73	3.21	5.20	0.72
T_5	18.03	36.11	3.16	5.16	0.70
T_6	20.87	38.18	3.24	5.22	0.74
T_7	18.37	36.70	3.18	5.18	0.70
T_8	21.53	38.58	3.27	5.26	0.76
S.Em.±	0.51	0.75	0.03	0.04	0.01
CD (p=0.05)	1.55	2.27	0.09	0.11	0.04
Initial	**12.47**	**33.22**	**2.92**	**4.76**	**0.58**

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

increased the availability of SOM (16 %), phosphorus (60 %), potassium (4 %) and boron (34 %) more than 100 per cent RDF alone treatment.

Humic substances might have enhanced the breakdown of minerals, which inturn would have increased the nutrient availability in two ways. First, HA might have attacked the minerals and brought about their decomposition thereby releasing nutrients from a molecular state to an adsorbed state, which would have been made more readily available to higher plants. The second mechanism for increasing the availability of some nutrients would be through the formation of stable organo mineral complexes of ions such as Ca^{2+}, Fe^{2+}, Cu^{2+}, Zn^{2+} and Mn^{2+} with organic molecules. These cations are attracted from the minerals by the organic molecules and are held in complex form. Later they might become plant available form (Brady, 1996). Also in present study humic acid extracted from poultry manure with total acidity of (8.02 meq g^{-1}), pressmud (7.84 meq g^{-1}) and coffee pulp (7.68 meq g^{-1}) contain larger amount of functional groups, and gives strong complexing, chelating and surface adsorptions capacity. This helps in transforming the unavailable form of nutrients to available form.

4.5.8 Economics of capsicum crop production as influenced by different sources and levels of humic acid application

The data on economics of capsicum production are presented in Table 77.

Table 77: Economics of capsicum production as influenced by different sources and levels of humic acid

Treatments	Cost of cultivation	Gross returns	Net returns	B:C ratio
T_1	187404	592480	405076	3.16
T_2	202404	675780	473376	3.34
T_3	202201	742118	539927	3.67
T_4	209600	815100	605516	3.89
T_5	200178	750230	550020	3.75
T_6	206565	820200	613587	3.97
T_7	201101	757770	556616	3.77
T_8	207950	831150	623122	4.00

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

The benefit cost ratio has been calculated to evaluate the economics of cultivation of capsicum under different treatments imposed. The higher gross returns (Rs. 831150) was recorded in T_8 treatment receiving RDF + HA 90 kg ha^{-1} extracted from poultry manure followed by HA 90 kg ha^{-1}extracted from pressmud (Rs. 820200) and T_4 receiving RDF + HA 90 kg ha^{-1} extracted from coffee pulp (Rs. 815100). The least gross returns was recorded in T_1 receiving only RDF. Higher net returns was recorded (Rs. 623122) in T_8 followed by T_6 treatment (Rs. 613587) and T_3 (Rs. 605516). Treatment receiving RDF + FYM recorded gross returns and net income of (Rs. 675780 and Rs. 473376, respectively). The least net returns (Rs. 405076) was recorded in T_1 receiving RDF alone. The higher B: C ratio of 4.00 was recorded in T_8 receiving RDF + humic acid extracted from poultry manure followed by T_6 (3.97) receiving RDF + humic acid extracted from pressmud. Whereas the least B: C ratio (3.16) was observed in T_1 receiving RDF alone.

4.6 Field experiment II

Residual effect of humic acid application on growth of French bean and soil properties

4.6.1 Plant growth parameters

The data pertaining to residual effect of applying humic acid extracted from different sources and their levels on growth parameters of French bean viz., plant height, number of leaves and number of branches per plant are presented in Table 78 and Plate 8 and 9.

Plant height

The data on plant height of French bean at 30 DAS, 60 DAS and at harvest varied significantly due to treatments.

Application of higher level of HA i.e. @ 90 kg ha^{-1} recorded significantly higher plant height. The height of the plant ranged from 30.16 cm to 19.30 cm at 30 DAS and at harvest and found significantly higher compared to application of HA @ 60 kg ha^{-1}. There was no significant difference in plant height (cm) with different sources of HA. Among different treatment combinations differed significantly. Higher plant height of 20.04 cm, 30.08 cm and 31.04 cm at 30, 60 DAS and at harvest was recorded in treatment T_2 receiving RDF + FYM and was on par with T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). However, significant difference with respect to plant height was observed in treatment receiving HA @ 60 kg ha^{-1} with T_2 (RDF + FYM).

No. of leaves

The number of leaves per plant varied significantly at all stages (30, 60 DAS and at harvest) due to application of HA @ 60 and 90 kg ha^{-1}. The number of leaves ranged from 6.46 to 7.52, 9.07 to 10.64 and 10.68 to 12.39 at 30, 60 DAS and at harvest with application of 60 and 90 kg ha^{-1} of HA, respectively. Among different sources of HA viz., poultry manure, pressmud and coffee pulp there was no significant difference in the number of leaves was observed.

Plate 8: General view of field experiment II

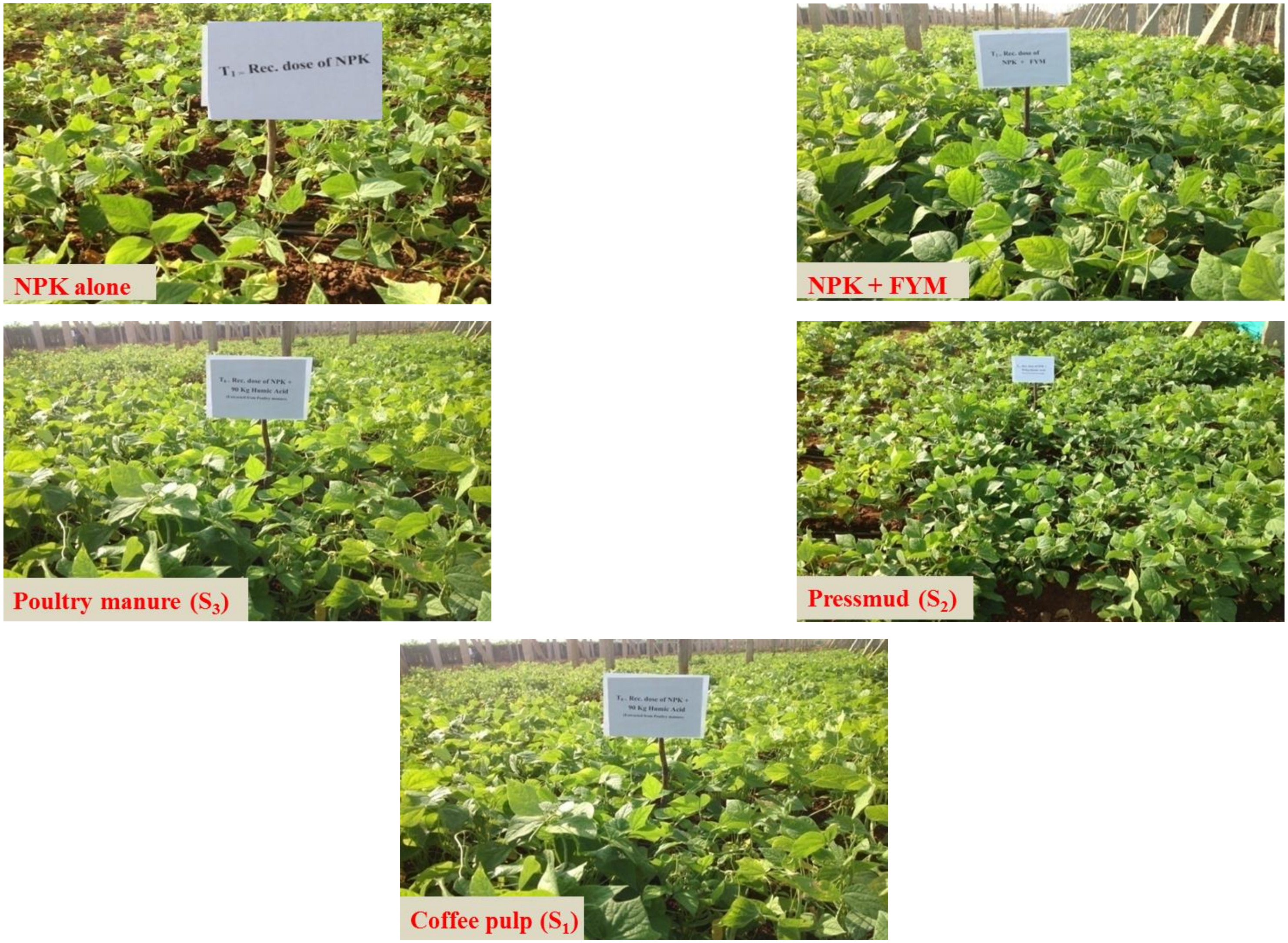

Plate 9: Growth performance of residual crop (French bean) as influenced by control and sources of HA@ 90 kg ha^{-1}

Table 78: Residual effect of different sources and levels of humic acid on plant height, number of leaves and number of branches of French bean at different intervals

	Plant Height (cm)			No. of Leaves			No. of Branches		
	30 DAS	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**
Levels (L)									
L_1	17.66	26.02	28.06	6.46	9.07	10.68	4.03	5.53	6.60
L_2	19.30	28.37	30.16	7.52	10.64	12.39	4.88	6.82	7.34
S.Em.±	0.24	0.37	0.27	0.15	0.15	0.14	0.11	0.13	0.09
CD (p=0.05)	0.75	1.17	0.84	0.47	0.49	0.46	0.34	0.40	0.27
Sources (S)									
S_1	18.21	26.73	28.49	6.75	9.53	11.28	4.40	6.10	6.79
S_2	18.46	27.04	29.19	6.93	9.83	11.58	4.44	6.18	7.01
S_3	18.77	27.82	29.65	7.30	10.21	11.74	4.54	6.25	7.11
S.Em.±	0.29	0.45	0.32	0.18	0.19	0.18	0.13	0.16	0.11
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment combinations with control									
T_1	15.58	23.43	25.42	5.36	7.59	9.34	3.08	4.38	5.66
T_2	20.04	30.08	31.04	7.75	11.02	12.83	4.98	6.97	8.05
T_3	17.34	25.51	27.68	6.10	8.63	10.38	3.94	5.44	6.39
T_4	19.08	27.94	29.30	7.40	10.43	12.18	4.85	6.75	7.20
T_5	17.68	25.78	27.89	6.30	8.93	10.68	4.00	5.54	6.66
T_6	19.25	28.30	30.50	7.55	10.73	12.48	4.87	6.82	7.35
T_7	17.97	26.79	28.63	6.99	9.66	10.97	4.15	5.60	6.74
T_8	19.57	28.85	30.67	7.60	10.76	12.51	4.92	6.90	7.47
S.Em.±	0.43	0.64	0.48	0.22	0.36	0.23	0.26	0.22	0.21
CD (p=0.05)	1.32	1.94	1.45	0.68	1.09	0.69	0.79	0.66	0.65

L_1=60 kg Humic acid, L_2=90 Kg Humic acid, $S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure NS = Non significant

$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Among treatment combinations in comparison with controls, higher number of leaves (7.75, 11.02 and 12.83) at 30, 60 DAS and at harvest in T_2 (RDF + FYM) and was on par with T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) with (7.60, 10.76 and 12.51) number of leaves at 30, 60 and at harvest followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). However, lower number of leaves was recorded in T_1 (Rec. NPK only) and the treatment receiving 60 kg ha^{-1} of humic acid was significant over T_2 (RDF + FYM), followed by T_8 (RDF + HA 90 kg ha^{-1} from poultry manure), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp).

Number of branches

Application of HA at 90 kg ha^{-1} (higher level) resulted in significant increase in number of branches (4.88, 6.82 and 7.34, respectively) at 30, 60 DAS and at harvest. However, lower number of branches (4.03, 5.53 and 6.60, respectively) was with application of HA @ 60 kg ha^{-1}.The different sources of HA did not show significant difference with respect to number of branches in French bean crop.

Number of branches, among different treatment combinations along with controls showed similar trend as that of plant height and number of leaves. The treatment receiving humic acid @ 90 kg ha^{-1} extracted from poultry manure (T_8) recorded higher number of branches (4.92, 6.90 and 7.47, respectively) at 30, 60 DAS and at harvest, while treatment receiving application of humic acid @ 60 kg ha^{-1} was found to record significantly lower plant height, number of leaves and branches compared to RDF + FYM (T_2) and application of humic acid @ 90 kg ha^{-1}.

4.6.2 Yield and yield parameters

The data number of pods per plant, fresh pod weight per plant, green pod yield (t ha^{-1}) and total dry matter (t ha^{-1}) are presented in Table 79 and Fig. 15.

Higher level of HA application i.e. 90 kg ha^{-1} recorded significantly higher in number of pods per plant (16.41), fresh pod weight per plant (76.53 g plant^{-1}), green pod yield (10.16 t ha^{-1}) and total dry matter (3.06 t ha^{-1}) while it was lower with application of HA application @ 60 kg ha^{-1}.

The different sources of HA viz., S_1 (coffee pulp), S_2 (pressmud) and S_3 (poultry manure) did not show any significant difference with respect to number of pods per plant, fresh pod weight per plant, green pod yield (t ha^{-1}) and total dry matter yield (t ha^{-1}).

The different treatment combinations receiving different sources and levels of HA, NPK + FYM and NPK alone differed significantly. Treatment T_2 (RDF + FYM) recorded 17.47 number of pods plant^{-1}, 79.46 fresh pod weight per plant (g), 11.34 (t ha^{-1}) green pod yield and 3.19 t ha^{-1} total dry matter and was on par with treatment receiving RDF + HA 90 kg ha^{-1} extracted from poultry manure (T_8) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee

Table 79: Residual effect of different sources and levels of humic acid on number of pods per plant, fresh pod weight per plant, green pod yield and total dry matter of French bean

	No. of pod per plant	**Fresh pod weight per plant (g)**	**Green pod yield (t ha^{-1})**	**Total dry matter (t ha^{-1})**
Levels (L)				
L_1	15.01	59.63	8.06	2.65
L_2	16.41	76.53	10.16	3.06
S.Em.±	0.20	1.76	0.31	0.06
CD (p=0.05)	0.64	5.55	0.97	0.19
Sources (S)				
S_1	15.48	67.75	8.90	2.80
S_2	15.70	67.90	9.02	2.85
S_3	15.96	68.60	9.19	2.91
S.Em.±	0.25	2.16	0.38	0.08
CD (p=0.05)	NS	NS	NS	NS
Treatment combinations with control				
T_1	13.24	46.51	7.86	1.96
T_2	17.47	79.46	11.34	3.19
T_3	14.74	59.33	7.87	2.60
T_4	16.21	76.18	9.87	3.01
T_5	15.02	59.29	7.97	2.65
T_6	16.37	76.51	10.06	3.05
T_7	15.27	60.28	8.16	2.69
T_8	16.64	76.91	10.23	3.12
S.Em.±	0.41	2.72	0.68	0.10
CD (p=0.05)	1.24	8.25	2.07	0.29

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

pulp). Lower values were recorded in T_1 (RDF only) with (13.24 t ha^{-1}, 46.51 t ha^{-1}, 7.86t ha^{-1} and 1.96 t ha^{-1}), respectively.

4.6.3 Nutrient content in French bean haulm

The major and secondary nutrients content of French bean haulm presented in Table 80.

Major nutrients content of French bean haulm

The nitrogen, phosphorus and potassium content in French bean haulm varied significantly and higher level of application (@ 90 kg ha^{-1}) resulted in higher N (2.01 %), P (0.23 %) and K (1.93 %). While lower concentration of N (1.79 %), P (0.20 %) and K (1.73 %) was with application of HA @ 60 kg ha^{-1}.

There was no significant difference with respect to concentration of N, P and K in French bean haulm with different sources of HA application.

The different treatment combinations along with control differed significantly. Higher concentration of N (2.04 %), P (0.23 %) and K (1.96 %) was in T_2 (RDF + FYM) followed by N, P and K content of (2.03, 0.24 and 1.95 %, respectively) in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure), followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp) with concentration of 2.01 and 1.99 per cent N, 0.23 and 0.22 per cent P and 1.93 and 1.92 per cent K, respectively in French bean haulm. Application of 60 kg ha^{-1} of HA extracted from poultry manure, pressmud and coffee pulp recorded significantly lower value compared to application of HA at 90 kg ha^{-1} and T_2 (RDF + FYM). Lower values were observed in treatment receiving RDF alone (T_1).

