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REVIEW OF LITERATURE

Sustainability in agriculture with respect to maintenance of soil fertility and stabilized crop production is the main concern in the present situation. Ever increasing cost of energy would be an important constraint for increased use of chemical fertilizers in crop production. Use of organic manures to meet the nutrient requirement of crop would be an inevitable practice in years to come for sustainable agriculture since organic manures generally improve the soil physical, chemical and biological properties and thus result in enhanced crop productivity along with maintaining the quality of crop produce.

The given literature pertaining to the influence of organic amendments such as composted paddy and coffee husk their influence on the growth, biochemical properties and yield of selected crops and the influence of these manures on leghaemoglobin content, soil fertility, antibacterial and anti oxidant activity are reviewed and presented in this chapter.

2.1 REVIEW ON COMPOSTING, BIOMETRIC, BIOCHEMICAL ANALYSIS AND YIELD PARAMETERS

Kumaresan *et al*., (2003) described that composting is a method of solid waste treatment where by the organic component of the solid waste is biologically degraded under controlled condition to supply plant nutrients without any detrimental effects on the environment and to crop to which applied.

Compost is considered as a valuable soil amendment for centuries. Composting is the decomposition of plant remains and other living materials to make the substance excellent for soil and crop growth. Use of compost in agriculture increases and acts as alternative to land filling for the management of biodegradable waste as well as means of increasing or preserving soil organic matter and nutrients. Composting is a biological process, in which heat is produced as a byproduct of microbial breakdown of organic matter. Composting process is completed both mainly by two processes degradation by fungi, bacteria and actinobacteria (physically and biochemically) and synthesis of stabilized humic substances (Kadalli *et al*., 2004; Sharma, 2016). Generally, successful composting depends on a number of factors that have both direct and indirect influence on the activities of the microorganisms. They include the type of raw material being composted, its nutrient composition, moisture content, temperature, acidity or alkalinity and aeration. The microorganisms that do lot of the work need high temperature, plenty of oxygen, and moisture (Taiwo and Oso, 2004). Lee *et al*., (2004) found that the application of food waste compost has increased the populations of fungi, bacteria in the compost and significantly increased the growth of lettuce.

Arancon and Edwards, (2005) have observed the application of vermicomposts in the field, enhanced the quality of soils by increasing microbial activity and microbial biomass which are key components in nutrient cycling, production of plant growth regulators and protecting plants soil-borne disease and arthropod pest attacks. Mastouri *et al*., (2005) reported that the potential of two agricultural waste composts, Tea Waste Compost (TWC) and Tree Bark Compost (TBC) as soil amendments has increased the growth of lettuce.

Ogunlela *et al*., (2005) stated that the organic manure is an important resource for crop production and soil sustainability; it is a source of almost all essential plant nutrients. It also provides an excellent source of organic matter when added to soils, restoring some organic matter depleted by many agricultural practices, and they found in their work cumulative number and yield of green pods increased significantly with the rates of cattle manure application in okra on semiarid and subtropical environment.

Ashwini and Sridhar, (2006) have reported in their experiments finger millet grown on areca compost has shown the highest shoot and root lengths and also FYM + areca and FYM + mixed litter composts have shown increased shoot length and total dry matter yield in black gram. Kabbashi *et al*., (2006) reported that the bio-composting process by solid-state bioconversion utilizing Palm Oil Mill Effluent (POME) and Empty Fruit Bunch (EFB) with the inoculation of microorganisms likes *Phanerochaete chrysosporium*, *Trichoderma harzianum*, *Aspergillus niger*, *Penicillium* sp helped to achieve good compost.

Masood, (2006) stated that compost is not only an alternative to chemical fertilizers or manure but is also one of nature's best protective covering to increase the soil's water holding capacity in clay as well as sandy soils.

Mixing of organic manures applied at the rate of 100 Mg ha^{-1} to the soil has increased Fe between 5 % in chicken manure (PM), 71% in cattle manure (CM), Zn increased between 312 % CM and 871 % in swine manure and Mn between 61 % in PM and 172 % in SM, Cu between 327% in PM and 978 % in SM. and increased the yield of rice (Eneji *et al*., 2001; Naeem *et al*., 2006).

Organic manures are generally of two types-bulky organic manures and concentrated organic manures. The manures that are applied in large quantities and contain low amount of plant nutrients are known as bulky organic manures such as farmyard manure, compost, night soil etc and concentrated organic manures contain higher percentage of major plant nutrients than bulky organic manures. Manure of application relatively enhances more labile organic carbon in the soil (Sleutel *et al*., 2006).

Kabashi *et al.*, (2007) investigated that the simple composting process using selected substrates, POME and empty fruit bunch plus wheat flour as a co substrate along with the strains of *P. chrysosporium, T. harzianum, A. niger* and *Penicillium* decreased the organic matter (OM) about 3 % while total nitrogen content initially at 0.744 g/g increased to 2.96 g/g. The C/N ratio and germination index (GI) achieved were 17 and 95 % respectively.

Roberts *et al*., (2007) reported that application of vermicompost was added to peat-based compost at rates of 0 %, 10 %, 20 %, 40 % and 100 % and it resulted in total fruit yield, marketable fruit yield, fruit number, individual fruit weight and vitamin C concentration were unaffected by the presence of vermicompost, but it may provide a viable alternative to peat-based growth media, overall, the results are found to be little added benefit from using vermicompost. Shilev *et al*., (2007) reported that using food and agricultural mature composted products resulted in improved soil properties and associated plant growth; it builds sound root structure, reduced plant stress from drought and frosts, improved nutritional content of food grown in compost-rich soils.

Iovino *et al*., (2008) conducted experiments on biodegradation of poly (lactic acid) /starch /coir biocomposites under controlled composting conditions and concluded with the evidences of SEM analyses of the compost aged samples. SEM micrographs showed the formation of patterns and cracks on the surface of the materials aged in the compost and it is proved profound loss of structure. Moreover, an extended biofilm was detected on the biodegraded materials, thus it indicated the growth of a large number of bacteria and fungi on their surfaces.

Parthasarathi *et al*., (2008) conducted experiments with clay loam, sandy loam and red loam soil and evaluated the efficacy of vermicompost on the physico-chemical and biological characteristics of the soils and on the yield and nutrient content of *Vigna mungo*, in comparison to inorganic fertilizers NPK. It was found vermicompost increased the pore space, reduced particle and bulk density, increased water holding capacity, cation exchange capacity, reduced pH and electrical conductivity, increased organic carbon content, available nitrogen, phosphorous, potassium and microbial population and activity in all the soil types, particularly clay loam.

Sanjutha *et al*., (2008) reported that application of FYM @ 15 t/ha + NPK @ 75:75:50 Kg/ha + Panchagavya @ 3 % foliar spray significantly influenced the plant height, number of branches and leaves, nutrient (NPK) content uptake, total dry matter production and quality characters in *Andrographis paniculata*. Recently organic farming is becoming an important component for environmentally sound and sustainable agriculture.

Baharuddin *et al*., (2009) viewed the structure of oil palm empty fruit bunch and partially treated palm oil mill effluent before and during composting treatment under SEM which showed the surface structure of the untreated shredded empty fruit bunch consisting of firmly bound threads of lignin with smooth surface along the structure, while the outer surface of treated empty fruit bunch has been altered with the presence of many holes indicating the lignin has been disrupted. Gopal *et al*., (2009) identified the amplification of plant beneficial microbial communities during conversion of coconut leaf substrate to vermicompost by *Eudrilus* sp.and the population of fungi was more in the coconut leaf vermicompost (17 9 10^4 CFU g^{-1}) *Trichoderma* population in pure Cow Manure (CMV) (6 9 10^3 CFU g^{-1}).

Manivannan *et al*., (2009) reported that the application of sugarcane trash and bagasse vermicpompost has enhanced the physico chemical properties of clay loam soil and sandy loam soil along with the growth, yield and nutrient content of *Phaseolus vulgaris*. The results of Sen and Chandra, (2009) revealed that composting of sugar industry wastes, made up of pressmud, trash, bagasse and dried cattle manure in 7:1:1:1 w/w ratio, during composting bacterial counts indicated a steady decrease in biological activity and population, whereas vermicomposting exhibited higher activity on day 30 and a reduction in bacterial counts on day 10.

Ansari and Kumar, (2010) have observed that the combination of vemicompost, and vermiwash influenced plant growth parameters in okra (*Abelmoschus esculentus*), and the average yield during trial recorded greater response in comparison with the control by 64.27%. Bustamante *et al*., (2010) stated that the composts obtained from industrial waste showed suitable physico-chemical and chemical properties for their use as organic amendment and a good degree of stability and maturity. Huerta *et al*., (2010) reported that (*Panicum sp* + grass-cocoa husks) vermicompost (V) enhanced the weight (23.4 g), height (26.7 cm) and production of leaves per plant (20.6 leaves) in Tabasco, Amashito pepper (*Capsicum annum var. glabriusculcum*). Joshi and Vig, (2010) investigated that the cattle dung vermicompost (VC) with 3 treatments VC15 (Soil+15 % VC), VC30 (Soil + 30 % VC), VC45 (Soil + 45 % VC) increased *Lycopersicum esculentum* plant height (cm) in all the 3 treatments (VC15, VC30 and VC45) found to be 63 cm, 63.4 cm and 63.5 cm respectively.