Secondary nutrients content of French bean haulm

Higher level of HA application i.e. 90 kg ha^{-1} (L_2) recorded significantly higher Ca, Mg and S content compared to that of L_1 (HA @ 60 kg ha^{-1} and the values were 0.49 per cent Ca, 0.27 per cent Mg and 0.31 per cent S.

The different sources of HA did not show significant difference in secondary nutrient content in haulm.

The treatment combinations along with control recorded significantly higher content of Ca (0.51 %), Mg (0.28 %) and S (0.31 %) in T_2 (RDF + FYM) followed by T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_3 (RDF + HA 90 kg ha^{-1}extracted from coffee pulp). Among treatments receiving 60 kg ha^{-1}humic acid, the HA extracted from poultry manure (T_7) recorded higher values (0.45 % Ca, 0.25 % Mg and 0.28 % S, respectively) followed by T_5 (RDF + 60 kg ha^{-1} HA extracted from pressmud) and T_3 (RDF + 60 kg HA ha^{-1} extracted from coffee pulp) and it significantly lower compared to application of HA @ 90 kg ha^{-1} and T_2 (RDF + FYM). Lower values were recorded in T_1 (RDF alone) with 0.32 per cent Ca, 0.17 per cent Mg and 0.19 per cent S, respectively.

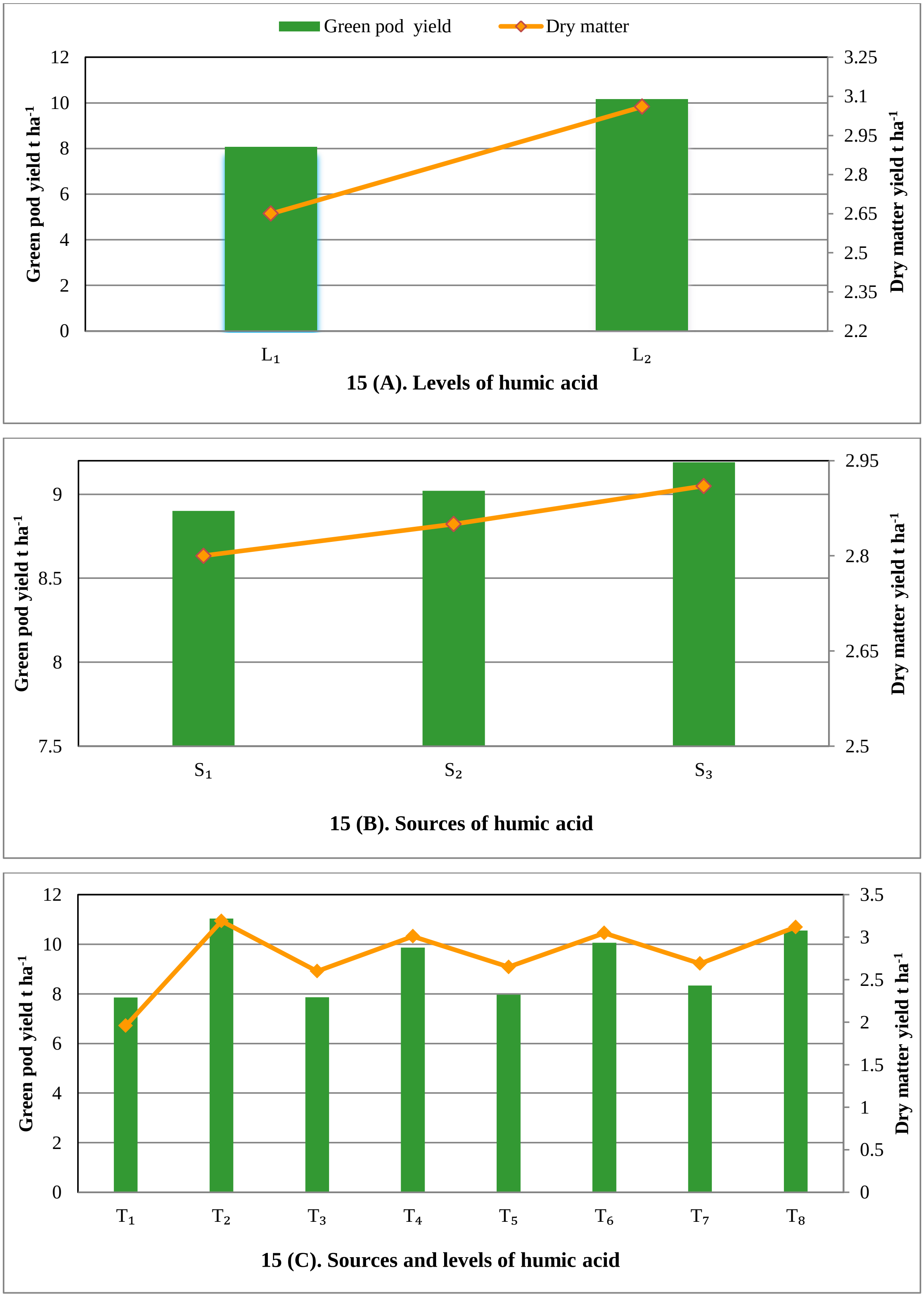

Fig. 15: Green pod yield and dry matter yield of French bean as influenced by different sources and levels of humic acid

Table 80: Residual effect of different sources and levels of humic acid on major and secondary nutrient content of French bean haulm

	N	p	K	Ca	Mg	S
	(%)					
Levels (L)						
L_1	1.79	0.20	1.73	0.44	0.24	0.27
L_2	2.01	0.23	1.93	0.49	0.27	0.31
S.Em.±	0.03	0.00	0.03	0.01	0.01	0.01
CD (p=0.05)	0.11	0.01	0.08	0.03	0.02	0.02
Sources (S)						
S_1	1.89	0.21	1.82	0.46	0.25	0.29
S_2	1.90	0.21	1.83	0.46	0.25	0.29
S_3	1.91	0.22	1.84	0.48	0.26	0.30
S.Em.±	0.04	0.00	0.03	0.01	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	1.61	0.16	1.55	0.32	0.17	0.19
T_2	2.04	0.23	1.96	0.51	0.28	0.31
T_3	1.78	0.19	1.72	0.43	0.24	0.27
T_4	1.99	0.22	1.92	0.49	0.27	0.30
T_5	1.79	0.20	1.73	0.43	0.24	0.27
T_6	2.01	0.23	1.93	0.49	0.27	0.30
T_7	1.80	0.20	1.73	0.45	0.25	0.28
T_8	2.03	0.24	1.95	0.51	0.28	0.31
S.Em.±	0.06	0.01	0.05	0.02	0.01	0.01
CD (p=0.05)	0.17	0.02	0.14	0.05	0.03	0.03

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Micronutrients content in French bean haulm

The concentration of micronutrients in French bean haulm as influenced by different sources and levels of HA application are presented in Table 81.

Application of HA @ 90 kg ha^{-1} (L_2) recorded significantly higher concentration of iron (180.69 mg kg^{-1}), manganese (67.76 mg kg^{-1}), zinc (35.61 mg kg^{-1}), copper (20.89 mg kg^{-1}) and boron (8.90 mg kg^{-1}) and it was lower when HA was applied @ 60 kg ha^{-1} (L_1).

There was no significant difference with respect to concentration of Fe, Mn, Zn, Cu and B when HA extracted from different sources was applied.

The different treatment combinations along with control showed significant differences and recorded higher concentration of Fe (184.84 mg kg^{-1}), Mn (69.32 mg kg^{-1}), Zn (35.81 mg kg^{-1}), Cu (21.27 mg kg^{-1}) and B (8.95 mg kg^{-1}) at 90 kg HA ha^{-1} extracted from poultry manure (T_8) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from pressmud). Higher values were recorded in T_2 (RDF + FYM) with 185.00 mg kg^{-1}of Fe, 69.38 mg kg^{-1} of Mn, 36.11 mg kg^{-1} of Zn, 21.33 mg kg^{-1} of Cu and 9.03 mg kg^{-1} of B, respectively and was significant compared to T_1 (RDF alone) and other treatments receiving 60 kg ha^{-1} of humic acid application

4.6.4 Nutrient content in French bean pod

The data pertaining to concentration of N, P, K, Ca, Mg and S in French bean pod are presented in Table 82.

Content of major nutrient in French bean pod

The N, P, and K content of French bean pod showed similar trend as that of haulm (leaves and stem). Higher N (3.19 %), P (0.25 %) and K (1.81 %) concentration was recorded in humic acid application @ 90 kg ha^{-1}(L_2), while it was lower in L_1 (HA @ 60 kg ha^{-1}).

The humic acid extracted from different sources did not show significant difference in the concentration of major nutrients. However, the different treatment combinations along with control showed significant differences. Higher concentration of N (3.24%), P (0.26 %) and K (1.82 %) was recorded in T_2 (RDF + FYM) followed by T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) with 3.22 per cent N, 0.26 per cent P and 1.82 per cent K, respectively followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). Lower concentration of N, P and K (2.66, 0.2 and 1.63 % N, P and K, respectively) was recorded in treatment receiving NPK only (T_1) and was found to vary significantly over different levels and sources of humic and application along with RDF + NPK treatment.

Table 81: Residual effect of different sources and levels of humic acid on micro nutrients content of French bean haulm

	Fe	Mn	Zn	Cu	B
	(mg kg^{-1})				
Levels (L)					
L_1	160.17	60.06	32.33	16.34	8.02
L_2	180.69	67.76	35.61	20.89	8.90
S.Em.±	3.43	1.28	0.51	0.16	0.13
CD (p=0.05)	10.80	4.05	1.60	0.51	0.40
Sources (S)					
S_1	167.70	62.89	33.82	18.46	8.41
S_2	169.26	63.47	33.98	18.52	8.47
S_3	174.33	65.37	34.12	18.87	8.51
S.Em.±	4.20	1.57	0.62	0.20	0.16
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	148.72	41.83	27.88	12.12	6.97
T_2	185.00	69.38	36.11	21.33	9.03
T_3	157.56	59.09	32.25	16.34	7.98
T_4	177.84	66.69	35.38	20.57	8.84
T_5	159.12	59.67	32.33	16.22	8.04
T_6	179.40	67.28	35.63	20.83	8.91
T_7	163.82	61.43	32.42	16.47	8.06
T_8	184.84	69.32	35.81	21.27	8.95
S.Em.±	6.01	2.20	0.80	0.27	0.20
CD (p=0.05)	18.24	6.67	2.44	0.82	0.61

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Table 82: Residual effect of different sources and levels of humic acid on major and secondary nutrient content of French bean pod

	N	P	K	Ca	Mg	S
	(%)					
Levels (L)						
L_1	2.85	0.22	1.68	0.53	0.28	0.28
L_2	3.19	0.25	1.81	0.60	0.33	0.34
S.Em.±	0.03	0.00	0.02	0.01	0.00	0.00
CD (p=0.05)	0.10	0.01	0.06	0.04	0.01	0.01
Sources (S)						
S_1	3.00	0.23	1.74	0.56	0.30	0.31
S_2	3.02	0.24	1.74	0.56	0.30	0.31
S_3	3.04	0.25	1.75	0.58	0.31	0.32
S.Em.±	0.04	0.00	0.02	0.01	0.00	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	2.66	0.20	1.63	0.37	0.20	0.25
T_2	3.24	0.26	1.82	0.62	0.33	0.34
T_3	2.83	0.22	1.67	0.53	0.27	0.28
T_4	3.16	0.25	1.80	0.59	0.32	0.33
T_5	2.85	0.22	1.68	0.53	0.28	0.28
T_6	3.19	0.26	1.80	0.60	0.33	0.34
T_7	2.86	0.23	1.69	0.55	0.28	0.29
T_8	3.22	0.26	1.82	0.62	0.33	0.35
S.Em.±	0.06	0.01	0.03	0.02	0.01	0.01
CD (p=0.05)	0.20	0.02	0.09	0.06	0.02	0.02

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Content of secondary nutrients in French bean pod

The Ca, Mg and S content of French bean pod differed significantly with different sources and levels of HA application.

The Ca, Mg and S concentration increased with increase in the levels of humic acid application. Higher Ca (0.60 %), Mg (0.33 %) and S (0.34 %) concentration in French bean pod was recorded in L_2 (HA @ 90 kg ha^{-1}) and lower values were recorded at 60 kg ha^{-1} (L_1). Application of different sources of HA did not have significant effect on the secondary nutrients concentration in French bean pod. The treatment combinations along with control showed significant difference. Higher concentration of secondary nutrients with (0.62, 0.33and 0.34 % of Ca, Mg and S, respectively) followed by T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). Application of HA @ 60 kg ha^{-1} differed significantly compared to T_2, T_8, T_6 and T_4 treatments. Lower concentration of Ca, Mg, S (0.37, 0.20 and 0.25 %, respectively) was recorded in T_1 (NPK only).

Micronutrients content in French bean haulm

The data on residual effect of micronutrients (Fe, Mn, Zn, Cu and B) concentration in French bean pod as influenced by different sources and levels of humic acid are presented in Table 83.

The micronutrients concentration increased with increase in levels of HA and higher values were recorded with (HA @ 90 kg ha^{-1}). The interaction effect between different sources and levels of HA was non-significant with respect to micro nutrient content in French bean pod.

Significant difference was observed between different treatment combinations along with control. The treatment receiving RDF along with FYM recorded higher content of Fe, Mn, Zn, Cu and B (225.68, 85.73, 52.50, 27.49 and 12.49 mg kg^{-1} , respectively) followed by T_8 (RDF HA 90 kg ha^{-1} extracted from poultry manure) with Fe, Mn, Zn, Cu and B (223.84, 84.73, 52.13, 26.47 and 12.51 mg kg^{-1}, respectively), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). The treatment involving humic acid application @ 60 kg ha^{-1} with different sources viz., coffee pulp (S_1), pressmud (S_2) and poultry manure (S_3) differed significantly compared to higher level of application (@ 90 kg ha^{-1}) and the treatment receiving RDF + FYM. Higher concentration of Fe (202.61 mg kg^{-1}), Mn (79.36 mg kg^{-1}), Zn (47.06 mg kg^{-1}), Cu (23.93 mg kg^{-1}) and B (10.76 mg kg^{-1}) were recorded in T_7 (RDF + 60 kg ha^{-1} HA extracted from poultry manure) followed by T_5 and T_3. Lower values were recorded in RDF alone with 185.88, 61.95, 34.62, 14.28, 8.52 mg kg^{-1}, respectively of Fe, Mn, Zn, Cu and B and this treatment showed significant variation compared to other treatments receiving over varied levels of humic acid application (60 and 90 kg ha^{-1}) and RDF + FYM (T_2).

Table 83: Residual effect of different sources and levels of humic acid on micro nutrients content of French bean haulm

	Fe	Mn	Zn	Cu	B
	(mg kg^{-1})				
Levels (L)					
L_1	202.08	78.60	46.69	23.00	10.77
L_2	222.54	83.35	51.88	26.63	12.24
S.Em.±	3.18	0.81	0.68	0.51	0.25
CD (p=0.05)	10.01	2.54	2.13	1.62	0.78
Sources (S)					
S_1	211.34	80.09	49.06	23.68	11.33
S_2	212.36	80.79	49.20	25.57	11.54
S_3	213.23	82.04	49.59	25.20	11.63
S.Em.±	3.89	0.99	0.83	0.63	0.30
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	185.88	61.95	34.62	14.28	8.52
T_2	225.68	85.73	52.50	27.49	12.49
T_3	201.57	77.88	46.69	21.19	10.73
T_4	221.12	82.30	51.43	26.16	11.94
T_5	202.06	78.58	46.33	23.88	10.82
T_6	222.66	83.01	52.08	27.27	12.27
T_7	202.61	79.36	47.06	23.93	10.76
T_8	223.84	84.73	52.13	26.47	12.51
S.Em.±	5.03	1.25	1.03	0.82	0.37
CD (p=0.05)	15.26	3.79	3.13	2.49	1.11

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

4.6.5 Nutrient uptake by haulm (stem and leaves) of French bean.

The residual effect of applying HA extracted from different organic wastes on major and secondary nutrients uptake by French bean haulm is presented in Table 84.

The uptake of major nutrients increased significantly with increase in levels of HA application. Higher N (61.41 kg ha^{-1}), P (6.76 kg ha^{-1}) and K (59.13 kg ha^{-1}) was recorded in L_2 (HA @ 90 kg ha^{-1}) and was lower in L_1 (HA @ 60 kg ha^{-1}).With respect to different sources of HA, there was no significant difference in the N, P and K uptake by French bean haulm (Fig. 16).