Reghuvaran and Ravindranath, (2010) reported that 75 % coir pith compost along with 25% garden soil yielded significant growth of medicinal plants *Andrographis paniculata, Bacopa monneiri* and *Piper longum.* Singh *et al*., (2010) reported that biocomposting of extracted peppermint plant residue (*Mentha piperita)* using red worms (*Eisenia fetida)* on the growth of *Vigna mungo* (Urad) noticed that the bio-compost transformed from 1:3 waste: dung medium when mixed with soil in 1:3 ratio used as growing medium, increased the shoot length of *Vigna mungo* (28.2 cm). Veeresh *et al*., (2010) investigated the effect of conversion of agroindustrial waste to manure through rapid vermicomposting and revealed that the inoculation of a biodynamic consortium (*jeevamrutha*) to organic substrates enhanced the bacterial and actinomycete densities than treatments including cow dung and control groups.

Baharuddin *et al.*, (2011) reported that pressed-shredded Empty Fruit Bunches (EFB) and palm oil mill effluent (POME) anaerobic sludge from a 500 m3 closed anaerobic digester system was utilized for the co-composting treatment. Scanning Electron Microscopy (SEM) analysis showed that the shredding-pressing treatment on EFB gave better results in removing the debris and silica bodies as compared to only shredding treatment. However, similar characteristics were detected in both physically-treated EFB samples by Fourier transform infrared (FTIR) analysis, mainly in the regions of 900 to 1740 and 2800 to 3400 cm^{-1}.

Kasthuri *et al*., (2011) conducted pot culture experiments with the application of municipal solid waste compost (MSWC) amendments (0, 50, 100, 250, 500, 750 and 1000 g) with garden soil (6 kg) on the growth and the yield of green gram (*Vigna radiata* (L) wilczek) and fenugreek (*Trigonella foenum-graecum* L.) they were enhanced by MSWC application upto 500g. Raphael and Velmourougane, (2011) conducted experiments on coffee pulp vermicomposting with exotic (*Eudrilus eugeniae*) and native earthworm (*Perionyx ceylanesis*), it was concluded that the microbiological properties of vermicasts from exotic and native earthworms were different. Bacteria (185.7 CFU 9 10^4/g), fungi (48.7CFU 9 10^4/g) and yeast (152.7 CFU 9 10^4/g) population found to be higher in the vermicasts from the native earthworms as compared to exotic, while the actinomycetes (38.0 CFU 9 10^4/g) counts found to be higher with the vermicasts of exotic worms.

Azarpoor *et al*., (2012) found that the highest seed yield was obtained in soybean from $N_2V_3D_2$ treatment (seeds inoculated with nitroxin, 10 t/ha vermicompost application and 65 plants per m^2) with 3831 kg/ha. Gezahegn *et al*., (2012) observed that vermicomposting of vegetable waste + cow dung, Coffee husk waste + cow dung, Enset waste (*Ensete ventricosum*) + cow dung and Khat waste (*Catha edulis*) + cow dung along with epigeic earthworm *Eisenia andrei* has increased the total phosphorus (TP) 58.9 % - 73.2 %, total K 29.6 - 43.6 % ca 39.6 - 61.5 % TOC showed decrease between 35 - 38.4 % and C:N ratio reduced between 60 - 68 %. Gobi and Gunasekaran, (2012) concluded that application of vermicompost of sugar factory pressmud (PM) using two different species of earthworms, *Eudrilus eugeniae* and *Lampito mauritii*, which showed vigorous production of black gram, where *Eudrilus* compost applied pots showed maximum yield (17.59 g) which was 93.72 % yield increase over control.

Basheer and Agrawal, (2013) stated that application of vermicompost produced from the mixture of garden waste and cow dung using *Eudrilus eugeniae* significantly increased the tomato plant height (2 - 2.9 cm), number of leaves (37 - 45) and fruit weight (450.43 – 570.87 Kg) as compared to control. Prakash and Hemalatha, (2013) recorded maximum microbial population of bacteria, fungi and actinomycetes on 15th, 30th, 45th and 60th day in vermicompost (leaf litter (Teak) 3 Kg + Cow dung 1:1 ratio + *Eisenia fetida*). Ranjan *et al*., (2013) reported that combined application of vermicompost (1.92 kg/bed) + *Biospirillum* (10 ml/kg of seed) + Biophos (10 ml/kg of seed) + Biopotash (10 ml/kg of seed) sustained yield (18.57 q/ha), chlorophyll ‘a’ (3.055 mg/g), chlorophyll ‘b’ (0.556 mg/g) and ‘total’ chlorophyll (3.627 mg/g) of baby corn under the north-west Himalayan conditions. Selvamurugan *et al*., (2013) reported that the application of bio methanated distillery spent wash and pressmud biocompost (BDS @ 100 m^3 ha^{-1}) compared to recommended NPK as chemical fertilizers on groundnut registered higher pod, grain and haulm yield of 1774, 1272 and 4668 kg ha^{-1}, respectively and the increase was to the tune of 35.83, 43.57 and 46.01 %, respectively over control.

Badar and Qureshi, (2014) investigated the effects of composted rice husk (5 and 26; 10 g/2 kg of soil/pot) on growth and biochemical parameters of sunflower plants. Results showed the improvement in biochemical parameters total chlorophyll (36 to 41 %), carbohydrate (46 to 243 %), crude protein (239 %), on 30th day. Dharani and Sarojini, (2014) suggested that the composting of coirpith using bacteria (*Pseudomonas* and *Streptococci)* and fungi (*Aspergillus* and *Rhizopus*) influenced the growth and productivity of sugarcane plant by 80 %. Nattudurai *et al.*, (2014) reported that vermicomposting of coirpith with cowdung by *Eudrilus eugeniae* have increased N, P and K and C:N ratio was dramatically decreased and it enhanced the growth of *Cyamopsis tetragonaloba.*

Senthil Kumar *et al*., (2014) evaluated the changes of surface morphology and functional groups in the control and vermicompost using scanning electron microscope and revealed more fragments and pores are found in vermicompost than control. Varghese and Prabha, (2014) revealed that the application of (jackfruit waste (*Artocarpus heterophyllus*) + cow dung in 3:1 ratio and *Eudrilus eugeniae*) vermiwash increased protein (75 mg) and carbohydrate (55 mg) in *Capsicum frutescens*.

Joshi *et al*., (2015) stated that the application of vermicompost increases the seed germination, stem height, number of leaves, leaf area, leaf dry weight, root length, root number, total yield, number of fruits/plant, chlorophyll content, micro and macro nutrients, carbohydrate and protein content and improved the quality of the fruits and seeds.

Kannahi and Ramya, (2015) observed that the application of biofertilizer (*Azospirillum*), vermicompost and biocompost on the seedling of *Lycopersicum esculentum* has enhanced chlorophyll a (12, 0453, 0.0345 mg), chlorophyll b (0.0598, 0.0389, 0.299 mg), total chlorophyll (0.0678, 0.0452, 0.355 mg), carbohydrate (6.643, 4.69, 6.397 mg) and protein (4.620, 4.367, 5.620 mg). Ramya *et al*., (2015) recorded that application of 1.5 % of seaweed liquid extract of *Stoechospermum marginatum* to brinjal plant enhanced total chlorophyll pigments, (77 %), protein (38 %), reducing sugar (201%), ascorbic acid (36 %) and nitrate reductase activity (159 %).

Beykkhormizi *et al*., (2016) reported that under salt stress, 10 % of vermicompost increased the photosynthetic rate and concentrations of potassium (K^+) and calcium (Ca^+) in leaf and root tissues of *Phaseolus vulgaris.* Lim and Wu, (2016) recorded that SEM images confirmed palm oil mill by product vermicompost higher surface area with no long fibers (fragmented nature) and FT-IR spectra showed decomposition of carbohydrates, reductions in band height at the 3100-3600 cm^{-1} region. Olle, (2016) revealed that the application of 25 % vermicompost, peat, gravel, concrete block on tomato plant have enhanced the number of leaves (54.3) and growth.

Baliah and Muthulakshmi, (2017) reported that application of vermicompost + *Azospirillum brasilense* has increased the total chlorophyll (4.86 mg/g LFW), carotenoid (2.46 mg/g LFW) protein (15.28 mg/g LFW) and amino acids (12.61 mg/g LFW) in *Abelmoschus Esculentus.* Bhat *et al*., (2017) stated that SEM as a powerful magnification technique with focused beams of electrons obtains surface information by providing the essential data on surface morphology of vermicompost and FT-IR spectroscopy technique confirms the decomposition process of polypeptides, polysaccharides, aliphatic, aromatic, carboxylic, phenolic groups and lignin during vermicomposting process. Choudhary *et al*., (2017) revealed that application of FYM @ 5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} significantly increased *Sesamum indicum* plant height, number of capsules per plant, number of seeds per capsule, seed and stalk yield over rest of the treatments.

Ali and Kashem, (2018) stated that the highest yield (42.12 t ha^{-1}) of cabbage was obtained when planted with 392 - 330 - 150 -133 - 8 - 5 kg ha^{-1} of urea -TSP - MoP Gypsum-Zinc sulphate-Solubor boron (BFRG - 2012) + vermicompost (5 t ha^{-1}). Canatoy, (2018) found that the application of full RRIF (recommended rate of inorganic fertilizer) + 1 ton vermicompost ha^{-1} has influenced the plant height of sweet corn at 20 DAS (44.58 cm) as well as the yield with the highest number of ears (48820 ha^{-1}). Hosseinzadeh *et al*., (2018) evaluated the photosynthesis, physiological and biochemical responses of chickpea under water deficit stress and use of vemicompost fertilizer revealed that vermicompost fertilizer had a positive effect on physiological, biochemical, and photosynthetic responses of chickpea under non-stress and moderate stress conditions, but no positive effect was determined under severe water stress.

Khatua *et al*., (2018) reported that the FTIR spectra revealed the reduction of polypeptides, polysaccharides, aromatic structures and extensive mineralization of organic compounds during the final stage of decomposition during vermicomposting of banana stem waste using *Eisenia fetida*. Patil *et al*., (2018) recorded in their work that 20:80 combination of coir waste and cow dung showed the best micronutrients contents between the two species of earthworms, *Eudrilus euginae* species of earthworm found superior over *Eisenia fetida* in respect of most of the manurial value parameters studied. Thiyageshwari *et al*., (2018) observed that composting RRH with 2 % lignocellulolytic fungus (Raw Rice Husk + *Aspergillus* sp.) increased the nutrient content (NPK) and decreased the OC content and the SEM images showed the epidermis of rice husk became loose, rugged and lumpy because the composition of RRH viz., cellulose, hemicellulose, lignin and pectin were decomposed by microbial penetration.

Ganguly and Chakraborthy, (2019) assessed the maturity of paper mill sludge vermicompost and found that a sharp decline in C/N ratio of primary and secondary sludge initially 132.19 and 91.60 respectively, which finally found 12.06 and 6.58. FTIR spectroscopy indicated the degradation of vermicompost for both the sludges which displayed an intense wide band in between 3200 -3500 cm^{-1} which indicates an –OH stretching of acid, phenols and alcohols group. Gul *et al*., (2019) investigated that combined application of (urea 75 g + *Rhizobium japonicum* 2.5 g) enhanced the chlorophyll 'a' (1.34 mg/g Fw), chlorophyll 'b' (0.44 mg/g Fw) and total chlorophyll (1.78 mg/g Fw) contents in cluster bean plant.

Kiran, (2019) reported that the application of vermicompost (at 2.5 and 5 %) on lettuce (*Lactuca sativa* var. crispa) plants under drought stress conditions have showed higher shoot height, shoot fresh weight, relative water content, stomatal conductance, chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid contents. Mahmud *et al*., (2019) reported that the application of commercial vermicompost (10 t ha^{-1}) promoted chlorophyll 'a' (1.866 µg/g) chlorophyll 'b' (5.496 µg/g), total chlorophyll (7.362 µg/g) and chlorophyll a/b ratio (0.340 µg/g) in pineapple (*Ananas comosus* (L.) Merr.).

Saha *et al*., (2019) conducted experiment with the integrated application of biochar (5 t ha^{-1}) from lemon grass and chemical fertilizer (CF) (60:20:40 NPK kg ha^{-1}) on *Andrographis paniculata* and observed that it has influenced the growth parameters and yield (140.8 g $plant^{-1}$). Singh *et al*., (2019) conducted experiments on mango ginger (*Curcuma amada* Roxb.) with the application of municipal solid waste vermicompost increased the photosynthetic pigments i.e., chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoids contents in treatment 4 (75 % VC and 25 % sodic soil) as well as total carbohydrate in T5 (100 % VC and 0 % sodic soil). Zou and Yang, (2019) stated that SEM images of rice husk ash obtained by combustion of rice husk the major parts retained their original shape, but small parts of rice husk ash suffered structural damage. Both the external and internal surfaces of rice husk ash have a dense structure, resulted in showing the exterior and interior surface of rice husk ash compact membrane without any micropores.

Mahmud *et al*., (2020) revealed that the application of vermicompost (10 t·ha^{-1}) has increased the fruit extracts of ex vitro MD2 pineapple plants higher chlorophyll 'a' (0.977 µg/g), chlorophyll 'b' (3.094 µg/g) and total chlorophyll contents (4.071 µg/g) than from other treatments. Srivastava *et al*., (2020) observed through the FT-IR spectra the disappearance of polysaccharides, carbohydrates and aliphatic methylene from the initial waste mixture while aromatic compounds, nitro group and humic structures appeared in municipal solid waste vermicompost depicting its stability and maturity also discovered through SEM images (4000x) the compacted and flock like structure of the initial waste mixture and more porous, fragmented and granular structure of the vermicompost. Yassen *et al*., (2020) conducted experiments with the foliar application of vermiwash (4 ton fed^{-1} + Vermiwash 150 ml/ L foliar application) has enhanced the plant height (38.11cm) number of leaves (44.67) leaf area (290 mm^{2}) fresh matter of leaves (425.58 g /plant), dry matter of leaves 87.10 g /plant), total yield (19.06 ton/Fed) in lettuce plant vermicompost at 4ton Fed^{-1} + Vermiwash 150 ml/ L foliar application).

Jarboui *et al*., (2021) investigated in the non-aerated fermented extract (NFCE) and found that it contains low EC and relatively high carbon content (COD = 9700 mg/l) and intense microbial activity, especially mesophilic bacteria. With the increase of 225, yeasts by 25 and molds by 10 times compared to those of the investigated composts. Palia *et al*., (2021) conducted experiment with the application of organic and inorganic fertilizers on brinjal (*Solanum melongena* L.) the results showed increase in overall vegetative parameters and yield parameters like average fruit weight (262.83 g), length of fruit (16.78 cm), diameter of fruit (29.18 cm), fruit per plot (18.90 Kg), fruit per plant (2.10 Kg) and fruit per hectare (472.67 ton) was influenced significantly at 20 tonnes farm yard manure + 5 tonnes poultry manure.

Orta-Guzmán *et al*., (2021) observed SEM images of Sugar Cane Bagasse (SCB) with typical fingerprint of cellulose, hemicellulose and lignin compounds. They also observed in FTIR spectra analysis wide band centered at ~3620 cm^{-1} corresponded to O-H stretching and at 2917 cm^{-1} appeared the C-H stretching vibration, the signal at ~2330 with alkyne groups, which can contain the lignin. Silpa *et al*., (2021) stated that the combined application of microorganism treated biocomposting units C8 (Raw jackfruit peel + 10 g *Pleurotus eous* + 10 g *Pleurotus florida* + *Eudrilus eugeniae*) & C4 (Raw cocoa shell + 10 g *Pleurotus eous* + 10 g *Pleurotus florida* + *Eudrilus eugeniae*) are microbiologically more active than other composting units.

Application of vermicompost (0, 2 and 6 gr) in 3 doses to the 1000 g of soil pot and significantly increased the fresh weight (16.397, 22.167, 20.914 gr), dry weight (1.730, 2.631, 2.457 gr), plant height (85.20, 92.10, 87. 26 cm) and total chlorophyll (3.126, 3.439, 4.391 mg g^{-1} FW) of corn *Zea mays* L. (Dizikisa *et al*., 2022).

Naik *et al*., (2022) reported combined application of 50 % RDF + 25 % *Rhizobium* + 25 % *Azotobacte*r on chickpea (*Cicer arietinum* L.) enhanced the leaf area index (0.407), chlorophyll content (348.67), protein content in seed (24.30) and leaf area per plant (50.39). Sarkar *et al*., (2022) reported that the application of tea waste treated soil has promoted cowpea [*Vigna unguiculata* (L.) Walp.] stem, root and fruit fresh weight (9.76, 4.61, 9.86 g), dry weight of stem, root and fruit (3.01, 1.38, 1.83 g) length of stem, root and fruit (23.13, 20.1, 21 cm). Teja *et al*., (2022) stated that organic manures (FYM, vermicompost, neem cake) have more impact on increase in protein and alkaloid content ashwagandha (*Withania somnifera*) and decrease in fiber content when compare to recommend dose of fertilizers NPK (40:60:20 kg ha^{-1}).

Voko *et al.*, (2022) reported that application of seaweed extract [Kelpak® (KEL 0.6%) and smoke-water (SW 1:1000 (v/v) on cowpea (*Vigna unguicula*) watered once- and thrice-a-week has improved chlorophyll 'a' + chlorophyll 'b' (1422.34 to 1362.70 µg g^{-1} FW). Saranraj *et al*., (2022) observed that vermicomposting of market waste + cow dung + *Trichoderma resii* + earthworm has reduced 60 % in cellulose content, 55 % in hemicelluloses content and 40 % in lignin content. pH ranged from 7.3 to 7.0, EC reduced from 1.16 to 0.69 dsm^{-1}. Dash *et al*., (2022) observed highest bacterial (6.2, 6.0 10^{-3}& 10^{-4} dilution) and fungal population (5.4, 5.2 10^{-2} and 10^{-4} dilution) in elephant dung when applied with microbial consortium on rice straw degradation, it is found that reduction in C:N ratio of rice straw composting from initial level (60.0 to 67.3 %) to 28th day of composting (24.8 to 27.7 %).