The different treatment combinations along with control resulted in significant difference. The treatment receiving NPK + FYM (T_2) recorded higher uptake of N (65.04 kg ha^{-1}), P (7.15 kg ha^{-1}) and K (62.62 kg ha^{-1}) followed by T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) with (63.15, 6.95 and 60.80 kg ha^{-1} of N, P and K, respectively), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). With respect to different levels of application of HA @ 60 kg ha^{-1} recorded significantly lower uptake of N, P and K compared to higher levels of HA application (@ 90 kg ha^{-1}) and treatment receiving NPK + FYM (T_2). Lower uptake was recorded in treatment receiving NPK alone (T_1) with uptake of 31.64 N kg ha^{-1}, 3.23 P kg ha^{-1} and 30.33 K kg ha^{-1}, respectively.

The uptake of Ca, Mg and S by haulm (stem and leaves) of French bean differed significantly with different sources and levels of HA application (Table 84).

Application of higher level HA 90 kg ha^{-1} resulted in significant increase in Ca (15.16 kg ha^{-1}), Mg (8.32 kg ha^{-1}) and S (9.43 kg ha^{-1}) uptake. However, lower uptake of Ca (11.59 kg ha^{-1}), Mg (6.36 kg ha^{-1}) and S (7.21 kg ha^{-1}) was observed with application of HA (@ 60 kg ha^{-1}).

The different sources of HA did not show significant difference with respect to Ca, Mg and S uptake by haulm in French bean.

With respect to different treatment combinations, treatment T_2 (NPK + FYM) recorded higher Ca (16.12 kg ha^{-1}), Mg (8.85 kg ha^{-1}) and S (10.03 kg ha^{-1}) compared to other treatments. With respect to different levels and sources T_8 (RDF + HA 90 kg ha^{-1}extracted from poultry manure) recorded higher uptake of Ca, Mg and S (15.79 kg ha^{-1}, 8.67 kg ha^{-1} and 9.82 kg ha^{-1}, respectively) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). With respect to 60 kg ha^{-1} of humic acid application the treatment T_7 (RDF + HA 60 kg ha^{-1} extracted from poultry manure) recorded 12.06 kg ha^{-1} of Ca, 6.62 kg ha^{-1} of Mg and 7.50 kg ha^{-1} of S, respectively followed by T_5 (RDF + HA 60 kg ha^{-1} extracted from pressmud) and T_3 (NPK + HA 60 kg ha^{-1} extracted from coffee pulp) and was found to vary significantly with T_2, T_8, T_6 and T_4 treatments. Lower values were recorded in T_1 (6.20 kg ha^{-1} of Ca, 3.28 kg ha^{-1} of Mg and 3.72 kg $ha^{-1}$of S, respectively).

Table 84: Residual effect of different sources and levels of humic acid on major and secondary nutrients uptake by French bean haulm

	N	P	K	Ca	Mg	S
	(kg ha^{-1})					
Levels (L)						
L_1	47.44	5.22	45.67	11.59	6.36	7.21
L_2	61.41	6.76	59.13	15.16	8.32	9.43
S.Em.±	1.13	0.22	1.09	0.53	0.29	0.33
CD (p=0.05)	3.57	0.68	3.44	1.66	0.91	1.03
Sources (S)						
S_1	53.13	5.84	51.15	12.91	7.09	8.03
S_2	54.35	5.98	52.33	13.30	7.30	8.27
S_3	55.80	6.14	53.73	13.92	7.64	8.66
S.Em.±	1.39	0.15	1.34	0.64	0.35	0.40
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	31.64	3.23	30.33	6.20	3.28	3.72
T_2	65.04	7.15	62.62	16.12	8.85	10.03
T_3	46.34	5.10	44.62	11.19	6.14	6.96
T_4	59.91	6.59	57.68	14.64	8.03	9.10
T_5	47.51	5.23	45.75	11.53	6.33	7.17
T_6	61.19	6.73	58.91	15.06	8.27	9.37
T_7	48.45	5.33	46.65	12.06	6.62	7.50
T_8	63.15	6.95	60.80	15.79	8.67	9.82
S.Em.±	1.90	0.22	1.85	0.84	0.46	0.52
CD (p=0.05)	5.78	0.66	5.60	2.56	1.40	1.59

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

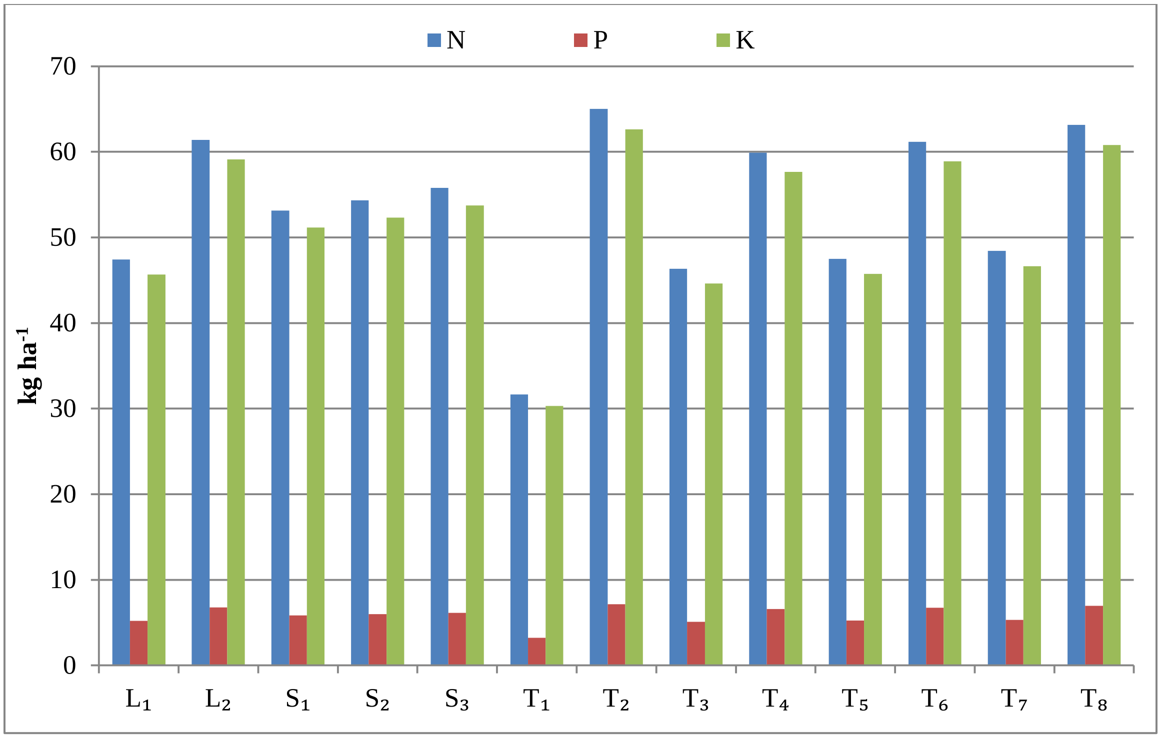

Fig. 16: N, P and K uptake by French bean haulm (stem and leaves) as influenced by different sources and levels of humic acid application

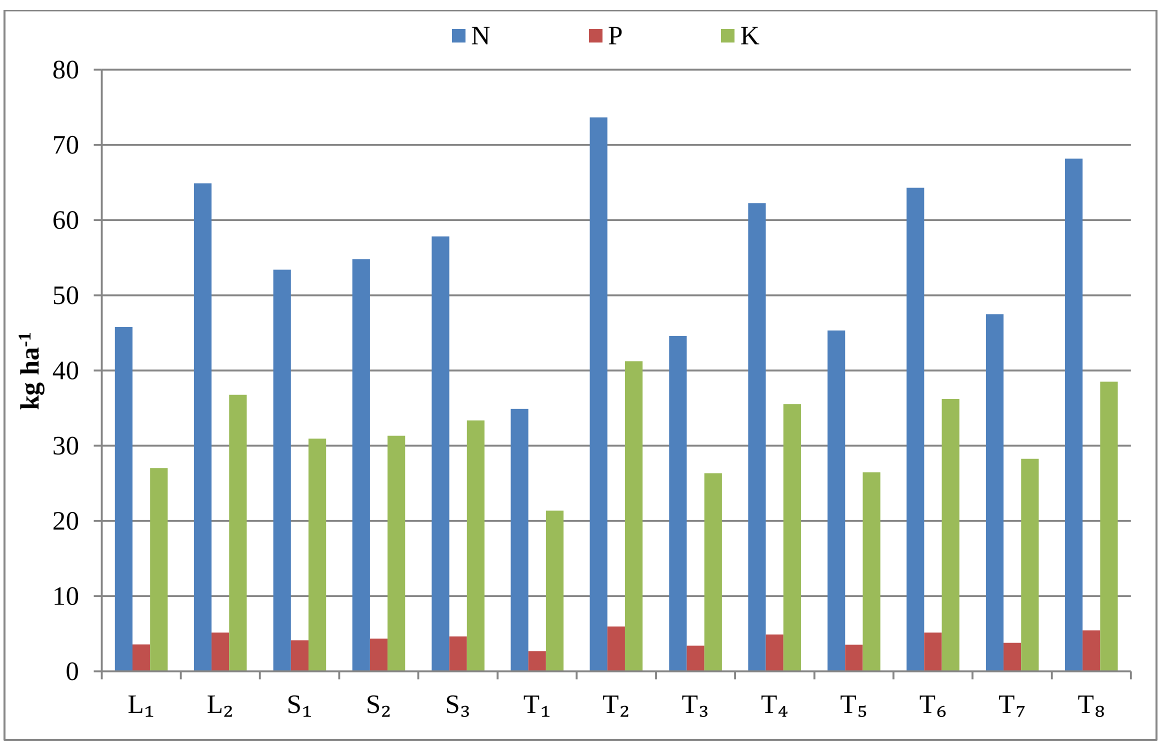

Fig. 17: N, P and K uptake by French bean pod as influenced by different sources and levels of humic acid

The uptake of micronutrients by French bean haulm as influenced by different sources and levels are presented are Table 85.

Micronutrients uptake differed significantly with application of HA @ 90 kg ha^{-1}. Higher uptake of iron (554.77 g ha^{-1}), manganese (208.04 g ha^{-1}), zinc (109.12 g ha^{-1}), copper (63.90 g ha^{-1}) and boron (27.28 g ha^{-1}) was recorded at L_2 (90 kg ha^{-1}) and it was low at L_1 (HA @ 60 kg ha^{-1}).

There was no significant difference with respect to concentration of Fe, Mn, Zn, Cu and B with different sources of HA.

The different treatment combinations comparison with two controls differed significantly and followed similar trend as that of major and secondary nutrients uptake. T_1 (NPK alone) resulted in lower uptake of Fe (291.87 g ha^{-1}), Mn (82.09 g ha^{-1}), Zn (54.68 g ha^{-1}), Cu (23.76 g ha^{-1}) and boron (13.67 g ha^{-1}).

4.6.6 Nutrient uptake by French bean pod

The major (N, P and K) and secondary (Ca, Mg and S) nutrients uptake by French bean pod with respect to different sources and levels humic acid are presented in Table 86.

The N, P and K uptake by French bean pod showed similar trend as that of haulm (stem and leaves) of French bean. Higher N (64.92 kg ha^{-1}), P (5.18 kg ha^{-1}) and K (36.77 kg ha^{-1}) uptake was recorded in L_2 (HA @ 90 kg ha^{-1}) while it was lower in L_1 (HA @ 60 kg ha^{-1}). The different sources and levels of HA application did not show significant variation in the uptake of major nutrients (Fig. 17).

The different treatment combinations along with control recorded higher uptake of N (73.67 kg ha^{-1}), P (5.96 kg ha^{-1}) and K (41.27 kg ha^{-1}) was recorded in T_2 (NPK + FYM) followed by T_8 (NPK + HA 90 kg ha^{-1} extracted from poultry manure) with uptake of 68.19 kg ha^{-1} N, 5.48 kg ha^{-1}P and 38.51 kg ha^{-1} K with respect to uptake at $L_{1,}$ application of 60 kg ha^{-1} of humic acid extracted from poultry manure (T_7) recorded higher uptake of N (47.51 kg ha^{-1}), P (3.81kg ha^{-1}) and K (28.27 kg ha^{-1}), respectively, followed by T_5 (NPK + HA 60kg ha^{-1} extracted from pressmud) and T_3 (NPK + HA 60 kg ha^{-1} extracted from coffee pulp). These values were significantly lower compared to uptake at higher level of HA application (L_2) and NPK + FYM (T_2) treated plots. Among all the treatments, lower values of (34.89 kg ha^{-1}) N, (2.69 kg ha^{-1}) P and (21.39 kg ha^{-1}) K were recorded in treatment receiving NPK alone (T_1).

Higher level of HA application i.e. 90 kg ha^{-1} (L_2), recorded significant increase in uptake of Ca (12.21 kg ha^{-1}), Mg (6.65 kg ha^{-1}) and S (6.95 kg ha^{-1}) compared to that of lower level (L_1). The different sources of HA did not show significant difference in secondary nutrients uptake by French bean pod.

Table 85: Residual effect of different sources and levels of humic acid on micro nutrients uptake by French bean haulm

	Fe	Mn	Zn	Cu	B
	(g ha^{-1})				
Levels (L)					
L_1	424.18	159.07	85.59	43.27	21.25
L_2	554.77	208.04	109.12	63.90	27.28
S.Em.±	19.25	7.22	3.20	1.20	0.80
CD (p=0.05)	60.67	22.75	10.08	3.78	2.53
Sources (S)					
S_1	472.47	177.18	95.17	52.20	23.68
S_2	486.54	182.45	97.16	53.23	24.23
S_3	509.41	191.03	99.73	55.34	24.88
S.Em.±	23.58	8.84	3.92	1.47	0.98
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	291.87	82.09	54.68	23.76	13.67
T_2	589.87	221.20	115.08	67.98	28.77
T_3	409.45	153.54	83.83	42.47	20.74
T_4	535.50	200.81	106.50	61.92	26.62
T_5	421.97	158.24	85.62	42.99	21.29
T_6	551.10	206.66	108.70	63.48	27.18
T_7	441.11	165.42	87.32	44.36	21.72
T_8	577.72	216.64	112.15	66.31	28.04
S.Em.±	31.03	11.56	4.90	1.79	1.23
CD (p=0.05)	94.13	35.07	14.87	5.42	3.74

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant

$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure

$T_{1:}$ Recommended dose of fertilizer (RDF)

T_2: RDF + FYM

$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp

$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp

$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud

$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud

$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure

$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Table 86: Residual effect of different sources and levels of humic acid on major and secondary nutrients uptake by French bean pod

	N	P	K	Ca	Mg	S
	(kg ha^{-1})					
Levels (L)						
L_1	45.82	3.59	27.03	8.56	4.46	4.57
L_2	64.92	5.18	36.77	12.21	6.65	6.95
S.Em.±	1.13	0.12	0.96	0.46	0.19	0.18
CD (p=0.05)	3.55	0.38	3.01	1.44	0.61	0.58
Sources (S)						
S_1	53.43	4.15	30.95	10.00	5.33	5.50
S_2	54.82	4.36	31.35	10.23	5.48	5.68
S_3	57.85	4.64	33.39	10.93	5.85	6.10
S.Em.±	1.38	0.15	1.17	0.56	0.24	0.22
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Treatment combinations with control						
T_1	34.89	2.69	21.39	4.87	2.58	3.21
T_2	73.67	5.96	41.27	13.99	7.54	7.78
T_3	44.61	3.41	26.35	8.26	4.29	4.42
T_4	62.26	4.89	35.55	11.73	6.38	6.58
T_5	45.34	3.55	26.47	8.44	4.41	4.50
T_6	64.30	5.17	36.24	12.01	6.54	6.85
T_7	47.51	3.81	28.27	8.96	4.68	4.78
T_8	68.19	5.48	38.51	12.89	7.02	7.42
S.Em.±	2.55	0.21	1.49	0.78	0.41	0.30
CD (p=0.05)	7.73	0.63	4.51	2.38	1.24	0.92

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
S_1= Coffee pulp, S_2= Pressmud, S_3= Poultry manure
T_1: Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
T_3: RDF + 60 kg Humic acid extracted from Coffee pulp
T_4: RDF + 90 kg Humic acid extracted from Coffee pulp
T_5: RDF + 60 kg Humic acid extracted from Pressmud
T_6: RDF + 90 kg Humic acid extracted from Pressmud
T_7: RDF + 60 kg Humic acid extracted from Poultry manure
T_8: RDF + 90 kg Humic acid extracted from Poultry manure

Similar trend was observed with respect to different combinations as that of major nutrients uptake by French bean pod. Significantly higher uptake of Ca (13.99 kg ha^{-1}), Mg (7.54 kg ha^{-1}) and S (7.78 kg ha^{-1}) was recorded in T_2 (NPK + FYM) followed by T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + 90 kg ha^{-1} HA extracted from coffee pulp). The lower level of HA application i.e. 60 kg ha^{-1} recorded significantly lower uptake compared to treatment receiving RDF + FYM (T_2) and RDF + HA 90 kg ha^{-1} extracted from different sources.

The micronutrients uptake by French bean pod as influenced by different sources and levels of HA application are presented in Table 87.

Higher concentration of iron (450.17 g ha^{-1}), manganese (169.14 g ha^{-1}), zinc (105.44 g ha^{-1}), copper (54.30 g ha^{-1}) and boron (24.86 g ha^{-1}) was recorded in L_2 (HA@ 90 kg ha^{-1}) and was lower in L_1 (HA@ 60 kg ha^{-1}). The different sources of HA did not show significant differences.

Among different treatment combinations differed significantly in uptake of micronutrients by French bean pod. Higher Fe, Mn, Cu, Zn and B uptake by French bean pod was significantly higher in T_2 (RDF + FYM). Among humic acid treatments higher Fe (465.96 g ha^{-1}), Mn (177.41 g ha^{-1}), Zn (109.87 g ha^{-1}), Cu (56.61 g ha^{-1}) and B (26.31 g ha^{-1}) was in T_8 (RDF HA + 90 kg ha^{-1} extracted from poultry manure) followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). Treatment receiving HA from different sources applied @ 60 kg ha^{-1} from different sources differed significantly compared to higher level of application L_2 (@ 90 kg ha^{-1}) and T_2 (RDF + FYM). Lower uptake of Fe (243.72 g ha^{-1}), Mn (81.20 g ha^{-1}), Zn (45.39 g ha^{-1}), Cu (18.73 g ha^{-1}) and B (11.18 g ha^{-1}) was in T_1 (RDF alone).

4.6.7 Changes in soil properties after harvest of French bean crop

Chemical properties

The residual effect of different sources and levels of humic acid application on chemical properties (pH, EC and OC) of soil after harvest of French bean crop are presented in Table 88.

There was no significant difference in pH and EC of soil due to different levels of HA application (60 and 90 kg ha^{-1}). There was a slight decrease in the organic carbon content of soil and the values were 0.82 per cent in L_1 and 0.90 per cent in L_2.The different sources of HA application did not show significant difference with respect to pH, EC and OC content of soil after harvest of French bean crop.

The different treatment combinations found non significant with respect to pH and EC. With respect to organic carbon found significant difference with treatment combinations. The Treatment receiving RDF + 90 kg HA extracted from poultry manure resulted in higher pH (6.82), EC (0.72 dS m^{-1}) and OC (0.90 %) followed by T_6, T_4, T_5, T_3, T_2, respectively. Significantly lower value of pH (6.59), EC (0.56 dS m^{-1}) and OC (0.69 %) was with T_1 (RDF alone).

Table 87: Residual effect of different sources and levels of humic acid on micro nutrients uptake by French bean pod

	Fe	Mn	Zn	Cu	B
	(g ha^{-1})				
Levels (L)					
L_1	325.67	126.10	75.15	37.06	17.39
L_2	450.17	169.14	105.44	54.30	24.86
S.Em.±	12.87	4.05	2.91	2.18	0.65
CD (p=0.05)	40.56	12.78	9.16	6.86	2.04
Sources (S)					
S_1	377.07	142.82	87.58	42.41	20.21
S_2	384.96	145.79	89.50	46.45	21.02
S_3	401.73	154.25	93.82	48.19	22.15
S.Em.±	15.77	4.97	3.56	2.67	0.79
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	243.72	81.20	45.39	18.73	11.18
T_2	511.92	194.43	119.11	62.31	28.34
T_3	317.47	122.72	73.54	33.28	16.86
T_4	436.67	162.93	101.62	51.53	23.55
T_5	322.05	124.50	74.17	38.13	17.31
T_6	447.87	167.08	104.83	54.77	24.73
T_7	337.50	131.09	77.76	39.77	17.99
T_8	465.96	177.41	109.87	56.61	26.31
S.Em.±	25.61	8.88	6.31	3.79	1.54
CD (p=0.05)	77.68	26.92	19.15	11.50	4.68

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Table 88: Residual effect of different sources and levels of humic acid on pH, electrical conductivity and OC of soil after harvest of French bean crop

	pH (1:2.5)	EC (dSm^{-1}) (1:2.5)	OC (%)
Levels (L)			
L_1	6.77	0.66	0.82
L_2	6.80	0.70	0.90
S.Em.±	0.02	0.02	0.01
CD (p=0.05)	NS	NS	0.02
Sources (S)			
S_1	6.76	0.66	0.86
S_2	6.80	0.69	0.86
S_3	6.81	0.69	0.86
S.Em.±	0.03	0.02	0.01
CD (p=0.05)	NS	NS	NS
Treatment combinations with control			
T_1	6.59	0.56	0.69
T_2	6.70	0.63	0.88
T_3	6.71	0.64	0.82
T_4	6.80	0.68	0.89
T_5	6.81	0.67	0.82
T_6	6.79	0.71	0.90
T_7	6.79	0.67	0.81
T_8	6.82	0.72	0.90
S.Em.±	0.08	0.03	0.01
CD (p=0.05)	NS	NS	0.03

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

The data pertaining to changes in available nitrogen, phosphorus and potassium content of soil after the harvest of residual crop (French bean) varied due to levels and sources of humic acid application are presented in Table 89.

After harvest of French bean crop there was decline in available major nutrients status of soil compared to main crop. Higher levels of HA application significantly recorded higher content of N (237.11 kg ha^{-1}), P (105.39 kg ha^{-1}) and K (249.68 kg ha^{-1}) at 90 kg ha^{-1} of HA (L_2) and lower values were observed in (L_1).The application of different sources of HA did not show significant difference in N, P and K content of soil.

There was significant difference among treatments with respect to available major nutrients contents of soil. Higher N (238.23 kg ha^{-1}), P (106.20 kg ha^{-1}) and K (251.30 kg ha^{-1}) was recorded in T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure followed by 236.90 kg ha^{-1} N, 105.07 kg ha^{-1} P and 249.34 kg ha^{-1} of K in T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + 90 kg ha^{-1} HA extracted from coffee pulp). The treatment receiving RDF + FYM (T_2) recorded 227.03 kg ha^{-1}, 100.60 kg $ha^{-1}$and 224.50 kg $ha^{-1}$of N, P_2O_5 and K_2O respectively and was on par with T_8, T_5 and T_3. Lower N, P and K content of soil was recorded in T_1 (210.57 kgha^{-1}) N, (97.37 kg ha^{-1}) P and (218.63 kg ha^{-1}) K. Similar was the trend observed with respect to exchangeable calcium, magnesium and available sulphur. Higher level of humic acid application treatments (L_2) recorded higher exchangeable Ca ranged from (4.94 - 5.21) cmol (p+) kg^{-1}), Mg (1.54 -1.67 cmol (p+) kg^{-1}) and available S (7.68 - 9.86 mg kg^{-1}) in L_2 @ 90 kg ha^{-1}, compared to L_1 (60 kg ha^{-1}) application. There was non-significant difference observed with respect to different sources of humic acid application.

Among different treatment combinations along with control differed significantly. Higher exchangeable Ca (5.23 cmol (p+) kg^{-1}), Mg (1.69 cmol (p+) kg^{-1}) and available S (9.91 mg kg^{-1}) was recorded in T_8 (RDF + 90 kg ha^{-1} humic acid extracted from poultry manure) followed by T_6 and T_4 receiving higher level of HA. With respect to lower level (60 kg ha^{-1})of HA application humic acid extracted from poultry manure (T_7) recorded higher Ca (4.97 cmol (p+) kg^{-1}), Mg (1.56 cmol (p+) kg^{-1}) and S (8.13 mg kg^{-1}) and was found to be on par with T_5 (RDF + HA 60 kg ha^{-1} extracted from pressmud), T_3 (RDF + HA 60 kg extracted from coffee pulp) and T_2 (RDF + FYM). Lower values 4.80 cmol (p+) kg^{-1} Ca,1.53 cmol (p+) kg^{-1} Mg and 7.02 mg kg^{-1}) of sulphur were observed in T_1 (RDF only).

Data pertaining to availability of DTPA extractable micronutrients viz., Fe, Mn, Zn, Cu and B content of soil after harvest of residual (French bean) are presented in Table 90.

Higher content of DTPA extractable iron, manganese zinc, copper and boron was observed at higher levels of HA application i.e. 90 kg ha^{-1} (L_2) while lower values were observed in L_1 (HA 60 kg ha^{-1}). With respect to different sources no significant difference was observed.

Table 89: Residual effect of different sources and levels of humic acid on available major and secondary nutrient content of soil after harvest of French bean

	Available-N (kg ha^{-1})	Available-P_2O_5 (kg ha^{-1})	Available-K_2O (kg ha^{-1})	Exch. Ca [cmol (p+) kg^{-1}]	Exch. Mg [cmol (p+) kg^{-1}]	Avail-S (mg kg^{-1})
Levels (L)						
L_1	225.28	99.44	233.34	4.94	1.54	7.68
L_2	237.11	105.39	249.68	5.21	1.67	9.86
S.Em.±	1.21	0.78	1.79	0.02	0.01	0.30
CD (p=0.05)	3.82	2.47	5.63	0.06	0.04	0.95
Sources (S)						
S_1	229.25	101.98	239.40	5.06	1.58	8.56
S_2	231.13	102.35	241.50	5.07	1.61	8.73
S_3	233.20	102.90	243.63	5.10	1.63	9.02
S.Em.±	1.48	0.96	2.19	0.02	0.01	0.37
CD (p=0.05)	NS	NS	NS	NS	NS	1.17
Treatment combinations with control						
T_1	210.57	97.37	218.63	4.80	1.53	7.02
T_2	227.03	100.60	224.50	5.05	1.59	8.57
T_3	222.30	99.07	230.40	4.92	1.51	7.31
T_4	236.20	104.90	248.40	5.19	1.66	9.81
T_5	225.37	99.63	233.67	4.94	1.54	7.60
T_6	236.90	105.07	249.34	5.20	1.67	9.86
T_7	228.17	99.61	235.97	4.97	1.56	8.13
T_8	238.23	106.20	251.30	5.23	1.69	9.91
S.Em.±	2.18	1.21	3.02	0.05	0.02	0.46
CD (p=0.05)	6.61	3.68	9.17	0.14	0.06	1.40

L_1=60 kg Humic acid, L_2=90 Kg Humic acid, $S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure NS = Non significant

$T_{1:}$ Recommended dose of fertilizer (RDF)

T_2: RDF + FYM

$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp

$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp

$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud

$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud

$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure

$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

Table 90: Residual effect of different sources and levels of humic acid on available micronutrients content of soil after harvest of French bean

	DTPA-Fe	DTPA-Mn	DTPA-Zn	DTPA-Cu	Hot water-B
	(mg kg^{-1})				
Levels (L)					
L_1	7.53	22.11	2.11	3.63	0.44
L_2	9.87	24.66	2.39	4.09	0.52
S.Em.±	0.26	0.41	0.05	0.08	0.01
CD (p=0.05)	0.82	1.30	0.15	0.25	0.03
Sources (S)					
S_1	8.37	23.12	2.23	3.83	0.49
S_2	8.75	23.38	2.25	3.84	0.50
S_3	8.97	23.65	2.28	3.91	0.50
S.Em.±	0.32	0.51	0.06	0.10	0.01
CD (p=0.05)	NS	NS	NS	NS	NS
Treatment combinations with control					
T_1	6.27	21.06	2.08	3.26	0.41
T_2	8.23	23.97	2.33	3.95	0.49
T_3	7.22	21.78	2.09	3.58	0.46
T_4	9.52	24.45	2.37	4.08	0.52
T_5	7.53	22.13	2.11	3.62	0.47
T_6	9.96	24.64	2.39	4.06	0.52
T_7	7.83	22.41	2.13	3.68	0.47
T_8	10.12	24.89	2.43	4.13	0.52
S.Em.±	0.44	0.66	0.08	0.13	0.01
CD (p=0.05)	1.33	2.02	0.24	0.39	0.04

L_1=60 kg Humic acid, L_2=90 Kg Humic acid NS = Non significant
$S_{1=}$ Coffee pulp, $S_{2=}$ Pressmud, $S_{3=}$ Poultry manure
$T_{1:}$ Recommended dose of fertilizer (RDF)
T_2: RDF + FYM
$T_{3:}$ RDF + 60 kg Humic acid extracted from Coffee pulp
$T_{4:}$ RDF + 90 kg Humic acid extracted from Coffee pulp
$T_{5:}$ RDF + 60 kg Humic acid extracted from Pressmud
$T_{6:}$ RDF + 90 kg Humic acid extracted from Pressmud
$T_{7:}$ RDF + 60 kg Humic acid extracted from Poultry manure
$T_{8:}$ RDF + 90 kg Humic acid extracted from Poultry manure

There was significant difference with respect to different treatment combinations. There was slight decrease in the micronutrients status of soil after harvest of French bean. Among treatments, higher Fe (10.12 mg kg^{-1}), Mn (24.89 mg kg^{-1}), Zn (4.13 mg kg^{-1}), Cu (2.43 mg kg^{-1}) and B (0.63 mg kg^{-1}) was recorded in treatment receiving RDF + HA 90 kg ha^{-1} extracted from poultry manure (T_8) followed by Fe (9.96 mg kg^{-1}), Mn (24.64 mg kg^{-1}), Zn (4.06 mg kg^{-1}), Cu (2.39 mg kg^{-1}) and B (0.61 mg kg^{-1}) content of soil in T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and Fe (9.52 mg kg^{-1}), Mn (24.45 mg kg^{-1}), Zn (4.08 mg kg^{-1}), Cu (2.37 mg kg^{-1}) and B (0.60 mg kg^{-1}), respectively with T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). Treatments receiving 60 kg ha^{-1} humic acid application and T_2 (RDF + FYM) showed significant difference compared to higher levels (90 kg ha^{-1} of humic acid (L_2)). Lower values of Fe (6.27 mg kg^{-1}), Mn (21.06 mg kg^{-1}), Zn (3.26 mg kg^{-1}), Cu (2.08 mg kg^{-1}) of and B (0.41 mg kg^{-1}) were recorded in treatment receiving in RDF only (T_1) and differed significantly compared to other treatments.

The growth and yield attributes of residual crop French bean viz., plant height, number of branches, number of leaves, number of pods $plant^{-1}$, dry matter yield and green pod yield was significantly higher in RDF + FYM (T_2) treated plots. This might be attributed due to the fact that application of FYM, a bulky organic manure resulted in slow decomposition and release of nutrients and the effect was found to be more pronounced in sustaining the growth and yield of residual crop compared to main crop. Narayana Reddy and Krishnaiah (1999) reported that one third of total N and K, half of P were available to first crop and rest of nutrients are available to the succeeding crop as residual effect. Application of humic acid @ 90 kg ha^{-1} was found to be on par with T_2 (RDF + FYM treated plots). The increase in French bean growth and yield parameters in treatments involving humic acid may be due to the residual effect of HA on soil properties conducive for plant growth. Humic acid through its effect on root biomass and growth helped in uptake of nutrients and due to better soil microbial activity the conversion of insoluble forms of nutrients to soluble forms slowly and thus rendering them less sensitive to losses through leaching, volatilization or fixation (Sibanda and Young, 1986). Humic acid induced increases in plant growth on sustainable basis are associated with effect on root enzymes and rhizosphere soil (Vaughan and Donald, 1985).

With respect to nutrient concentration of French bean higher nutrient concentration was recorded in T_2 (RDF + FYM) followed by HA treated plots @ 90 kg ha^{-1} and were found to be significantly different compared to application of HA @ 60 kg ha^{-1}. These results are in agreement with Warman and Termeer (2005) who found an increase in N in the forage, amended with compost in the second harvest in the second year. Mahimairaja *et al.* (1995) from their study found that organic manure applied were equally effective as urea during the second season crop. This may be the reason for increase in the N concentration in FYM treated plots.

The buildup in soil nutrient status (major and micronutrients) after the harvest of capsicum facilitated in supplying required quantity of nutrients for the growth of French bean indicating that application of HA extracted from organic wastes with higher nutrient content served as a better nutrient source in building up of nutrient status of soil which in turn was better utilized by the residual crop. Thus it can be concluded that the application of humic acid extracted from organic wastes rich in plant nutrients viz., poultry manure, pressmud and coffee pulp helped in sustaining the nutrient requirement of both main (capsicum) crop and residual (French bean) crop.