Libutti *et al*., (2023) stated that application of vermicompost to the soil both alone and in a mixture with biochar from vine prunings has interestingly increased the plant height, leaf area and total yield of leafy vegetable (*Beta vulgaris* L.). Zhou *et al*., (2023a) reported that composting of industrial aromatic plant residues (*Cinnamomum camphora* leaf) have reduced hemicellulose (200 g kg^{-1}), cellulose (143 g kg^{-1}), lignin (15.5 g kg^{-1}), starch (5.48 g kg^{-1}) and soluble sugar (0.56 g kg^{-1}). During composting the relative abundance of the main bacterial phylum *Firmicute* decreased from 85.1 % to 40.3 % while *Actinobactreia* increased from 14.4 % to 36.7 % fungal class *Eurotiomycetes* decreased from 60.9 % to 19.6 % while *Sordariomycetes* increased from 16.9 % to 69.7 %.

Zhou *et al.*, (2023b) reported that the addition of low doses of Aromatic Plant Biomasses (APBs) on *Stropharia rugosoannulata* compost has significantly altered the content of cellulose, hemicellulose, lignin and protein of compost products and increased *Proteobacteria* and *Sordariomycetes.* Arrijani and Setyawati, (2023) observed the use of cocopeat addition in plant media of papaya seedling at the age of 2 months after germination has showed high number of leaves (8), leaf size (25.5 cm), wet weight (1.65 kg) and dry weight (0.75 kg).

Aydi *et al*., (2023) reported that the date palm compost with animal manure when used as soil less substrate improved growth, photosynthesis and yield of melon (*Cucumis melo* L). Chandukishore *et al*., (2023) reported that the application of plant extract-based vermiwash (VW2) on *Capsicum annum* (bell pepper) has improved shoot length (81.66 cm), number of leaves (88.33), number of branches (70.5) and number of flowers (16.13) on 14^{th} week of germination. El-Hefny *et al*., (2023) observed that the combined application of compost (50 and 25 %) and metallic nanoparticles (30 mg/L) on *Asclepias curassavica* has showed maximum plant height (59.77 cm), diameter (45 cm), number of branches/plant (9), total fresh weight (63.67 g), total dry weight (24.10 g) and leaf area (13.66 cm^2).

Gopinath *et al*., (2023) studied the impact of organic (FYM + *Trichoderma viridae* at 2.5 kg/ha) and integrated (FYM + mineral fertilizers) production systems on yield and seed quality of rain fed crops and the results showed higher yield in pigeonpea (827 kg/ha) compared to control (chemical inputs) (748 kg/ha). Organically produced pigeonpea (19.6 and 20.0 %) and greengram (21.8 & 21.4 %) seeds had similar protein content with that of integrated system. Khan *et al*., (2023) reported that the application of growth promoting rhizobacteria biofertlizers (PGPRs) on maize has significantly improved the root length (91 %), shoot length (85.1 %), phenolics (71%), flavonoids (85 %) and protein (94 %) and increased grain yield (81 %) with 100 grain weight 25.37 % as compared to control.

Kumngen *et al*., (2023) studied the effect of food waste compost (supplied by BIOAXEL Co., Ltd.,) on the growth of lettuce (*Lactuca sativa* Var. Crispa L.) the results showed (in 10 % BA compost + 90 % soil) highest root length (21.83 ± 0.83 cm), plant length (30.00 ± 1.00 cm), number of leaves (23.33 ± 1.15), thickness of plant (12.47 ± 0.57 mm), width of bush (26.33 ± 0.58 mm), fresh plant weight (113.03 ± 1.28 g), dry plant weight (4.58 ± 0.14 g), chlorophyll a and b (0.38 and 0.38 mg/mL), carotenoid

(155.28 mg/mL), protein (443.38 µg/mL), carbohydrate (4, 321.31 µg/mL) and reducing sugar (683.33 µg/mL). The physico chemical parameters of food waste and BA compost (supplied by BIOAXEL Co., Ltd.,) showed significant changes in pH (5.11 to 6.66), total nitrogen (1.67 to 2.53 %), total P_2O_5 (0.88 to 1.40 %) total K_2O (0.60 to 1.43 %), C/N ratio (26.1 to 15.1) and EC (4.31 to 3.42 µS/cm).

Mazumder *et al*., (2023) assessed the multi –metal contaminant in agricultural soil amended with organic wastes (vegetable waste rotary drum compost (VWC), water hyacinth compost (WHC) and *Hydrilla verticillata* compost (HVC). VWC followed by WHC and *Hydrilla verticillata* compost (HVC) showed improved results in soil metal immobilization, plant metal uptake and morphological parameters of *Solanum lycopersicum* plant showed higher fruit yield and quality of the crop. Pottipati *et al*., (2023) assessed the maturity of vegetable waste vermicompost and found that a sharp change in pH initially 5.6 which finally found 8 during vermicomposting. FTIR spectroscopy indicated the degradation of vegetable waste vermicompost which displayed an intense wide band in between 3590 and 3650 cm^{-1} were attributed to monomeric alcohols and phenols.

Rahimi *et al*., (2023) observed the effect of vermicompost, compost and animal manure on *Thymus vulgaris* L. under water stress. Low water stress enhanced the amount of oil and the oil yield with the respective highest values of 2.61 % and 3.68 g/m under the application of vermicompost, it was concluded that the plants of thyme showed a good response to organic fertilizers under water deficit circumstances, with vermicompost being the most effective. Sabourifard *et al*., (2023) conducted experiment on maize (*Zea mays* L.) with the application of Urea (200 kg N ha^{-1}), farmyard manure (FYM) (200 kg N ha^{-1}) and vermicompost (200 kg N ha^{-1}) recorded maximum oleic acid (17.38 %) in vermicompost which was 12% higher than control. The highest seed yield was achieved in urea + vermicompost treatment (5570 kg ha^{-1}). It is concluded from the experiment that application of urea with vermicompost is more effective than other treatments. Shanker and Ram, (2023) reported that combined application of vermicompost (10 t/ha) + neem seed kernel extract (NSKE 5 %) on chickpea, *Cicer arietinum* L, has enhanced plant height (60.493 cm), branches per plant (7.567) highest number of pods per plant (69.94) with 1569.45 kg/ha grain yield with greater values of protein (20.47 g), fat (6.04 g), carbohydrate (62.95 g), fiber (12.2 g), sugar (10.78 g), calcium (57.56 mg) and Iron (4.37 mg).

Van Chuong, (2023) observed the effect of NPK + (chicken manure) CM 6t /ha + *Rhizobium* sp and found enhancement in peanut plant height (56.7 cm), number of branches (4.55) biomass (138 g), weight of filled pods (60.8 g) empty pods (1.78 g), fresh yield of groundnut (7.60 t/ha) yield quality of peanut (7.60 t/ha), oil % (50.6 %), seed protein percentage (26.8 %) as well as NPK content in seed (4.32, 0.912 and 0.999 %) respectively.

Al-Tawarah *et al*., (2024), observed that inclusion of 100% vermicompost (VC 100%) resulted in notable enhancements across various growth parameters of common beans. Specifically, the plant height increased to 85.33 cm, while the number of leaves and branches reached 96.00 and 63.00 respectively. Additionally, both shoot dry weight (13.71 g) and shoot fresh weight (83.91 g) reached significant increase. Moreover, root length extended to 17.60 cm, and yield characteristics exhibited improvements, including the number of pods per plant (93.33), pod weight (15.92 g), pod diameter (16.30 cm), seed weight (1.061 g), and the number of seeds per pod (13.00), ultimately resulting in a yield per plant of 1487 g for common beans. Similar results were noted by Calapardo and Bryl, (2024) that the incorporating of garden soil alongside rice hulls and vermicompost boosted substantial increase in the number of leaves (104.83 at 45 days) fresh weight (297.81 g), dry weight (78.61 g), herbage yield (7,231.25 g) accompanied by high visual quality rating (4.88) of stevia.

Chau and Diem, (2024) reported that employing spent coffee waste, cow manure, abalone mushroom residue, and rice husk ash as amendments for spinach cultivation resulted in notable improvements across various growth parameters. Specifically, the plant height increased to 25.0 cm, while the number of leaves per plant reached 29.1. Additionally, leaf length and width expanded to 23.8 cm and 8.3 cm respectively, and chlorophyll content measured at 39.6 (SPAD). Furthermore, root length extended to 14.3 cm, stem diameter widened to 0.8 cm, ultimately leading to an increased yield of 76.0 g.

Elshaboury *et al*., (2024) noted that by employing a combination of chicken manure and plant residue with proline (100 mgL^{-1}), significant improvements were observed across various growth parameters. Specifically, the plant height increased to 95.93 cm, while foliage fresh weight and dry weight measured at 62.95 g and 15.90 g respectively. Moreover, the number of pods per plant reached 90, with a corresponding pods weight of 62.78 g. Additionally, seed weight increased to 32.58 g, resulting in a notable seed yield of 1700.78 Kg fed^{-1}.

Hanyabui *et al*., (2024) found that applying pineapple waste biochar at a rate of 10 t ha^{-1} along with compost at the same rate has led to notable enhancements in various growth parameters of pineapple plants. Specifically, the plant height increased to 102.75 cm, while the number of leaves reached 22. These improvements consequently resulted in enhanced fruit weight (979.30 g), fruit length (6.76 cm), and fruit diameter (13.68 cm) of the pineapple variety (sugar loaf V2F5) cultivated in Ghana.

Hutomo *et al*., (2024) reported that advancements in kailan plant (*Brassica oleracea* L.) development through the utilization of coffee husk waste compost at a rate of 20 g per plant. This application exerted a significant influence on various growth parameters. Specifically, the number of leaves increased to 14.00, while the plant height reached 5.33 cm. Additionally, the leaf area expanded to 101.05 cm^2, and both total fresh weight (62.82 g) and fresh weight suitable for consumption (57.85 g) experienced notable increments. Moreover, the dry weight measured at 19.25 g, indicating enhanced biomass accumulation in the plants.