Future line of work

The present study is unique and innovative in terms of extracting the humic acid from various organic sources and using it as a concentrated to enhance soil properties. These studies or /of preliminary nature and needs to be conducted on following lines.

- Alternate methods of applying HA to soil or plant needs to be standardized.
- Fortification of HA with micronutrients and release mechanism needs to be studied.
- Enrichment of HA with major, secondary and micronutrients and mechanism of rate of release needs to be taken up.

V SUMMARY

The results of the study on “Extraction and characterization of humic acid from organic wastes, evaluation of their impact on soil properties, growth and yield of crops” conducted during 2014-2015 are summarized below:

Characteristics of organic wastes

- The organic wastes viz., coco peat, coffee pulp, pressmud, biofuel waste, distillery biocompost, sewage sludge, poultry manure, vermicompost, urban compost and farmyard manure (FYM) collected for the study were analyzed for important physical and chemical properties and the results are presented below.
- The bulk density of different organic wastes ranged from 0.22 Mg m^{-3} in coco peat to 0.69 Mg m^{-3} in biofuel waste. The water holding capacity was high in coco peat (85.50 %) and lowest (40.21 %) was in biofuel waste.
- Poultry manure (pH 8.32) and distillery biocompost (pH 8.03) were distinctly alkaline in nature while coffee pulp (pH 7.78), pressmud (pH 7.18) urban compost (pH 7.59) and FYM (pH 7.12) were slightly alkaline compared to vermi compost, sewage sludge, coco peat and biofuel waste with pH value of 6.52, 5.95, 5.68 and 5.28, respectively which were acidic to slightly acidic in nature. Electrical conductivity was high 1.59 dS m^{-1} in distillery biocompost followed by FYM 1.50 dS m^{-1}. Lower salt content with EC value of 0.99 dS m^{-1} was recorded in vermi compost. Organic carbon content was highest (40.99 %) in biofuel waste and lower organic carbon (14.13 %) was observed in sewage sludge.
- Poultry manure recorded higher total N,P K and Ca (2.85 %, 1.56 %, 1.92 % and 3.89 %, respectively) content followed by higher N and P content (2.01 % and 1.56 %, respectively) in coffee pulp. However, lowest N (0.42 %) was in FYM, P content was lowest (0.12 %) in coco peat and sewage sludge recorded lowest K (0.2 %).
- Among heavy metals the concentration of nickle was highest (41.70 mg kg^{-1}) in urban compost while the concentration of cadmium (8.75 mg kg^{-1}), lead (36.10 mg kg^{-1}) and chromium (33.91 mg kg^{-1}) was highest in sewage sludge. Lead and cadmium were not detected in other organic waste samples except sewage sludge and urban compost.
- Highest recovery of humic and fulvic acid, (8.92 and 4.21 %, respectively) was recorded in pressmud followed by poultry manure (8.20 and 3.88 % humic and fulvic acid, respectively) and coffee pulp 7.40 and 3.01 per cent humic and fulvic acid, respectively). However, least was in coco peat with 3.43 and 2.45 per cent, respectively.

Elemental compositionof humic acid extracted from organic wastes

- The humic acid extracted from biofuel wastes recorded higher carbon content (61.04 %) followed by coco peat (50.91 %) and distillery biocompost (48.48 %). With respect to hydrogen, highest (8.89 %) concentration was recorded in biofuel waste and lowest concentration (4.08 %) was observed in poultry manure. With respect to oxygen content, higher value (52.31%) was in sewage sludge followed by FYM (52.19 %) and vermicompost (47.56 %).

- Humic acid extracted from poultry manure had higher (6.01%) nitrogen content followed by pressmud (5.37 %), coffee pulp (5.07 %) and urban compost (4.95 %) while least was in FYM (2.32 %).
- The H/C ratio in different organic waste samples ranged from 0.09 to 0.15. Lower H/C ratio was observed in poultry manure (0.09) followed by coffee pulp, pressmud and urban compost and similar was the trend with N/C ratiobeing highest with (0.13) wasin poultry manure followed by pressmud (0.12), coffee pulp (0.11) and urban compost (0.11).
- The carboxyl (6.08 meq g^{-1}), phenolic hydroxyl (1.94 meq g^{-1}) groups and total acidity (8.02 meq g^{-1}) was highest in poultry manure followed by pressmud and coffee pulp. However, lower content of carboxyl (2.84 meq g^{-1}) phenolic hydroxyl group (1.32 meq g^{-1}) and total acidity (4.16 meq g^{-1}) was observed in biofuel waste.
- The E_4/E_6 ratio was highest in humic acid extracted from poultry manure (5.21) followed by pressmud (5.12), coffee pulp (5.10) and urban compost (5.10). Lower E_4/E_6 ratio (4.01) was recorded in biofuel waste.

Characteristics of humic acid extracted from organic wastes

- Humic acid samples extracted from different organic wastes were found to be acidic in reaction. The electrical conductivity of organic wastes ranged from 0.11 to 0.51 dS m^{-1}.
- The concentrations of phosphorus and potassium were highest (0.071 % and 0.25 %, respectively) in humic acid extracted from poultry manure. While it was lowest (0.026 % and 0.06 %, respectively) in humic acid extracted from biofuel waste.
- The calcium content of humic acid was highest in poultry manure (1830 mg kg^{-1}) followed by pressmud (1245 mg kg^{-1}) and coffee pulp (1090 mg kg^{-1}). With respect to magnesium, humic acid extracted from sewage sludge recorded higher Mg content (1100 mg kg^{-1}) while least was in FYM (192 mg kg^{-1}). The sulphur concentration was higher (1.96 %) in sewage sludge while it was lowest (0.57 %) in FYM.
- The concentration of Fe, Mn, Zn and Cu was more in humic acid extracted from poultry manure followed by pressmud and coffee pulpand least concentration was in biofuel waste.
- Among heavy metals, slightly higher concentrations of nickel (21.8 mg kg^{-1}) and chromium (17 mg kg^{-1}) was observed in humic acid extracted from sewage sludge. Lower concentration of nickel (8.35 mg kg^{-1}) was in biofuel waste and with that of chromium (5.50 mg kg^{-1}) was low in pressmud. The lead and cadmium were below the detection limits.

Greenhouse experiment

- In the pot experiment with maize as test crop, there was significant difference in growth parameters (plant height, number of leaves, leaf area and SPAD meter reading with application of graded levels of humic acid @ 30, 60 and @ 90 kg ha^{-1} during all the growth stages of maize (20, 40 and 60 DAS). The application of HA @ 60 kg ha^{-1} was on par with application of humic acid @90 kg ha^{-1}.

- Significantly higher shoot and root dry weight (70.45 and 15.32 g pot^{-1}, respectively) of maize was recorded with addition of humic acid @ 90 kg ha^{-1} and minimum shoot and root dry weight of 56.96 and 13.03 g plant^{-1}, respectively was recorded with humic acid @ 30 kg ha^{-1}. However, application of humic acid @ 60 kg ha^{-1} was found to be on par with application at 90 kg ha^{-1}. Significantly higher shoot (71.43 g pot^{-1}) and root (15.42 g pot^{-1}) dry weight was recorded with humic acid extracted from poultry manure (S_7). While, lower shoot and root dry weight (60.46 and 13.66 g pot^{-1}) was in biofuel waste (S_4).

- Treatment receiving NPK alone recorded lowest shoot and root dry weight of 47.99 and 11.53 g pot^{-1} compared to HA treatments. However, treatment receiving NPK + FYM was found to be on par with application of humic acid @ 30 kg ha^{-1} and recorded higher shoot (59.37 g pot^{-1}) and root (13.46 g pot^{-1}) dry weight compared to NPK alone.

- Treatment receiving RDF + humic acid extracted from poultry manure (S_7) recorded higher concentration and uptake of major, secondary and micronutrients in shoot and root of maize followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9).

- Application of HA at graded levels (@ 30, 60 and 90 kg ha^{-1}) resulted in significant increase in available major, secondary and micronutrients content in soil after harvest of maize crop.

- Application of graded levels of humic acid resulted in higher CEC (16.19 cmol (p+) kg^{-1}) @ 90 kg ha^{-1}, while it was lower (15.63 cmol (p+) kg^{-1}) with application of humic acid @ 30 kg ha^{-1}. With respect to NPK alone treatment, there was decrease in CEC (14.46 cmol (p+) kg^{-1}) over initial value, whereas NPK + FYM recorded higher CEC value of 15.79 cmol (p+) kg^{-1}.

- With respect to different sources of HA, treatment receiving RDF + humic acid extracted from poultry manure (S_7) resulted in higher nutrient status in soil followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9). While, lower nutrient contentwas in S_4 (biofuel waste).

- In the pot experiment with capsicum as test crop, application of humic acid at varied levels(@ 30, 60 and 90 kg ha^{-1}) resulted in significant difference in growth parameters, yield and soil properties.

- Treatment receiving RDF + humic acid extracted from poultry manure (S_7) performed better followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9).

- Maximum shoot and root dry weight of 43.33 and 8.08 g pot^{-1}, respectively was recorded with addition of HA @ 90 kg ha^{-1} and minimum of 25.11 and 4.34 g pot^{-1}, respectively was recorded with HA application @ 30 kg ha^{-1}. Treatment which received NPK alone recorded 20.14 and 3.74 g pot^{-1} of shoot and root dry weight. Application of NPK + FYM was found to be on par with application of humic acid @30 kg ha^{-1} with shoot (27.57 g pot^{-1}) and root (4.72 g pot^{-1}) dry weight.

- Significantly higher shoot (38.02 g pot^{-1}) and root dry weight (6.66 g pot^{-1}) was recorded in S_7 (poultry manure) followed by S_3 (pressmud), S_2 (coffee pulp) and S_9 (urban compost). Lower shoot and root dry weight of 31.63 and 5.65 g pot^{-1} was in S_4 (biofuel waste).
- Significantly higher content and uptake of major, secondary and micronutrients in shoot and root of capsicum was recorded with varied levels of humic acid application.
- With respect to different sources of HA, treatment receiving RDF + humic acid extracted from poultry manure (S_7) recorded higher concentration and uptake of major, secondary and micronutrients in shoot and root of capsicum followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9).
- Application of HA at graded levels (@ 30, 60 and 90 kg ha^{-1}) resulted in significant increase in available major, secondary and micronutrients content in soil after harvest of capsicum crop.
- Higher cation exchange capacity value (16.26 cmol (p+) kg^{-1}) was recorded with application of HA @ 90 kg ha^{-1}. While it was lower (15.69 cmol (p+) kg^{-1}) with application of HA @ 30 kg ha^{-1}. With respect to NPK alone, there was decrease in cation exchange capacity of soil (14.46 cmol (p+) kg^{-1}) over initial value of 14.8 cmol (p+) kg^{-1}.
- Treatment receiving RDF + humic acid extracted from poultry manure (S_7) resulted in higher build available of nutrients status followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9) and lower nutrient status was observed in biofuel waste (S_4).

Field experiment I

- In the field experiment with capsicum as test crop to evaluate the selected sources viz., coffee pulp, pressmud and poultry manure on growth and yield parameters showed significant difference with application of graded levels of humic acid and was non significant with respect to sources.
- Maximum fruit length, breadth and pericarp thickness was at 5th picking and the values were 10.08, 8.85 and 0.68 cm, respectively in L_2 (HA @ 90 kg ha^{-1}) compared to that of 9.57, 8.45 and 0.60 cm, respectively in L_1 (HA @ 60 kg ha^{-1}).
- Treatment receiving RDF + 90 kg HA extracted from poultry manure (T_8) resulted in increase in fruit length (10.13 cm), breadth (8.90 cm) and pericarp thickness (0.69 cm) followed by T_6 (RDF + HA 90 kg extracted from pressmud) and T_4 (RDF + HA 90 kg extracted from coffee pulp). Among T_1 (RDF) and T_2 (RDF + FYM) higher fruit length, breadth and pericarp thickness values were recorded in T_2. The values in these two treatments differed significantly compared to treatments receiving graded levels and sources of humic acid.

- HA application @ 90 kg ha^{-1} recorded significant increase in per cent fruit set (78.63), number of fruits plant^{-1} (25.10), fruit yield (2.69 kg plant^{-1}), total yield (54.81 t ha^{-1}) and dry matter yield (3.63 t ha^{-1}) while it was lowest with HA application @ 60 kg ha^{-1}. With respect to different sources of HA, there was no significant difference noticed with respect to per cent fruit set, number of fruits plant^{-1}, fruit yield (kg plant^{-1}), total yield (t ha^{-1}) and dry matter yield (t ha^{-1}).

- Different sources and levels of HA application showed higher per cent fruit set (79.53), number of fruits plant^{-1} (25.35) fruit yield (2.81 kg plant^{-1}), total yield (55.41 t ha^{-1}) and dry matter yield (3.66 t ha^{-1}) in T_8 (RDF + HA 90 kg extracted from poultry manure) followed by T_6 (RDF + HA 90 kg extracted from pressmud) and T_4 (RDF + HA 90 kg extracted from coffee pulp).

- Lower per cent fruit set (60.83), number of fruits plant^{-1} (15.96), fruit yield (1.48 kg plant^{-1}), total yield (42.32 t ha^{-1}) and dry matter yield (2.68 t ha^{-1}) was observed in treatment which received RDF alone (T_1).

- Application of humic acid at 90 kg ha^{-1} along with recommended dose of fertilizers recorded significantly higher TSS (6.36^0 Brix), ascorbic acid content (143.97 mg 100 g^{-1}) at 5th picking and ten fruit weight (1516.32, 1542.37 and 1274.87 g) at 2nd, 5th and 8th picking, respectively.

- Among different treatment combinations with control showed significant difference. Higher TSS (6.57^0 Brix), ascorbic acid (144.23 mg 100 g^{-1}) at 5th pickingand fruit weight (1568.23 g) at 5th picking was observed in T_8 (RDF + HA 90 kg extracted from poultry manure).

- Application of HA at varied levels (@ 60 and 90 kg ha^{-1}) resulted in significant increase in major, secondary and micronutrients content both in haulm (stem and leaves) and fruits of capsicum crop. However, treatment receiving humic acid extracted from different sources was found to be non significant.

- Humic acid application @ 60 and 90 kg ha^{-1} resulted in significant increase in physical and chemical properties of soil after harvest of capsicum crop.

- Decrease in bulk density (1.32 Mg m^{-3}) and increase of MWHC (40.71 %) of soil was recorded in L_2 (HA @ 90 kg ha^{-1}) while the BD was slightly higher (1.37 Mg m^{-3}) and MWHC (38.40 %), respectively in L_1 (HA @ 60 kg ha^{-1}). No significant difference was observed with application of HA extracted from different organic wastes.

- The treatment T_8 (RDF + HA 90 kg ha^{-1} extracted from poultry manure) recorded higher CEC value of 15.24 cmol (p+) kg^{-1} followed by T_6 and T_4. However application of RDF alone (T_1) resulted in lower values of CEC (12.97 cmol (p+) kg^{-1}).

Field experiment II

- In another field experiment with French bean as test crop to study the residual effect of humic acid significant difference in growth and yield was recorded with graded levels of humic acid application while there wasno significant difference with respect to sources.
- Treatment receiving RDF + FYM recorded significantly higher growth and yield parameters compared to humic acid treated plots and was found to be on par with application of HA @ 90 kg ha^{-1}.
- Treatment receiving RDF + FYM (T_2) recorded higher number of pods plant^{-1} (17.47), fresh pod weight 79.46 g^{-1} plant, green pod yield 11.34 (t ha^{-1}) and total dry matter yield of 3.19 t ha^{-1} and was found to be onpar with treatment receiving RDF + HA 90 kg ha^{-1} extracted from poultry manure (T_8). Lower values were recorded in T_1 (RDF alone) with (13.24 t ha^{-1}, 46.51 t ha^{-1}, 7.86 t ha^{-1} and 1.96 t ha$^{-1,}$ respectively).
- The major, secondary and micronutrients content in French bean haulm and pod varied significantly with higher level of application (@ 90 kg ha^{-1}).While lower was with application of HA @ 60 kg ha^{-1}. There was no significant difference with respect to HA application from different sources.
- The interaction effect between different sources and levels resulted in significant difference in major, secondary and micronutrients concentration and uptake by French bean haulm and pod. Highest values were observed in T_2 (RDF + FYM) followed by T_8 (RDF + 90 kg ha^{-1} HA extracted from poultry manure), T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + 90 kg ha^{-1} HA extracted from coffee pulp).
- Application of 60 kg ha^{-1} of HA extracted from poultry manure, pressmud and coffee pulp recorded significantly lower concentration and uptake of nutrients compared to application @ HA 90 kg ha^{-1} and T_2 (RDF + FYM). Lowest values were observed in treatment receiving RDF alone.
- After harvest of French bean crop there was decrease in availability of major, secondary and micronutrients in soil compared to the values after the harvest of main crop.
- However, application of HA @ 90 kg ha^{-1} resulted in significant increase in available major, secondary and micronutrients contents of soil after harvest of French bean crop.
- Treatment receiving RDF + HA 90 kg ha^{-1} extracted from poultry manure (T_8) recorded higher available nutrient status in soil followed by T_6 (RDF + HA 90 kg ha^{-1} extracted from pressmud) and T_4 (RDF + HA 90 kg ha^{-1} extracted from coffee pulp). Lower values were observed in T_1 (RDF alone).