Wang *et al*., (2024) reported that applying of bio organic fertilizers lead to reductions in soil bulk density (1.51 g/cm3) and solid phase content (54.58), while simultaneously increasing the total porosity (47.10 %), water content (16.57 %), liquid phase (24.92) and gas phase (22.95) of the soil. Additionally, this application has been found to enhance levels of nitrate nitrogen, ammonium nitrogen, and total nitrogen in the soil by 13.59 % to 52.56 %, 4.47 % to 18.27 %, and 4.40 % to 12.09 %, respectively.

Mawardiana *et al*., (2024) observed that the application of forage compost (2 kg) to shallot plants elicited improvements across various parameters. Notably, this application led to an increase in plant height (37.78 cm), the number of onion cloves (9.81), wet stash weight in the plot (615.56 g), dry stash weight (565.56 g), and yield in hectares (6.16 tons).

Zapałowska and Jarecki, (2024) investigated the influence of compost (sewage sludge (90 kg) + sawdust (10 kg) + garden and park waste (100 kg) + earthworms) on various parameters of corn plants. Their findings revealed notable impacts, including an increase in plant height (160.2 cm), cob length (14.00 cm), number of grains in the cob (200.3), thousand grains weight (264.6 g), plant dry weight (99.8 g) and grain yield per plant (52.9 g).

Rahman *et al*., (2024) documented that the application of compost (consisting of sawdust, kitchen garbage, rice straw, and cow dung in equal proportions) supplemented with 300 g of wheat grain colonized *Trichoderma* resulted in significant improvements across multiple parameters in tomato plants. Specifically, they observed an increase in root length (56.00 cm), root diameter (5.67 cm), fresh root weight (51.33 g), dry root weight (13.33 g), fresh shoot weight (388.0 g), dry shoot weight (122.7 g), plant height (102.2 cm), number of branches (21.00), number of leaves (5.667), and yield (41.60 tons/ ha).

Shukurovich and Akbarovich, (2024) noted that the utilization of chicken manure combined with semi-rotted cattle manure at a rate of 30 tons per hectare consistently enhanced the height (81.5 cm) and number of leaves (12.5) of acorn plants. Similarly, comparable outcomes were documented by Sinha *et al*., (2024) recorded that the application of 75% NPK + *Acetobacter* (10^9cell/ml culture) + phosphate solubilizing bacteria (10^8 cell/ml culture) + Biocompost (7.5 t/ha) exhibited the highest number of millable cane NMC (103.0×10^3 ha^{-1}), cane yield (85.8 t ha^{-1}) and sugar yield (11.21 t ha^{-1}) in sugar cane plant.

Umeh *et al*., (2024) noted similar outcomes in okra plants when treated with a combination of poultry manure, rice husk, compost, and cow dung. This treatment exhibited notable improvements in plant height (67.33 cm) and number of leaves (30.00), as well as leaf area (335.00 cm), number of fruits (4.00), stem girth (4.38 cm) and fruit weight (13.80 g).

2.2 Studies on leghaemoglobin content

Krouma and Abdelly, (2003) reported that iron is essential for leghaemoglobin biosynthesis that transported oxygen within cells in the nodule of soyabean. Nayak *et al*., (2004) investigated the soils of rice fields which were inoculated with the combination of blue green algae (BGA) and *Azolla* biofertilizers and found significant enhancement in chlorophyll accumulation and nitrogenase activity. Shiferaw *et al*., (2004) stated that nitrogen is the nutrient demanded in largest quantities by plants, and most expensive in the process of industrial production. Nitrogen is abundant in the atmosphere, but plants cannot directly utilize the elemental form available in the air. Biological nitrogen fixation occurs mainly through symbiotic association of legumes and some woody species with certain N_2 -fixing microorganisms that convert elemental nitrogen into ammonia.

Jebara *et al*., (2005) conducted experiments on common bean (*Phaseolus vulgaris*) genotypes with the inoculation of *Rhizobium tropici* CIAT899 under phosphorus deficiency and found P deficiency affected differently the genotypes for nodule number and size.

Ott *et al*., (2005) observed in *Lotus japonicas* three symbiotic leghemoglobins, LjLb1, LjLb2 and LjLb3, expressed exclusively in nodules, and two non symbiotic leghemoglobins, LjNSG1 and LjNSG2 proved that symbiotic leghemoglobins are crucial for Nitrogen fixation in legume root nodules.

Gad, (2006) concluded that cobalt is an essential element for certain microorganisms particularly, those fixing atmospheric nitrogen, its deficiency can depress the efficiency of N_2 fixation and decrease the nitrate accumulation. Hati *et al*., (2006) observed that root length up to the 30 cm depth was increased in soybean due to the use of organic manure with chemical fertilizers (NPK + FYM 31.9 % and 70.5 %) provided better aeration and low bulk density of the surface soil, thus helped better root proliferation. Roy *et al*., (2006) reported that cobalt is an essential element in fixing the N in microorganism and its deficiency can inhibit the formation of leghaemoglobin as well as N_2 fixation.

Araujo *et al*., (2007) investigated the effect of composted textile sludge (0, 9.5, 19 and 38 t ha^{-1}) on growth, nodulation and nitrogen fixation of soybean and cowpea and revealed that at 36 and 63 days after planting maximum growth and nodulation was noticed. Fatima *et al*., (2007) studied the effect of combined application of *Rhizobium* strain with P and found increase in growth and yield of soybean and also improved soil fertility, NPK uptake by plant tissues with 2.54 and 2.78 g nodule wt/plant.

Ali *et al*., (2008) stated that the application of the auxins (IAA or 4 - Cl - IAA) improved the growth, leghaemoglobin content and nitrogenase activity in mung bean (*Vigna radiata* (L.) Wilczek) plants, 4 - Cl - IAA (10^{-8} M) was found to be more effective than IAA. De Araujo *et al*., (2008) stated that *Rhizobium* legume symbiosis is characterized by high host specificity and the Biological Nitrogen Fixation (BNF) and number of nodules. Changes in microbial populations, nitrogen fixing bacteria and root nodule bacteria has been used as an indicator of soil pollution based on the organism's sensitivity to pesticides, urban and industrial wastes and heavy metals, but new DNA techniques are available now to measure the structure and functional diversity of *rhizobia* which are useful and unexplored for using *rhizobial* and biological nitrogen fixation as indicator of soil pollution.

Dutta and Bandyopadhyay, (2009) found that combined application of phosphorus (26.2 kg/ha) and bio-fertilizers influenced the chick pea growth attributes, nodulation, leghaemoglobin content, nitrogenase activity, yield components, seed and stover yields, harvest index in laterite soil.

Gan *et al*., (2010) concluded that optimum productivity of chickpea was achieved with the application of effective *Rhizobium* inoculants and stated that best N management practices are to be adopted in the succeeding crops due to a large negative N balance after a chickpea crop.

Padminee and Bandyopadhyaya, (2011) reported that the integrated application of *Rhizobium leguminosarum* and phosphate solubilizing bacteria increased the leghaemoglobin content of nodule with increase in the nodule number, fresh nodular weight and yield of French bean crop (*Phaseolus vulgaris* L.). Sajid *et al*., (2011) concluded that the inoculation of *Rhizobium* to groundnut has significantly increased plant height (88.43 cm), number of shoots (19.9 / plant), number of leaves (173.27 / plant), number of pods (79.8 / plant), number of nodules (156.27 / plant), yield (252.66 g / plant) and production (1856 kg ha^{-1}). Sharma *et al*., (2011) reported that inoculation of *Rhizobium* (IRC-6 strain) on groundnut (*Arachis hypogaea* L.) enhanced number of pink colored nodules, nitrate reductase activity and leghaemoglobin content at 50 Days After Sowing (DAS).

Azarpoor *et al*., (2012) suggested that vermicompost application at 10 t/ha, at plant population density of 65 plants per m^2 with inoculation of biological nitrogen fertilizer on seeds will be suitable for growing soybean and the results showed the highest yield of 3831 kg/ha. Tajini *et al*., (2012) found that the combined inoculation of Arbuscular *Mycorrhiza*l Fungi (AMF) *Glomus intraradices* fungi and *Rhizobium tropici* (CIAT899) increased common bean (*Phaseolus vulgaris* L.) plant growth parameters and also found higher nitrogen and phosphorus accumulation in the shoots.

Singh and Vijayalakshmi, (2013) reported that the combined effect of composted coirpith (6.5 t/ha) + composted pressmud (6.5 t/ha) + farmyard manure (6.5 t/ha) enhanced the leghaemoglobin content (0.0560 mg/g) in the nodules of green gram on

45 days after sowing. Tagore *et al*., (2013) studied the effect of *Rhizobium* and phosphate solubilizing bacterial inoculants on symbiotic characters, nodule leghaemoglobin and yield of chickpea genotypes and found the genotype IG - 593 *Rhizobium* + PSB most effective in nodule number (27.66 nodules plant^{-1}), nodule fresh weight (144.90 mg plant^{-1}), nodule dry weight (74.30 mg plant^{-1}), shoot dry weight (11.76 g plant^{-1}) and leghemoglobin content (2.29 mg g^{-1} of fresh nodule).

Verma *et al.*, (2014) concluded that the application of (6 t ha-^{1}) vermicompost and 40 kg of sulphur (ha^{-1}) on fenugreek enhanced higher growth attributes, root nodules (27.48), number of effective root nodules (15.87) leghaemoglobin content (2.00 mg/g), seeds (15.54 q/ha) and straw yields (40.04 q/ha).

Kannahi and Ramya, (2015) studied the effect of biofertilizer *Azospirillum*, vermicompost, biocompost and chemical fertilizer on different morphological and phytochemical parameters of Lycopersicum esculentum L. which enhanced morphological parameters such as height of the plant, number of leaves, number of roots, shoot length and root length on 45th day.

Adak and Kibritci, (2016) observed the effect of four different nitrogens (0, 30, 60, 90 kg/ha) and three phosphorus (0, 40, 80 kg/ha) levels on soil in faba bean (*Vicia faba* L.) enhanced the number of pods/plant, biological and grain yield per unit area, grain and plant N content, highest nodule, nodule weight/plant, 100 - kernel weight at 80 kg/ha phosphorus and 30 kg/ha nitrogen combination.

Bidyarani *et al*., (2016) observed enhancement of plant growth and yield in chickpea (*Cicer arietinum* L.) through novel cyanobacterial and biofilmed inoculants and found in the inoculants – *Anabaena laxa* and *Anabaena* – *Rhizobium* biofilmed formulation proved to be high in leghaemoglobin content of nodules. N'Zi *et al*., (2016) studied the nodulation and its effect on some agro morphological parameters of soyabean (*Glycine max* L.), the results showed the highest number of nodules (11) per plant in the variety Doko on lowest emergence time of 6.49 days after sowing (DAS).

Baliah and Muthulakshmi, (2017) studied the effect of *Azospirillum* enriched vermicompost on the growth of Okra (*Abelmoschus esculentus* (L.) Moench) and the results showed increased total chlorophyll, carotenoid, protein and amino acids.

Seleiman, and Abdelaal, (2018) observed the effect of biofertilizer which produced the highest values of seed quality (total nitrogen, total crude protein and carbohydrate percentages) in the chickpea (*Cicer arietinum* L.) variety Giza 195 cultivar. Shekhawat *et al*., (2018) conducted an experiment to study the effect of phosphorus & bio-organics on quality and symbiotic efficiency of black gram (*Vigna mungo* L.) and the results revealed that theapplication of 40 kg P_2O_5 ha^{-1} + 2.5 t vermicompost ha^{-1} + *Rhizobium* + PSB significantly increased yield, quality and symbiotic efficiency of black gram.

Nohong *et al*., (2019) stated that nitrogen fertilization was effective in stimulating growth, production and nodulation at early nursery stage, yet higher nitrogen doses (200 Kg N/ha) are ineffective and have inhibitory effects of growth and production, also observed high - dose nitrogen fertilizers in legume plants should be avoided because *Indigofera zollingeriana* is able to fix nitrogen from the atmosphere as in other legumes. Roy *et al*., (2019) conducted an experiment with various tillage practices and fertilizer management on the growth and nitrogen efficiency in soybean and found increase in nitrogen in all treatments, and the highest quantity of total nitrogen (476.7 Kg/ha) was observed in no tillage (NT) with green manure.

Godlewska and Ciepiela, (2020) observed the performance and content of selected organic compounds in *Trifolium pratense* treated with various biostimulants against the background of nitrogen fertilisation (0, 30 kg. ha^{-1}) and it is found nitrogen applied at the rate of 30 kg. ha^{-1} significantly increased red clover yield, chlorophyll content in leaves and protein. Khatik *et al*., (2020) studied the effect of nitrogen scheduling and cultivars on yield attributes and yields of sorghum (*Sorghum bicolor* L.) and the results showed higher number of grains per panicle, 1000 grain weight, grain yield (1521 kg/ha), harvest index (13.17) and nitrogen content in cultivar CSH 16.

Gomathinayagam *et al*., (2021) reported *Rhizobium* + PB (phosphobacteria) mixer enhanced the seed germination, shoot and root length, leaf fresh weight, leaf dry weight, shoot and root dry weight, total chlorophyll content, soluble protein and nitrate activities in both black gram and maize. Hasan *et al*., (2021) observed the growth, yield, nodulation and aminoacid content of bambara groundnut (*Vigna subterranean*) under inorganic and organic fertilizer application and the results were plant height (21.73 cm), leaf area

(2802.9 cm^2) and the number of the pods per plant (41.75) increased with the application of N and P, nodule number (35.50) of the plant influenced N30P60 kg/ha. Lysine content in seed was 5.13 mg/kg was influenced by compost 10 t/ha. Kouki *et al*., (2021) evaluated the impact of *Rhizobium* strain Ar02 on the nodulation, growth, nitrogen (N) fixation rate and ion accumulation in *Phaseolus vulgaris* L. under salt stress. The inoculated plants showed higher number of nodules and nodule biomass at 75 mM NaCl, root and shoot length increased with higher biomass and shoot's Ca^{+2}, Na^+ and K^+ content were higher.

Khan *et al*., (2022) reported that the integrated application of normal animal manure with half di-ammonium phosphate (DAP) improved the physiological attributes such as chlorophyll a (3.6 µg mL^{-1}), carotenoids (1.5 µg mL^{-1}) and leghaemoglobin contents (112.5 mM) also increased protein contents, nodule count and nodule weight up to 78.38 %, 147 % and 93.59 % than the control.

Owaresat *et al*., (2023) stated that nitrogen is an important element for synthesizing proteins, nucleic acids and other cellular parts of the living organism. This mineral can be naturally enriched in soil by the biological nitrogen fixation process where the rate of this process intensely depends upon the optimum range of the environmental abiotic and biotic factors, so, several eco-friendly strategies or management should be followed for fixing nitrogen minerals naturally in croplands. Van Chuong, (2023) observed the effect of NPK + 6t CM/ha + *Rhizobium* sp which enhanced the number of nodules (92.9) and weight of dry nodules (0.831 g) in peanut.

2.3 Studies on soil status

Bokhtiar *et al*., (2003) reported green manuring with dhaincha (*Sesbania aculeata*) and sunhemp (*Crotalaria juncea*) increases organic matter, total N, available P and S of the soil and productivity of a subsequent sugarcane (*Saccharum officinarum*) crop. Rajkhowa *et al*., (2003) conducted an experiment to study the effect of vermicompost in combination with fertilizer on green gram improved soil organic carbon, available N, P and K. Yaduvanshi, (2003) reported that application of green manure (10 t FYM/ha) on rice–wheat cropping sequence resulted in higher removal of inorganic fertilizer in crops and increased soil N, P, K, organic C and reduced soil pH.

Choudhary *et al*., (2004) observed integrated application of gypsum and farmyard manure (FYM at 20 t ha^{-1}) improved yield, quality of sugarcane, soil pH, EC and ESP under semiarid conditions. Feichtinger *et al*., (2004) conducted experiment to compare organic (compost) and mineral fertilization and combination of both, nitrogen dynamics in the soil were calculated using the STOTRASIM. The results exhibited a close relation between the amount of a slow decomposable fraction and the net N-mineralization during the vegetation period.

Bohme *et al*., (2005) suggested that the application of farmyard manure enhanced the soil organic matter and total nitrogen as reflected by hydrolytic enzyme activities and affect the functional and structural soil microbial properties. Eriksen, (2005) reported that when soil was mixed with inorganic S levels (0 and 10 μgSg^{-1} soil) and three plant residues (wheat straw, perennial rye grass and oilseed rape) the rates of sulphur (S) was reduced from the soil.

Abou El Magd and Hoda, (2005); Abou El-Magd *et al*., (2006) reported that the application of organic manures (cattle and poultry manures) in the soil has increased the total yield and enhanced soil aggregation, soil aeration and increasing water holding capacity thus offers good environmental conditions for the root system of broccoli plants. Akpor *et al*., (2006) investigated the decomposition of *Theobroma cacao* leaf litters in tropical soil setting and found increase in the organic carbon of the soil. Zahid and Niazi, (2006) suggested that the pressmud @ 25 tons ha-^{1} has considerable quantities of Ca, S, organic carbon, N, P and K which is a cheaper source of organic matter rather than gypsum, which can successfully be used for the reclamation of saline sodic soil.

Rangaraj *et al*., (2007) reported that agro industrial wastes pressmud @ 12.5 t ha^{-1} had greater influence on soil fertility and yield of finger millet. Ravindran *et al*., (2007) observed that combined application of Farmyard Manure (FYM) Phosphate Solubilising Bacteria (PSB) on *Arachis hypogaea* L. and the results showed significant decrease in the pH, EC and of the soil.

Kumar and Prasad, (2008) conducted experiments with application of mineral fertilizers and green manure on crop yield and nutrient availability under rice-wheat cropping system and significant increase was found in organic carbon, available N, P and

K in soils. Parthasarathi *et al*., (2008) conducted field experiment on clay loam, sandy loam and red loam soil and evaluated the efficacy of vermicompost on the physico-chemical and biological characteristics of the soils and found vermicompost had increased the pore space, reduced particle and bulk density, increased water holding capacity, cation exchange capacity, reduced pH and electrical conductivity, increased organic carbon content, available nitrogen, phosphorous, potassium and microbial population and activity in all the soil types, particularly clay loam.