Conclusion

Humic acid extracted from different organic wastes can be utilized as a nutrient rich resource for enhancing the growth, yield, quality of crops. Humic acid application @ 60 kg ha^{-1} was found to be sufficient for maize, while vegetable crops responded well, with application at 90 kg ha^{-1}. Application of humic acid extracted from different sources and applied at 60 and 90 kg ha^{-1} resulted in increased growth, nutrient uptake and buildup of soil nutrient status. Humic acid extracted from different organic wastes can be efficiently utilized as one of the best alternative source of organic manure for sustaining yield of crops and also soil health.

Practical significance of the study

Soil organic matter the “life of soil” is imperative for productive functioning of soil. With decreased availability of bulky manures use of concentrated forms such as humic acid has evolved. The humic acid poses properties of long chain functional groups, exchange surface and nutrient holding capacity. On addition to soil it enhances organic matter status and nutrient retention capacity.

The above study clearly indicates the importance of humic acid inclusion in nutrient management practices. Thus, in the future year inclusion of humic acid would be an important component in nutrient management.

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*Originals not seen

APPENDIX

Calculation of detailed cost of cultivation of capsicum hybrid Indra green grown under open field condition during *kharif*, 2015

I. Cost of infrastructure/facilities (fixed cost)

Sl. No.	Particulars	Total cost (Rs.)	Depreciated cost (Rs.) for one crop
1.	Structure/drip irrigation facilities		
a)	Structure (excluding cladding material)	0	0
b)	Cladding material	0	0
c)	Drip irrigation system @ Rs.45/m^2 for life span of 10 years (50% subsidy) therefore, Rs.22.5/m^2	22500	22500
2.	Interest on fixed cost (a, b and c) @ 18 % per annum	-	2250
3.	Repair and maintenance cost	-	460
	Total operational cost		24750

II. Cost of seedlings (ha^{-1})

Sl. No.	Spacing	Planting density	Total cost (Rs.)
1.	100 cm x 40 cm	25,000	20000

III. Cost of land preparation (ha^{-1})

Sl. No.	Particulars	Unit	Cost per unit (Rs.)	Total units used	Total cost (Rs.)
1.	FYM	Ton	600	25	15000
2.	Tractor plough and harrowing	Hour	500	9	4500
3.	Polythene mulching	Roll	1620	10	16200
4.	Labour cost	Men Women	200 Rs/day 150 Rs/day	23 8	4600 1200

IV. Cost of labours for training spraying and harvesting

Sl. No.	Type of labour	Cost per unit (Rs.)	Total cost (Rs.)
1.	Men labour-95 man days	200/day	19,000
2.	Women labour-90 man days	150/day	13,500

V. Cost of plant protection chemicals (ha^{-1})

Particulars	Unit	Cost per unit (Rs.)	Total units used	Total cost (Rs.)
a) Blitax @ 2 g lit^{-1}	Kg	500	3.0	1500
b) Z-78 @ 2 g lit^{-1}	Kg	540	4.0	2160
c) Master @ 2.5 g lit^{-1}	Kg	1100	2.0	2200
d) Confidor @ 0.5 ml lit^{-1}	Litre	3000	0.6	1800
e) DM-45 @ 2 g lit^{-1}	Kg	360	1.6	576
f) Dicofol @ 2 ml lit^{-1}	Litre	400	1.6	640

VI. Cost of fertilizers (ha^{-1})

Sl. No.	Particulars	Unit	Cost per unit (Rs.)	Total units used	Total cost (Rs.)
1.	Urea	Kg	6.8	85	578
2.	SSP	Kg	6.2	242	1500
3.	MOP	Kg	17	50	850
4.	19:19:19 All	Kg	110	390	42900
5.	KNO_3	Kg	150	102	15300
6.	$CaNo_3$	Kg	80	150	12000

VII. Cost of other inputs

Sl. No.	Particulars	Unit	Cost per unit (Rs.)	Total units used	Total cost (Rs.)
1.	Vegetable special	Kg	150	11 Kg	1650
2.	Humic acid	Kg	*	*	*

* Quantities of different humic acid and their cost varies according to the treatment

Source of humic acid	Cost kg^{-1}
Coffee pulp	246.62
Pressmud	212.90
Poultry manure	228.28

VIII. Quantity of different organic wastes required to extract 90 kg humic acid

Sl. No.	Sources	Organic waste required (t)
1.	Coco peat	2.62
2.	Coffee pulp	1.21
3.	Pressmud	1.01
4.	Biofuel waste	1.48
5.	Distillery biocompost	2.49
6.	Sewage sludge	1.85
7.	Poultry manure	1.10
8.	Vermicompost	1.81
9.	Urban compost	1.43
10.	FYM	2.16

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Effect of Different Levels and Sources of Humic Acid Extracted from Organic Wastes on Soil Properties, Growth, Yield and Nutrient Uptake by Maize

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ABSTRACT

A pot culture experiment was conducted to assess the effect of different levels and sources of humic acid extracted from different organic wastes on soil properties, growth, yield and nutrient uptake by maize during *rabi* 2014. The response of maize increased with increase in the levels of humic acid application. Higher root dry weight (15.32 g plant^{-1}) and shoot dry weight (70.54 g plant^{-1}) was recorded with application of humic acid at 90 kg ha^{-1}, which was on par with application of humic acid at 60 kg ha^{-1}. Among the humic acid extracted from different organic wastes, humic acid of poultry manure (S_7) recorded higher root and shoot dry weight (71.43 and 15.42 g plant^{-1}, respectively) followed by humic acid of pressmud (S_3) (70.51 and 15.26 g plant^{-1}, respectively), coffee pulp (S_2) (69.89 and 15.11 g plant^{-1}, respectively) and urban compost (S_9) (69.34 and15.09 g plant^{-1}, respectively). A dry matter yield of 59.37 and 13.36 g plant^{-1} was recorded in pots which received only NPK+FYM and was on par with application of humic acid at 30 kg ha^{-1} level. Lower biomass yield of maize (47.99 and 11.53 g plant^{-1}, respectively) was recorded in treatment which received NPK alone. Similar was the trend with nutrient uptake. Higher NPK content in soil after harvest of maize was recorded @ 90 kg ha^{-1} of humic acid application (312.99, 105.82 and 299.43 kg ha^{-1}) and among the humic acid sources extracted from different organic wastes the build up of N (314.84), P (111.3) and K (299.48) kg ha^{-1} was high on application of poultry manure humic acid (S_7) compared to humic acid extracted from other organic wastes. Lower nutrient content in soil was recorded in only NPK treated soils (271.01, 87.48 & 276.85 kg ha^{-1}).

HUMIC acid (HA) is the main fraction of humic substances and it is the most active component of soil organic matter. It enhances the nutrient availability and improves the physical, chemical and biological properties of soil. The direct and indirect beneficial effects of humic acid on plant growth and development is their effect on cell membranes which leads to the enhanced transport of minerals, improved protein synthesis and plant harmones. It promotes photosynthesis, modifies enzyme activities, solubility of macro and micro nutrient elements, reduces active levels of toxic minerals and increases microbial population.

In view of the above benefits of humic acid a green house pot culture study was conducted during *Rabi* 2014 at Department of Soil Science and Agril. chemistry, UAS, GKVK, to study the effect of different levels and sources of humic acid extracted from different organic wastes on soil properties, growth, dry matter yield and nutrient uptake by maize.

The study was undertaken by filling 5 kg of air dried powdered 2 mm sieved soil (0-15 cm depth) collected from farmer's field of Harohalli village, Devanahalli Taluk, Bangalore Rural district. The soil was sandy clay loam in texture with slightly acidic reaction (6.61), normal electrical conductivity (0.49 dsm^{-1}) and high in organic carbon (0.81 %). The soil was medium in available nitrogen (293.68 kg ha^{-1}) high in phosphorus (91.53 kg ha^{-1}) and medium in potassium (284.68 kg ha^{-1}). The experiment consisted of ten sources of humic acid applied at three levels and three replications in factorial CRD. The pots were treated with three graded levels of humic acid (30, 60 and 90 kg ha^{-1}) extracted from 10 different organic wastes (Table I). All treatments received 100 per cent RDF (150: 75:40 kg ha^{-1}). The pots were maintained at field capacity and Hybrid maize variety HEMA was taken as test crop. The pots which received NPK alone and NPK+FYM were considered for comparison where in no humic acid was applied. The experiment was conducted upto 60 days and in each pot a single plant was maintained. At the end of experiment plant (shoot and root) and soil samples were collected and were dried, powdered and subjected to nutrient analysis by adopting standard procedures.

The humic acid extracted from different organic wastes were subjected to elemental analysis. The elemental composition of humic acid used for pot experiment is presented in (Table I). The carbon content was found to be higher in humic acid compared to that of oxygen and hydrogen followed by nitrogen. Among different organic wastes higher carbon content (61.04 %) was noticed in HA extracted from biofuel waste whereas nitrogen content (6.07 %) was higher in HA extracted from poultry manure. Which was related to the dominant proteinaceous composition of this material. With respect to hydrogen higher value (8.29 %) was recorded in HA from biofuel waste and lower value (4.08 %) was observed in HA from poultry manure. The oxygen content was high (52.31 %) in HA extracted from sludge followed by FYM (52.19 %). The results of molar ratios of elements suggest stoichiometric relationship that exists among the elements. The N/C (0.13) and O/C (0.99) ratios were considerably high in HA extracted from poultry manure (S_7) followed by press mud (S_3), coffee pulp (S_2) and urban waste (S_9). This indicated that the acid insoluble nitrogen content increased considerably which might have enriched the humus. Further lower H/C ratios in humic acids of these organic materials suggest that polymerization or condensation takes place more, due to presence of carboxylic functional groups and oxidation of phenolic compounds with methoxy groups or aliphatic side chain in humic acid (Vila *et al.*, 1982).

Increasing the levels of HA application resulted in increase in shoot and root yield. Application of HA @ 90 kg ha^{-1} recorded significantly higher dry weight of shoot (70.45 g plant^{-1}) and root dry weight (15.32g plant^{-1}) which was on par with application of HA @ 60 kg ha^{-1} with shoot dry weight of 68.04 g plant^{-1} and 15.08 g plant^{-1} of root dry weight followed by application of HA @ 30 kg ha^{-1}. However among the HA extracted from different organic wastes, poultry manure (S_7) recorded significantly higher shoot and root dry weight (71.43 and 15.42 g plant^{-1}, respectively) followed by pressmud (S_3) (70.51 and 15.26 g plant^{-1}, respectively). Significantly lower biomass yield (47.99 and 11.53 g plant^{-1}, respectively) was recorded with application of NPK alone. Increase in biomass yield could be attributed to direct or indirect effects of HA on plant growth and development. Humic acid stimulates root growth and affects root morphology by exudation of organic acid, which leads to increase in nutrient uptake and consequently improves the growth of crop (Canellas *et al.,* 2008). However higher nitrogen (6.07 %) recorded in HA of poultry manure (S_7) also correlated for higher biomass yield compared to other sources.

Application of HA resulted in positive effect interms of increasing the nutrient content and uptake by root and shoot of maize. Higher concentration of N (0.82 and 1.80 % in root and shoot respectively), P (0.18 and 0.57 %) and K (0.99 and 2.11 %) was recorded in HA extracted from poultry manure (S_7). However, lower concentration of N (0.60 and 1.08 %), P (0.09 and 0.38 %) and K (0.73 and 1.56 %) was recorded in treatment receiving NPK alone.

Wide variation in nutrient content and uptake was associated with different sources and levels of HA application. Generally uptake increased with increasing levels of HA (Fig 1, 2 and 3). Application of HA @ 90 kg ha^{-1} resulted in increased nutrient uptake (61.64, 18.10 and 69.94 kg NPK ha^{-1}, respectively). Increased uptake of nutrients with application of higher level of HA may be due to the fact that humic substances stimulates higher microbiological activity (May hew, 2004) and thereby enhances nutrient uptake and also biomass yield.

Soil analysis (after crop harvest) indicated that soil NPK content significantly increased with the different levels and sources of HA application (Table III). Among the different levels of HA, application of HA @ 90 kg ha^{-1} resulted in significantly higher concentration of NPK in soil, (6.38, 13.5 and 4.92 % more NPK) compared to initial value. Similar results were also reported by Sharif *et al,* (2002). Among the different sources of HA higher available N content (314.84 kg ha^{-1}) of soil was observed in treatment receiving HA from poultry manure (S_7) and was probably due to high N content. Vaughan and Ord (1991) found that inhibition of urease activity by humic acid led to reduced N losses thereby increased N concentration in soil. The available P content of soil has increased significantly with different sources of HA and build up of soil P (104.45 kg ha^{-1}) was observed @ 90 kg ha^{-1}. Humic acid has the ability to reduce P

TABLE I

Elemental composition and molar ratio's of humic acid (HA) extracted from different organic wastes

Sources		Contents of elements (%)				Molar ratios elements		
		C	N	H	O	H/C	N/C	O/C
S_1	Coco peat	50.91	3.05	5.8	40.24	0.11	0.06	0.79
S_2	Coffee pulp	47.1	5.07	4.40	43.43	0.09	0.11	0.92
S_3	Pressmud	46.4	5.37	4.35	43.88	0.09	0.12	0.95
S_4	Biofuel waste	61.04	3.01	8.89	27.06	0.15	0.05	0.44
S_5	Distillery bio compost	48.48	4.09	4.91	42.52	0.10	0.08	0.88
S_6	Sludge	40.35	2.95	4.39	52.31	0.11	0.07	1.30
S_7	Poultry manure	45.06	6.01	4.08	44.85	0.09	0.13	0.99
S_8	Vermi compost	44.54	2.84	5.06	47.56	0.11	0.06	1.07
S_9	Urban compost	46.57	4.95	4.39	44.09	0.09	0.11	0.95
S_{10}	FYM	40.02	2.32	5.47	52.19	0.14	0.06	1.30

TABLE II

Influence of different sources and levels of humic acid application on dry matter yield (g plant^{-1}) of maize after 60 DAS

Treatments (Humic acid sources)	Contents of elements (%)				Root dry weight (g plant^{-1})			
	L_1	L_2	L_3		L_1	L_2	L_3	
S_1	54.28	64.42	66.45	61.72	12.64	14.62	14.82	14.03
S_2	61.00	73.27	75.39	69.89	13.63	15.75	15.94	15.11
S_3	61.33	74	76.19	70.51	13.7	15.96	16.11	15.26
S_4	53.36	62.87	65.13	60.46	12.32	14.18	14.48	13.66
S_5	54.71	65.88	68.32	62.97	12.7	14.87	15.02	14.19
S_6	54.09	64.5	67	61.86	12.65	14.67	14.91	14.08
S_7	61.97	74.25	78.07	71.43	13.83	16.01	16.4	15.42
S_8	54.51	64.75	66.83	62.03	12.65	14.39	14.9	13.98
S_9	60.30	72.54	75.17	69.34	13.6	15.74	15.93	15.09
S_{10}	54.07	63.92	65.98	61.33	12.59	14.57	14.72	13.96
Mean L	56.96	68.04	70.45	-	13.03	15.08	15.32	-
	S.Em.+	CD (p=0.05)	-		S.Em.+	CD (p=0.05)	-	-
L	1.00	2.84	-	-	0.16	0.45	-	-
S	1.83	5.18	-	-	0.29	0.82	-	-
L X S	3.17	NS	-	-	0.5	NS	-	-
NPK only	47.99	-	-	-	11.53	-	-	-
NPK + FYM	59.37	-	-	-	13.46	-	-	-

L= Levels, S= sources, L_1=30 kg Humic acid, L_2=60 Kg Humic acid, L_3=90 Kg Humic acid

S_1= Coco peat, S_2= Coffee pulp, S_3= Pressmud, S_4= Biofuel waste, S_5= Distillery bio compost, S_6= Sewage sludge, S_7= Poultry manure, S_8= Vermi compost, S_9= urban compost and S_{10}= Farmyard manure