Manivannan *et al*., (2009) reported that application of vermicompost @ 5 tonnes ha^{-1} had enhanced pore space (1.09 and 1.02 times), water holding capacity (1.1 and 1.3 times), cation exchange capacity (1.2 and 1.2 times). It reduced particles (1.2 and 1.2 times), bulk density (1.2 and 1.2 times), pH (1 and 1.02 times) and electrical conductivity (1.4 and 1.2 times) and increased organic carbon (37 and 47 times), micro (Ca 3.07 and 1.9 times, Mg 1.6 and 1.6 times, Na 2.4 and 3.8 times, Fe 7 and 7.6 times, Mn 8.2 and 10.6 times, Zn 50 and 52 times and Cu 14 and 22 times) and macro (N 1.6 and 1.7 times, P 1.5 and 1.7 times, K 1.5 and 1.4 times) nutrients and microbial activity (1.4 and 1.5 times) in clay loam soil and sandy loam soil. Muhammad and Khattak, (2009) investigated the effect of pressmud (PM) on saline-sodic soil reclamation on the growth of maize (*Zea mays* L.) and concluded that the significant variations found in plant growth, nutrient uptake and post harvest soil properties of the two soils and they depend upon soil initial physico-chemical properties and quality of irrigation water.

Ansari and Kumar, (2010) reported that the combined application of vermiwash and vermicompost influenced the biochemical, physical and chemical properties of the soil with decreased pH, increase in OC, N, Mg, Ca and Zn. Gopal *et al*., (2010) studied the effect of Coconut Leaf Vermiwash (CLV) on crop production and capacities of soil revealed the soil organic carbon content increased in the Coconut Leaf Vermiwash (CLV) - applied plots in all the crops but the total N, available P and K content in soil was varied in different crops. Ravindra *et al*., (2010) confirmed that maximum number of fungi (20) was recorded in the cultivated agricultural soil amended with farm yard manure (FYM 40.6 x 10^4 g^{-1}).

Lazcano and Dominguez, (2011) stated that use of complex and variable composition of vermicompost in comparison with inorganic fertilizers and the myriad of effects that it can have on soil functioning and it needs to be unravel the interactions between vermicompost-soil-plant. Prativa and Bhattarai, (2011) reported that application of integrated nutrient management with ½ NPK + 15 mt/ ha vermicompost has increased the available nitrogen, phosphorus and potassium.

De Rezende *et al*., (2012) composted coffee husk with manure and observed decrease in the C/N ratio and better results for fresh and dry biomass in sorghum crop. Sujatha and Bhat, (2012) studied the effect of vermicompost (VC) and chemical fertilizer (CF) application on soil fertility status in areca nut found a significant increase in soil pH (6.3) organic carbon (2.85 - 3.00 %) phosphorus, calcium and magnesium of vermicompost (VC) than chemical fertilizer (CF).

Chesti *et al*., (2013) stated that the integrated application of 100% NPK + FYM 10t ha^{-1} promoted yield and fertility level of the soil in the intermediate zone of Jammu and Kashmir. Dzung *et al*., (2013) reported that the application of coffee husk (2 kgs to 3 kgs) compost improved the fertility of the soil. pH of the soil increased from 4.11 to 4.52 in plots after three years of the treatment, and improved OC % enhanced from 3.28 % in control (C) up to 3.82 % (F2); total N % from 0.154 % (C) up to 0.18 % (F2). In addition, physical structure of the soil such as bulk density, particle density and pore space (55.2 %) were improved. Meena *et al*., (2013) reported application of organic sources FYM 10 t ha^{-1} and vermicompost (5 t ha^{-1}) enhanced the nitrogen, phosphorus and potassium. FYM (20 t ha^{-1}) and vermicompost (10 t $ha^{-1,}$) enhanced zinc, iron and organic carbon of soil after the harvest of green gram.

Jayanthi *et al*., (2014) conducted a field experiment on clay loam soil with the application of vermifertilizer (VF 5 tons/ha) for the growth of chilli (*Capsicum annuum* L.) and the results showed increase in the pore space, water holding capacity, cation exchange capacity, organic carbon, available N, P, K, other micro-macro nutrients – Ca, Mg, Na, Fe, Mn, Zn, Cu and microbial population activity and humic acid content, reduced particle and bulk density, pH, EC in the field soil along with better yield of chilli. Maheswarappa *et al*., (2014) reported that application of 75 % N in the form of VC + 25 % NPK has enhanced the pH (4.53 to 4.68), soil organic carbon (1.19 to 1.34 %) and EC (199.50 to 203.50 μmhos/cm) of the soil. Moradi *et al*., (2014) stated that the continued use of chemical fertilizers causes health and environmental hazards such as ground and surface water pollution by nitrate leaching but use of compost with organic constituents undergo thermophilic decomposition that alters and decomposes the original organic materials.

Dhakal *et al*., (2015) observed that combined application of NPK enhanced early growth in mungbean (*Vigna radiata* L.) cell multiplication and absorption of more nutrients from the deeper layers of the soil. Kaur *et al*., (2015) stated that application of vermicompost and vermiwash processed by the naturally occur earthworms enhance the nutrients and other soil stimulants for plant growth and improve soil quality.

Nduka *et al*., (2015) reported that amendment of Coffee Husk (CH) and NPK in three rates to the nursery soil enhanced the post experiment soil with high N, P, K, Ca, Mg, soil pH, Soil Organic Carbon (SOC), and Soil Organic Matter (SOM) compared to the control and Coffee Husk (CH) with 0.00625 g^{-1} Kg concentration increased soil pH, soil organic carbon (SOC), soil organic matter (SOM), N, K, C, Mg and leaf N by 10.20 %, 10.50 %, 19.20 %, 8.33 %, 42.38 %, 25.00 %, 50.00 % and 93.20 %. Zaman *et al*., (2015) studied the effect of vermicompost (VC @ 10t ha^{-1}) on growth and leaf biomass yield of stevia and post harvest fertility status of soil and the results showed the decrease in acidity of acid (4.9 to 5.7) and non - calcareous (6.5 to 7.20) soils, also significant increase in NPK, Ca, Mg, S, Zn and B.

Bhagat *et al*., (2016) studied the effect of rice straw mulching @ 6 tonnes/ha on soil environment, microbial flora and growth of potato under field conditions and observed an improvement in soil organic content in mulched (0.32 %) over unmulched (0.24 %) soil samples and mineral nitrogen i.e., ammonia (235.2 kg/ha), nitrate (156.8 k/ha) and nitrogen were greatly affected at 90 DAS. Meena *et al*., (2016) reported that the application of $N_{20}P_{40}K_{40}$ + FYM @ 10 t ha^{-1} and *Rhizobium* significantly improved organic carbon - 0.75 %, available nitrogen - 333.23 kg ha - 1, phosphorus - 34.58 kg ha^{-1}, potassium - 205.83 kg ha^{-1}, pore space - 50.80 %, pH - 6.80.

Wang *et al*., (2017) confirmed the application of vermicompost (30t/ha) increased the soil quality with higher pH (7.23 vs. 7.37) and lower soil electrical conductivity (averaged 204.1 vs. 234.6 µS/cm). Kirnak *et al*., (2017) studied the soil characterstics of soyabean fields affected by compaction, irrigation and fertilization and the results showed that soil compaction had significant effect on soil nutrient contents of all depths except 0 - 30 cm layer, also found insignificant effect on the soil temperature at 10 cm.

Ceritoglu *et al*., (2018) stated that application of vermicompost improves the physical, chemical and biological properties of the soil, as well as organic matter in the soil. Hussain *et al*., (2018) examined that integrated application of vermicompost and *mycorrhizae* ($BDMV_1$ & V_2) has reduced the soil pH (5 and 6 %) organic matter OM (25 and 112 %), total N (41 %) and extractable P (200 %) in the soil. Mahmud *et al*., (2018) studied the effect of vermicompost amendment on nutritional status of sandy loam soil and revealed that soil pH was increased after second supplementation of vermicompost and also improved total N (0.15 %) P (0.04 %), K (0.07 %), Mg (0.06 %), S (0.02 %), Ca (0.08 %), Fe (0.80 %), Zn (37.63 mg kg^{-1}), B (2.56 mg kg^{-1}) and Al (3.48 %) in the soils. Rautela *et al*., (2019) noted that wheat straw vermicompost exhibited a lower pH of 7.54 compared to the initial soil pH of 8.63. Additionally, corn leaves vermicompost displayed a lower electrical conductivity (EC) of 0.03 mS/cm, compared with the initial soil EC of 0.14 mS/cm.

Kannika *et al*., (2019) evaluated the effect of vermicompost (poultry farm soild waste (PFSW) 250 g) on the soil fertility. After 30 days of incubation the results showed decrease in pH value of 6.65, EC 2.45 mS /cm, moisture 1.50 %, higher values in N (0.70 %), P (0.11 %), K (0.21 %) and C(21.1 %). Saha *et al*., (2019) integrated the application of biochar prepared from lemongrass (*Cymbopogon flexuosus*) and Chemical Fertilizers (CF) in different ratios on *Andrographis paniculata* (kalmegh). Remarkable improvement was detected in the soil carbon content, cation exchange capacity and nutrients accessibility. Shanmugasundaram *et al*., (2019) reported that continuous application of fertilizer NPK (50 %, 100 % and 150 %) along with organic manure (FYM) over four decades has brought significant impact on nutrient balance on soil system with increase of P (22.62 % in finger millet and 26.35 % in maize) available K (18.32 % in finger millet and 14.41 % in maize).