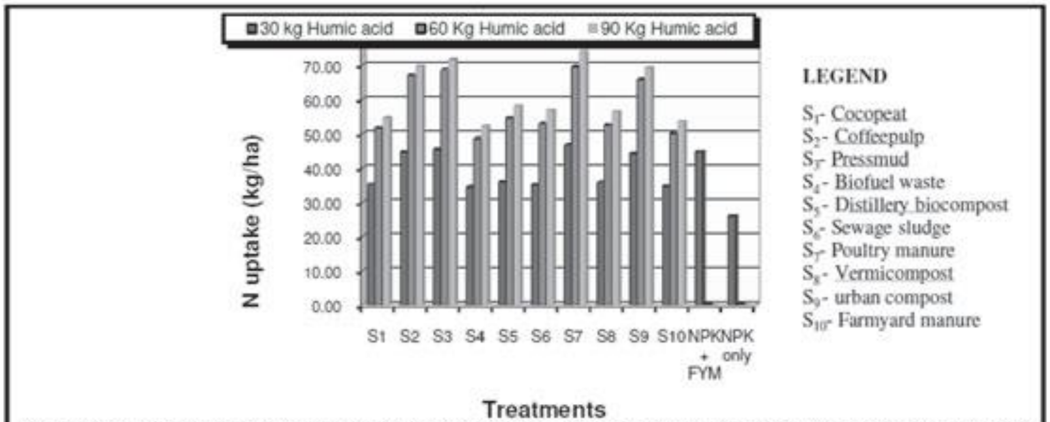

Fig. 1 : N uptake (kg /ha by maize as influenced by different levels and sources of humic acidn extracted from

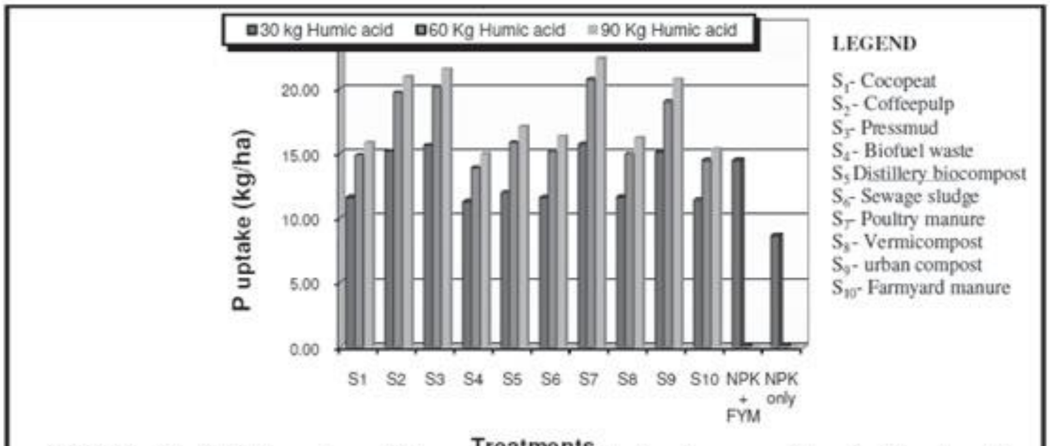

Fig. 2 : P uptake (kg/ha by maize as influenced by different levels and sources of humic acidn extracted

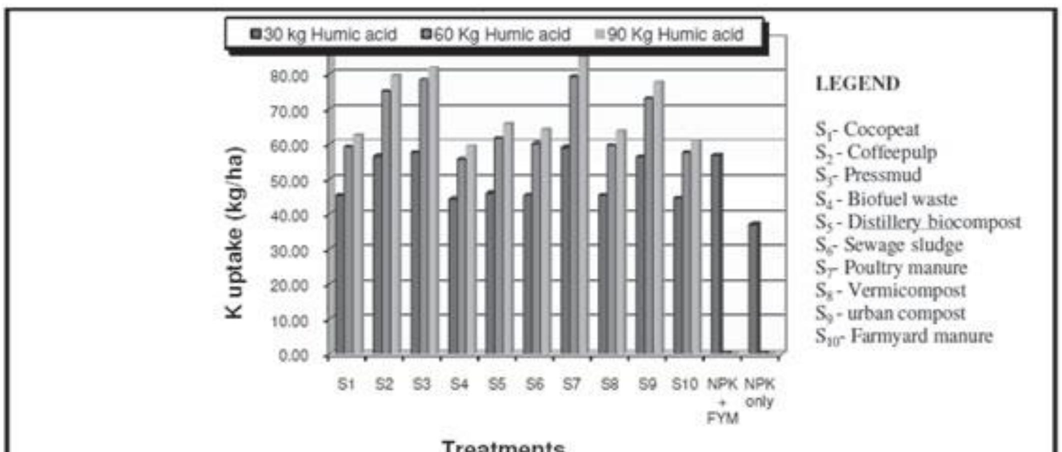

Fig. 3 : K uptake (kg /ha by maize as influenced by different levels and sources of humic acidn extracted

TABLE III

Available major nutrient status (kg ha^{-1}) of soil after harvest of maize as influenced by different sources and levels of humic acid (HA) application

Treatments (Humic acid sources)	N				P_2O_5				K_2O			
	L_1	L_2	L_3		L_1	L_2	L_3		L_1	L_2	L_3	
	30	60	90	Mean S	30	60	90	Mean S	30	60	90	Mean S
S1	302	306.07	310.7	306.26	92.83	95.64	102.17	96.88	286.63	289.48	296.15	290.75
S2	305.53	310.63	316.5	310.89	98.14	101.84	110.65	103.54	292.83	296.12	303.76	297.57
S3	306.2	311.47	317.1	311.59	98.28	102.1	111.03	103.8	293.38	296.86	305	298.42
S4	300.53	305.27	309.87	305.22	90.44	93.61	100.97	95.01	284.73	287.61	294.59	288.98
S5	302.9	307.4	311.83	307.38	94.15	97.38	104.92	98.81	287.73	290.95	297.89	292.19
S6	300.57	305.63	309.77	305.32	93.62	96.9	103.76	98.09	286.2	289.28	296.18	290.55
S7	308.8	314.53	321.2	314.84	99.16	102.9	111.3	104.45	294.37	297.83	306.26	299.48
S8	300.78	305.27	308.43	304.83	93.05	95.85	102.14	97.01	286.57	289.41	296.08	290.69
S9	305.87	310.17	316.03	310.69	98.52	101.73	109.79	103.35	292.63	295.66	303.06	297.12
S10	300.5	304.58	308.5	304.53	92.16	94.88	101.44	96.16	285.73	288.54	295.26	289.85
Mean L	303.37	308.1	312.99	-	95.03	98.28	105.82	-	289.08	292.17	299.43	-
	S.Em.+	CD(p=0.05)	-	-	S.Em.+	CD(p=0.05)	-	-	S.Em.+	CD(p=0.05)	-	-
L	0.87	2.45	-	-	0.81	2.3		-	0.89	2.52	-	-
S	1.58	4.47	-	-	1.48	4.2	-	-	1.63	4.6	-	-
L X S	2.74	NS	-	-	2.57	NS	-	-	2.82	NS	-	-
NPK only	271.01	-	-	-	87.28	-	-	-	276.85	-	-	-
NPK+FYM	304.84	-	-	-	98.42	-	-	-	292.2	-	-	-

L= Levels, S= sources, L_1=30 kg Humic acid, L_2=60 Kg Humic acid, L_3=90 Kg Humic acid

S_1= Coco peat, S_2 = Coffee pulp, S_3= Pressmud, S_4 = Biofuel waste, S_5 = Distillery bio compost, S_6= Sewage sludge, S_7= Poultry manure, S8 = Vermi compost, S_9 = urban compost and S_{10}= Farmyard manure fixation and solubilize insoluble P there by resulted in increasing P concentration in soil (Sibanda & Young, 1986). Similarly, increased soil available K (299.48 kg ha^{-1}) observed in this study may be attributed to the reduced K fixation as well as release of fixed K by humic acid (Chenghua *et al,* 2005).

The study clearly indicates that HA extracted from poultry manure (S_7) was found to be superior compared to HA extracted from other organic wastes. Among the different levels of HA, application @ 90 kg ha^{-1} was found to be superior and was on par with application @ 60 kg ha^{-1} followed by 30 kg ha^{-1}. However there was a build up in soil nutrient status with increase in the levels of HA application upto 90 kg ha^{-1} and thereby resulted in increased biomass yield and nutrient uptake.

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Evaluation of Humic Acid Extracted from Different Organic Wastes on Growth, Dry Matter Yield and Nutrient Composition of Capsicum Under Green House Condition

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ABSTRACT

A pot experiment was conducted, under green house condition at the Department of Soil Science and Agricultural Chemistry Bangalore during 2014 to study the response of capsicum to varied levels of humic acid extracted from different organic wastes. The humic acid extracted from ten different organic wastes was applied to soil at graded levels (30, 60 and 90 kg ha^{-1}) along with recommended dose of fertilizer (150:100:150 kg ha^{-1}). The pots which received NPK alone and NPK+FYM were considered as check. The treatments were replicated thrice and the design was factorial CRD. The experiment was carried out for 60 days. The effect of these treatments on plant height, chlorophyll content, dry matter production (shoot and root) and major nutrient concentration of root and shoot were studied. Results revealed that plant height, chlorophyll content and dry matter production (shoot and root) were significantly increased with increase in the levels of humic acid application. Among the humic acid extracted from different organic wastes, poultry manure (S_7) recorded higher growth parameters followed by pressmud (S_3), coffee pulp (S_2) and urban compost (S_9). The pots which received only NPK+FYM was on par with application of humic acid at 30 kg ha^{-1} level. Lower values were recorded in treatment which received NPK alone.

Key words *Humic acid (HA), organic wastes, capsicum*

Maintenance and improvement of soil quality is critical to sustain agricultural productivity and environmental quality. Increased inputs and modern technologies in vegetable production systems can often compensate for and mask losses in productivity associated with reductions in soil quality. Excessive application of chemical fertilizers may affect soil health and sustainable productivity. Addition of organic manure, which can supplement nutrient requirement of crops to some extent and also helps in the release of nutrients in gradual and controlled way thus leading to higher allowing greater production of vegetables with minor environmental impact. Use of bulky organic manures has been considered as a burden by the farmers as it requires large number of labourer for transportation and application and also a scarce commodity due to decline in cattle population. It is imperative to search for possible alternate organic source that can sustain soil health and crop production.

Humic acid (HA) is the main fractions of humic substance (HS) and the most active component of soil and organic manures. It is the active constituent of humus, which plays an important role in soil conditioning and enhancing plant growth. Many of the agro industrial units generate large quanties of organic wastes which pose problems of disposal. In this context extraction of humic acid from these agro industrial wastes would be a very valuable alternative. The industry would benefit in overcoming disposal problem. Thus humic acid derived from organic wastes like cocopeat, pressmud, coffee pulp, sewage sludge, poultry manure etc. which have substantial quantities of humic materials are of great importance in maintaining soil organic matter levels especially in the semi-arid tropics of India.

MATERIALS AND METHODS

A green house experiment was conducted at the Department of Soil Science and Agricultural Chemistry Bangalore during 2014 to study the response of capsicum to varied levels of humic acid extracted from different organic wastes on growth parameters and dry matter yield of capsicum.

A composite soil sample was collected from a farmer's field at Harohalli village, Devanahalli Taluk, Bangalore rural district and analyzed for physico-chemical properties by following standard procedure. The soil used for the study was sandy clay loam in texture, the soil was slightly acidic in reaction (pH 6.61) with low salt content (electrical conductivity of 0.49 dSm^{-1}). The organic carbon content of soil was high (0.81 per cent). With respect to major nutrients, the available nitrogen content was medium (293.68 kg ha^{-1}). The soil was sufficient with respect to DTPA extractable micronutrients (Fe, Mn, Zn and Cu) and the values were 13.55, 25.02, 2.59 and 1.33 mg kg^{-1}respectively.

The experiment consisted of ten sources of humic acids applied at three levels and three replications and the design was factorial CRD. The treatment details has been given in Table 1.

Five kg of air dried soil was filled in plastic pots. calculated quantity of humic acid powder was dissolved in a small quantity of 0.01 N potassium hydroxide solution and the pH was adjusted to 7.2. The pots were treated with graded levels of humic acid (30, 60 and 90 kg ha^{-1}) extracted from 10 different organic wastes along with recommended dose of fertilizer (150:100:150 kg ha^{-1}). The elemental composition of humic acids used for pot experiment is

Table 1. Treatment details

Treatments	Humic acid sources	L1	L2	L3
		kg ha^{-1}		
S_1	Coco peat	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_2	Coffee pulp	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_3	Pressmud	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_4	Biofuel waste	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_5	Distillery bio compost	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_6	Sewage sludge	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_7	Poultry manure	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_8	Vermi compost	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_9	Urban compost	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
S_{10}	Farmyard manure	30 + Rec. NPK	60 + Rec. NPK	90 + Rec. NPK
Only NPK				
Rec. NPK + FYM				

Note: S= sources L=levels.

presented in (Table 2). The pots which received NPK alone and NPK+FYM were considered as check since humic acid was not applied. The capsicum hybrid indra was grown as test crop. Twenty five days old capsicum seedlings were transplanted in the pots. The pots were maintained at field capacity moisture condition through out the experiment under green house condition and timely plant protection measures were followed. The growth parameters were recorded at 20, 40 and 60 days after planting and the dry matter (shoot and root dry weight) yield was recorded after harvest.

RESULTS AND DISCUSSION

The nutrient composition of humic acid extracted from different organic wastes given in Table 2. The organic carbon content was higher (61.04%) in bio fuel waste. While it was lowest (40.02 %) in sewage sludge. With respect to major nutrients poultry manure recorded higher total N,P K (6.01, 0.071 and 0.25%, respectively). However lowest N (2.32 %) was in FYM, P and K content was low (0.026 and 0.06 %, respectively) in biofuel waste.With respect to micronutrients higher concentrations 6054.5, 992.3, 148.3 and 595 mg kg^{-1} of iron, manganese, copper and zinc, respectively was observed in poultry manure. Lower concentration of 2265, 327.3, 81 and 93.5 mg kg^{-1} of iron, manganese, copper and zinc was in biofuel waste.

Plant height differed significantly with increase in the levels of humic acid application (Table 3). Higher plant height was recorded when HA was applied @ 90 kg ha^{-1} (45.79 cm) at 60 DAP and lower plant height was recorded at 20 DAP (14.12 cm) @ 90 kg ha^{-1}. However, addition of NPK alone and NPK + FYM recorded maximum plant height at 60 DAP (29.18 and 37.36 cm, respectively) and application of NPK + FYM was on par with HA application @ 30 kg ha^{-1}. Humic acid extracted from different organic wastes recorded significantly higher plant height of 44.04 cm due to S_7 (poultry manure) followed by 43.53 cm in S_3 (press

Table 2. Nutrient composition of humic acidextracted from different organic wastes

	Sources	C	N	P	K	S	Fe	Mn	Cu	Zn
		(%)					(ppm)			
S_1	Coco peat	50.91	3.05	0.038	0.08	0.96	3090.0	578.3	107.5	165.0
S_2	Coffeepulp	47.1	5.07	0.048	0.11	1.74	5645.0	795.8	140.3	378.5
S_3	Pressmud	46.4	5.37	0.061	0.15	1.80	5992.5	802.8	145.5	280.6
S_4	Biofuel waste	61.04	3.01	0.026	0.06	0.46	2265.0	327.3	81.0	93.5
S_5	Distillery bio compost	48.48	4.09	0.051	0.10	0.97	3832.0	628.0	123.3	268.8
S_6	Sludge	40.35	2.95	0.045	0.16	1.96	5053.5	528.8	127.0	474.3
S_7	Poultry manure	45.06	6.01	0.071	0.25	1.90	6054.5	992.3	148.3	595.0
S_8	Vermicompost	44.54	2.84	0.040	0.11	0.91	3345.0	515.3	118.5	263.0
S_9	Urban compost	46.57	4.95	0.038	0.15	1.30	5280.0	726.0	135.3	385.3
S_{10}	FYM	40.02	2.32	0.039	0.13	0.57	2900.0	579.8	116.3	251.0

Table 3. Plant height (cm) of capsicum at different intervals as influenced by sources and levels of humic acid

Humic acid sources	20 DAP				40 DAP				60 DAP			
	L1	L2	L3	Mean of sources	L1	L2	L3	Mean of sources	L1	L2	L3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S1	10.38	12.16	13.66	12.07	20.63	24.82	28.85	24.77	33.90	39.35	43.51	38.92
S2	11.39	13.18	14.78	13.12	23.27	27.96	31.99	27.74	37.78	43.93	48.37	43.36
S3	11.42	13.28	14.91	13.20	23.39	28.18	32.25	27.94	37.90	44.10	48.58	43.53
S4	10.14	11.76	13.26	11.72	20.17	24.43	28.01	24.20	32.95	38.76	42.86	38.19
S5	10.62	12.28	13.91	12.27	20.83	25.71	29.38	25.31	34.24	40.19	44.64	39.69
S6	10.45	12.23	13.83	12.17	20.63	24.87	29.08	24.86	34.07	39.80	44.36	39.41
S7	11.51	13.48	15.12	13.37	23.80	28.60	32.97	28.46	38.02	44.30	49.79	44.04
S8	10.64	12.23	13.76	12.21	20.76	24.77	28.86	24.80	34.13	39.57	44.10	39.27
S9	11.35	13.09	14.71	13.05	23.12	27.83	32.06	27.67	37.68	43.73	48.26	43.23
S10	10.36	11.84	13.28	11.82	20.53	24.45	28.41	24.46	33.96	39.33	43.48	38.93
Mean L	10.83	12.55	14.12		21.71	26.16	30.18		35.46	41.31	45.79	
			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)
L			0.14	0.39			0.38	1.08			0.61	1.73
S			0.25	0.71			0.70	1.98			1.12	3.16
L X S			0.43	NS			1.21	NS			1.94	NS
NPK only	9.01				18.87				29.18			
NPK + FYM	11.46				23.49				37.36			

L=Level S= Source DAP- Days after planting

S_1=	Coco peat	S_6=	Sewage sludge
S_2=	Coffee pulp	S_7=	Poultry manure
S_3=	Pressmud	S_8=	Vermi compost
S_4=	Biofuel waste	S_9=	Urban compost
S_5=	Distillery bio compost	S_{10}=	Farmyard manure

mud), 43.36 cm in S_2 (coffee pulp) and 43.23 cm in S_9 (urban compost) at 60 DAP, similar was the trend at 40 and 20 DAP. However, lower plant height (20.17, 24.20 and 38.19 cm at 20, 40 and 60 DAP respectively) was recorded with S_4 (bio fuel waste). The interaction effect between different sources and levels of HA application was non significant. The increase in plant height might be due to better cell division, cell elongation and increased physiological processes in capsicum upon application of humic acid along with chemical fertilizers. Also application of humic acid supplied essential elements which are required for plant growth and development slowly and steadily thus resulting in better utilization of nutrients by the capsicum plant. Similar observations were recorded by Harshad Thakur *et al.* (2013) in sunflower Singaravel *et al.* (1998) in sesame.

Chlorophyll content (SPAD meter reading) showed significant difference due to application of graded levels of HA extracted from different sources (Table 4). At 60 DAP, higher chlorophyll (SPAD meter reading) content (42.79) was recorded when humic acid was applied @ 90 kg ha^{-1}and it was 27.25 at 20 DAP. Application of NPK alone and NPK + FYM recorded maximum chlorophyll (SPAD reading) content at 60 DAP (34.43 and 41.90, respectively), and application of NPK + FYM was on par with HA application @ 30 kg ha^{-1}.

Humic acid extracted from different types of organic wastes influenced the chlorophyll (SPAD meter reading) content significantly and recorded higher value of 43.17 in S_7 (poultry manure) followed by 42.92 in S_3 (press mud), 42.73 in S_2 (coffee pulp) and 42.69 in S_9 (urban waste) at 60 DAP. Similar was the trend at 20 and 40 DAP. However lower chlorophyll content was recorded at 20, 40 and 60 DAP and the SPAD meter readings were 24.19, 32.31 and 40.81, respectively due to HA application extracted from bio fuel waste (S_4). The increase in chlorophyll content with graded levels of humic acid application may be due to increase in the amount of nitrogen and magnesium supplied which help to increase the leaf chlorophyll content of leaves.

Table 4. Chlorophyll content (SPAD meter reading) of capsicum leaves at different intervalsas influenced by sources and levels of humic acid

Humic acid sources	20 DAP				40 DAP				60 DAP			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	22.72	24.40	26.30	24.47	31.15	32.42	33.97	32.51	39.95	40.81	41.84	40.87
S_2	25.31	26.50	28.47	26.76	33.32	35.20	36.84	35.12	41.68	42.68	43.83	42.73
S_3	25.32	26.71	28.76	26.93	33.40	35.43	36.91	35.25	41.95	42.84	43.98	42.92
S_4	22.87	24.03	25.68	24.19	31.07	32.05	33.81	32.31	39.94	40.67	41.83	40.81
S_5	23.28	24.63	26.73	24.88	31.41	33.26	35.33	33.33	40.23	41.19	42.35	41.26
S_6	22.95	24.56	26.48	24.67	31.29	32.60	34.65	32.85	40.00	41.11	42.13	41.08
S_7	25.85	27.08	28.94	27.29	33.65	35.48	37.58	35.57	42.05	43.05	44.40	43.17
S_8	23.22	24.51	26.51	24.75	31.18	32.41	34.39	32.66	39.95	40.64	41.85	40.81
S_9	25.27	26.42	28.41	26.70	33.28	35.16	37.32	35.25	41.63	42.66	43.78	42.69
S_{10}	23.09	24.32	26.20	24.54	31.15	32.12	34.46	32.58	39.92	40.66	41.90	40.83
Mean of levels	23.99	25.32	27.25		32.09	33.61	35.53		40.73	41.63	42.79	
			S.Em.+	CD p=0.05)			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)
L			0.32	0.90			0.34	0.95			0.25	0.71
S			0.58	1.65			0.62	1.74			0.45	1.29
L X S			1.01	NS			1.07	NS			0.79	NS
NPK only	21.45				28.46				34.43			
NPK + FYM	25.64				33.27				41.90			

L=Level S= Source DAP- Days after planting

$S_{1=}$	Coco peat	$S_{6=}$	Sewage sludge
$S_{2=}$	Coffee pulp	$S_{7=}$	Poultry manure
$S_{3=}$	Pressmud	$S_{8=}$	Vermi compost
$S_{4=}$	Biofuel waste	$S_{9=}$	Urban compost
$S_{5=}$	Distillery bio compost	$S_{10=}$	Farmyard manure

Similar observations were recorded by Ferrara *et al.* (2010) who reported that application of humic acid exhibited an increase in shoot growth due to increases in nitrogen and chlorophyll contents in the leaves and higher SPAD values.

Increase in the levels of humic acid application resulted in significant increase in both shoot and root dry weight of capsicum (Table 5).Maximum shoot and root dry weight of 43.33 and 8.08 g pot^{-1} respectively was recorded with addition of humic acid @ 90 kg ha^{-1}. Minimum shoot and root dry weight of 25.11 and 4.34 g pot^{-1} respectively was recorded with humic acid application @ 30 kg ha^{-1}. Treatments which received NPK alone recorded 20.14 and 3.74 g pot^{-1} of shoot and root dry weight. Application of NPK + FYM was found to be on par with application of humic acid @30 kg ha^{-1} in terms of shoot (27.57 g pot^{-1}) and root (4.72 g pot^{-1}) dry weight.

Significant difference in dry matter yield was noticed with application of different of humic acid extracted from different organic wastes. Significantly higher shoot (38.02 g pot^{-1}) and root dry weight (6.66 g pot^{-1}) was recorded in S_7 (poultry manure) followed by shoot and root dry weight of 37.24 and 6.56 g pot^{-1} in S_3 (press mud), 36.96 and 6.50 g pot^{-1} in S_2 (coffee pulp) and 36.84 and 6.50 g pot^{-1} in S_9 (urban compost). Lower shoot and root dry weight of 31.63 and 5.65 g pot^{-1} was recorded in S_4 (biofuel waste). The increase in dry matter yield (shoot and root) with increasing levels of HA application might be due to the ability of humic acid to form stable soluble complex with nutrient metal ions which are made available to the plants over a period and also the improved root growth might be responsible for better absorption of macro and micro nutrients held by HA and improved growth and yield of crops (Dhanasekaran *et*

Table 5. Shoot and root dry matter yield (g pot^{-1}) of capsicum at harvest as influenced by sources and levels of humic acid

Humic acid sources	Shoot dry weight (g pot^{-1})				Root dry weight (g pot^{-1})			
	L_1	L_2	L_3	Mean sources	L_1	L_2	L_3	Mean sources
	30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})			
S_1	23.72	32.91	41.18	32.60	4.13	5.52	7.73	5.79
S_2	27.16	37.45	46.28	36.96	4.67	6.27	8.57	6.50
S_3	27.26	37.76	46.70	37.24	4.71	6.34	8.64	6.56
S_4	22.97	32.13	39.79	31.63	4.02	5.43	7.50	5.65
S_5	24.00	33.82	42.06	33.29	4.15	5.71	7.87	5.91
S_6	23.73	32.94	41.27	32.65	4.11	5.53	7.79	5.81
S_7	27.66	38.39	48.01	38.02	4.76	6.40	8.83	6.66
S_8	23.89	32.63	41.28	32.60	4.14	5.51	7.73	5.79
S_9	27.11	37.07	46.32	36.84	4.65	6.25	8.58	6.50
S_{10}	23.60	32.48	40.40	32.16	4.09	5.43	7.61	5.71
Mean level	25.11	34.76	43.33		4.34	5.84	8.08	
			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)
L			0.57	1.62			0.09	0.27
S			1.04	2.95			0.17	0.48
L X S			1.81	NS			0.30	NS
NPK only	20.14				3.74			
NPK + FYM	27.57				4.72			

L=Level S= Source

$S_{1=}$	Coco peat	$S_{6=}$	Sewage sludge
$S_{2=}$	Coffee pulp	$S_{7=}$	Poultry manure
$S_{3=}$	Pressmud	$S_{8=}$	Vermi compost
$S_{4=}$	Biofuel waste	$S_{9=}$	Urban compost
$S_{5=}$	Distillery bio compost	$S_{10=}$	Farmyard manure

Table 6. Nitrogen, phosphorus and potassium content (%) of capsicum shoot at harvestas influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})							
S_1	1.76	2.09	2.48	2.11	0.35	0.41	0.46	0.41	2.45	2.63	2.88	2.65
S_2	2.17	2.43	2.86	2.49	0.46	0.51	0.56	0.51	2.80	3.04	3.26	3.03
S_3	2.19	2.44	2.87	2.50	0.47	0.52	0.58	0.52	2.82	3.05	3.27	3.04
S_4	1.74	2.02	2.34	2.03	0.35	0.40	0.42	0.39	2.37	2.53	2.82	2.57
S_5	1.78	2.16	2.56	2.17	0.36	0.41	0.48	0.42	2.48	2.69	2.97	2.71
S_6	1.77	2.17	2.53	2.16	0.36	0.42	0.47	0.42	2.46	2.66	2.93	2.68
S_7	2.20	2.47	2.88	2.52	0.48	0.54	0.59	0.54	2.83	3.09	3.30	3.07
S_8	1.78	2.14	2.53	2.15	0.36	0.41	0.47	0.41	2.44	2.64	2.91	2.67
S_9	2.17	2.42	2.86	2.48	0.46	0.51	0.57	0.51	2.79	3.04	3.23	3.02
S_{10}	1.75	2.03	2.39	2.06	0.35	0.40	0.45	0.40	2.43	2.61	2.87	2.64
Mean of levels	1.93	2.24	2.63		0.40	0.45	0.51		2.59	2.80	3.05	
			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)
L			0.04	0.12			0.013	0.036			0.04	0.13
S			0.08	0.23			0.023	0.069			0.08	0.24
L X S			0.14	NS			0.04	NS			0.14	NS
NPK only	1.57				0.31				1.93			
NPK + FYM	2.20				0.48				2.83			

L=Level S= Source

$S_{1=}$	Coco peat	$S_{6=}$	Sewage sludge
$S_{2=}$	Coffee pulp	$S_{7=}$	Poultry manure
$S_{3=}$	Pressmud	$S_{8=}$	Vermi compost
$S_{4=}$	Biofuel waste	$S_{9=}$	Urban compost
$S_{5=}$	Distillery bio compost	$S_{10=}$	Farmyard manure

Table 7. Nitrogen, phosphorus and potassium content (%) of capsicum root at harvest as influenced by different sources and levels of humic acid

Humic acid sources	Nitrogen				Phosphorus				Potassium			
	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources	L_1	L_2	L_3	Mean of sources
	30	60	90		30	60	90		30	60	90	
	(kg ha^{-1})				(kg ha^{-1})				(kg ha^{-1})			
S_1	0.71	0.78	0.84	0.77	0.16	0.19	0.23	0.19	0.88	0.94	1.02	0.95
S_2	0.84	0.91	0.96	0.91	0.22	0.26	0.29	0.25	0.98	1.07	1.14	1.06
S_3	0.85	0.93	0.98	0.92	0.22	0.26	0.29	0.26	0.99	1.08	1.14	1.07
S_4	0.68	0.76	0.81	0.75	0.14	0.17	0.22	0.18	0.86	0.93	1.00	0.93
S_5	0.72	0.79	0.87	0.80	0.17	0.21	0.24	0.20	0.90	0.97	1.06	0.97
S_6	0.72	0.79	0.86	0.79	0.17	0.20	0.24	0.20	0.89	0.96	1.04	0.96
S_7	0.86	0.95	1.00	0.93	0.23	0.27	0.31	0.27	0.99	1.09	1.16	1.08
S_8	0.70	0.78	0.85	0.78	0.16	0.19	0.23	0.19	0.89	0.96	1.03	0.96
S_9	0.84	0.91	0.97	0.91	0.22	0.26	0.29	0.26	0.98	1.06	1.14	1.06
S_{10}	0.70	0.76	0.84	0.77	0.15	0.20	0.23	0.19	0.87	0.97	1.02	0.95
Mean of levels	0.76	0.84	0.90		0.18	0.22	0.26		0.92	1.00	1.08	
			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)			S.Em.+	CD (p=0.05)
L			0.016	0.045			0.008	0.022			0.013	0.037
S			0.029	0.083			0.013	0.039			0.022	0.066
L X S			0.051	NS			0.024	NS			0.041	NS
NPK only	0.65				0.12				0.81			
NPK + FYM	0.86				0.21				0.98			

L=Level S= Source

$S_{1=}$	Coco peat	$S_{6=}$	Sewage sludge
$S_{2=}$	Coffee pulp	$S_{7=}$	Poultry manure
$S_{3=}$	Pressmud	$S_{8=}$	Vermi compost
$S_{4=}$	Biofuel waste	$S_{9=}$	Urban compost
$S_{5=}$	Distillery bio compost	$S_{10=}$	Farmyard manure

al. (2008)). Sezer Sahin *et al.* (2014) reported that dry matter yield of tomato increased with increase in the levels of HA upto 120 mg kg^{-1}, significant increase in shoot and root fresh weight of okra by the application of lignite humic acid along with recommended fertilizer was observed by Kirn *et al.*(2010).

The chemical composition of capsicum (shoot and root) i.e. nitrogen, phophorus and potassium in shoot and root improved significantly with increased levels of humic acid (Table 6&7). Application of HA resulted in positive effect interms of increasing the nutrient content by root and shoot of capsicum. Higher concentration of N (0.93 and 2.52 % in root and shoot respectively), P (0.27 and 0.54 %) and K (1.08 and 3.07 %) was recorded in HA extracted from poultry manure (S_7). However, lower concentration of N (0.75 and 2.03 %), P (0.18 and 0.39 %) and K (0.93 and 2.57 %) was recorded in treatment receiving NPK alone. The enhancing affect of HA on N,P and K concentrations may be due to better development root systems (David *et al.*(1994)), increased the permeability of plant membranes (Ulukan (2008)). Furthermore, humic substances may interact with the phospholipids structures of cell membranes and react as carriers of nutrients through them. These results are in agreement with those obtained by El-Ghamry *et al* (2009).

Humic acid extracted from poultry manure, pressmud, coffee pulp and urban compost recorded higher growth parameters and dry matter yield due to higher nutrient composition and presence of different functional groups of humic molecules which form complexes with metals These findings are in conformity with Livens (1991). The functional group encourages movement of cations in soils and serves as natural chelate in soils.

CONCLUSION

The results revealed that application of HA @ 90 kg ha^{-1} was found to be superior and resulted in higher growth, biomass yield and nutrient content. Humic acid extracted from different organic wastes can be efficiently utilized as one of the best alternative source of organic manure for sustaining yield of crops and also soil health.

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