Das and Biswas, (2020) reported that the combined application of organic and inorganic fertilizer (Phosphorus Solubilizng Bacteria (PSB) + *Azotobacter*) in sesame cultivation on red and lateritic soils resulted higher yield with all the important implications of nutrient uptake of sesame from improved nutrition and improved productivity of soil. Elayaraja and Sathiyamurthi, (2020) investigated the influence of organic manures and micronutrients fertilization on the coastal saline soil and found that the application of 125% NPK + CCP @ 12.5 t ha^{-1} along with soil application of $ZnSO_4$ @ 25 kg ha^{-1} + $MnSO_4$ @ 5 kg ha^{-1} and foliar spray ($ZnSO_4$ + $MnSO_4$) @ 0.5 % twice, decreased the soil pH (8.15) and EC (1.15 dSm^{-1}) increased the soil organic carbon (2.78 g kg^{-1}) status as compared to initial status of soil. Haridha *et al.*, (2020) conducted field experiment on sandy clay loam soil to access the effect of goat manure and vermicompost (17 t ha^{-1}) on the physico-chemical and other properties of the soil and it is found in soil high potassium (K) and phosphorus (P) compared with nitrogen (N) and better pore space as well as water holding capacity.

Bordoloi, (2021) observed that the integrated application of vermicompost @ 1.0 t/ha + 50 % RDF (RDF: N: P_2O_5: K_2O:120: 80: 60 kg/ha) increased the soil nutrients organic carbon, 123.76 % nitrogen, 131 % available phosphorus and 169.07 % potassium. Suwarto and Asih, (2021) studied the growth of legume crops under cassava and its effect on soil properties and observed that the soil organic carbon increased to 2.25 - 2.38 % and soil bulk density ranged from 0.76 to 0.84 g cm^{-3} at 10 months after planting,

Hama-Ba *et al*., (2022) observed the effect of soil type on the nutritional quality of groundnut (*Arachis hypogaea* L) and found that groundnut seeds grown on clay soil are richer in fats and iron. Groundnut seeds grown on sandy soil are richer in total ash and groundnut seeds grown on gravelly soil are richer in protein. Singh *et al*., (2022) stated that organic farming enhances the food quality and productivity, under organic as well as integrated nutrient approaches there is no perceptible change in phosphorus and potassium after the completion of five cropping cycles.

Florence and Percy, (2023) stated that application of bioinoculants namely *rhizobia* colonize the rhizosphere, infect legume roots, and biologically fix N in soil by forming a symbiotic bond with the plant and convert the free N into ammonia for the plants to use thus making soils fertile for plant growth. Irin and Biswas, (2023) reported that residual effect of green manure (GM-T.aman-Mustard) on soil properties has increased soil organic matter 0.04% to 0.07 % and 0.02 % to 0.03 % , nitrogen 0.05 %, potassium 0.2 to 0.5 meq/100 g and phosphorus 2 ppm to 15 ppm. Gopinath *et al*., (2023) observed the soil organic carbon (SOC) content in the plots under organic (FYM + *Trichoderma viridae* at 2.5 kgha^{-1}) production system was 32.6 % more than the initial organic carbon of the soil (0.43 %) and higher soil nitrogen (179.0 to 205.2 kgha^{-1}) and potassium (218.1 to 244.8 kg ha^{-1}) compared with other treatments. Plots under integrated (FYM + mineral fertilizers) production system showed higher soil phosphorus (24.7 to 26.5 kg ha^{-1}).

2.4 Antioxidants, Antimicrobial and Phytochemical analysis

Asami *et al*., (2003) studied the comparison of the total phenolic and ascorbic acid content of freeze dried and air dried Marion berry, strawberry and corn plants and found that higher levels of total phenol (620 mg/100 g) (630 mg/100 g) were found in organically and sustainable grown foods as compared to those produced by conventional agricultural practices.Dumas *et al*., (2003) identified that antioxidants are important substances present in tomatoes. Lycopene is one of the main antioxidant along with carotenes (such as β-carotene), vitamin C, vitamin E and various phenolic compounds are also thought to be health-promoting factors with antioxidant properties are found in fresh tomatoes and processed tomato products. Temperatures below 12°C inhibit lycopene biosynthesis and temperatures above 32°C stop this process altogether. Wang and Lin, (2003) reported that the application of compost as soil supplement significantly enhanced the ascorbic acid, vitamin C content than chemically fertilized soil grown crops.

Caris-veyrot *et al*., (2004) observed that organic tomatoes as fresh matter had higher vitamin C, carotenoids and polyphenol contents than conventionally grown tomatoes. Kalt, (2005) revealed that major fruit and vegetable antioxidants like phenols are sensitive to the environmental conditions. Effect of processing decrease vitamin C and phenolics. Meda *et al*., (2005) investigated for total phenolic, flavonoid and proline contents their radical scavenging activity in 27 different Burkina Fasan honey samples. The IC_{50} values (1.63 to 29.13 mg/ml) and highest DPPH RSAs were found in all *Vitellaria* honeys.

Tarozzi *et al*., (2006) reported that organically grown red oranges have a higher phytochemical content (i.e., phenolics, anthocyanins and ascorbic acid), total antioxidant activity and bioactivity than integrated red oranges. Toor *et al*., (2006) observed that tomatoes grown under chickpea manure grass-clover mulch was high (17.6 % and 29 %) in total phenol and ascorbic acid content than the tomatoes grown with mineral nutrient solutions.

Podsedek, (2007) stated that post harvest storage, industrial processing and different cooking methods can affect the stability of bioactive compounds and antioxidant activity of vegetables.

Ghosh *et al*., (2008) investigated antibacterial activity of hot aqueous and methanolic leaf extracts of *Polyalthia longifolia* against six different bacteria. Highest antibacterial activity was noted against *Klebsiella pneumoniae* in both the leaf extracts and methanol extracts revealed that the presence of steroids, alkaloids, biterpenoids, carbohydrates, amino acids, essential oil, phenolics and flavonoids as major phytochemicals. Siddhuraju *et al*., (2008) reported that raw and processed seed samples of legumes (*Macrotyloma uniflorum* (Lam.) Verdc, *Dolichos lablab* L.) showed good source of dietary phenolics and tannins.

Sreeramulu *et al*., (2009) studied the antioxidant activity of commonly consumed cereals, millets, pulses and legumes in India and concluded that finger millet (*Eleusine coracana*), rajma (*Phaseolus vulgaris*) had the highest ferric reducing antioxidant power (FRAP 471.71, 372.76) and reducing power DPPH scavenging activity (1.73, 1.07).

Soma *et al*., (2010) investigated the antibacterial activity of chloroform + HCl extract of *Andrographis paniculata* and the chloroform extract showed better antibacterial activity against nine pathogenic bacterial strains. Wang *et al*., (2010) reported that application of cow manure vermicompost on chinese cabbage (*Brassica campestris* ssp. chinensis) has improved the antioxidant activities by 2, 2-Dipenyl-1-picrylhydrazyl-scavenging activity, hydroxyl $(OH)^-$ scavenging activity.

de Britto *et al*., (2011) detected the antibacterial activity of five medicinal plants (*Solanum nigrum, Solanum torvum, Solanum trilobatum, Solanum surattense and Solanum melongena*) against two gram negative bacteria *Xanthomonas campestris* and *Aeromonas hydrophila.* It was found that the methanol extracts of all the plant samples showed significant activity against the two tested bacteria. The methanol extracts of *S. nigrum, S. torvum* and *S. surattense* exhibited clear zone of inhibition against the tested microorganisms. Deshpande *et al*., (2011) investigated the scavenging activity of hydrogen peroxide (H_2O_2), reducing power and DPPH radicals by methanolic fruit extract of *Coccinia Grandis* L. Voigt. Results of the methanolic extract of the fruit showed H_2O_2 (0.309), reducing power assay (0.132) and DPPH (0.129) at 250 µg/ml concentration.

Perumal *et al*., (2012) assessed the preliminary phytochemicals of ethanolic extract of *Cayratia trifolia* and reported the presence of alkaloid, flavonoids, tannins, saponins and phenolic compounds along with DPPH free radical scavenging activity and the IC_{50} value was 74 ± 0.83 µg/mL. Mbaebie *et al*., (2012) evaluated the phytochemical constituents and antioxidant activities of aqueous extract of *Schotia latifolia* results revealed the presence of tannin (11.40 ± 0.02) alkaloid (9.80 ± 0.01), steroids (18.20 ± 0.01), glycosides (29.80 ± 0.01) and saponins (6.80 ± 0.00), also exhibited a positive linear correlation between polyphenols and the free radical scavenging activities.

Borguini *et al*., (2013) reported that alcohol and aqueous extracts from organic tomatoes presented higher antioxidant activity in the DPPH test (25.43 and 14.28 %,) than the conventional tomatoes (19.52 and 11.33 %) and stated that organic tomatoes had higher antioxidant potential probably due to its higher ascorbic acid and total phenolic values.

Nur *et al*., (2013) studied the effect of fertilizers on total phenolic total flavonoid, antioxidant activities and cyanogenic glycosides of cassava leaves and tuber. The phenolic and flavonoid content was significantly higher in the vermicompost and organic fertilizer application resulted in lower cyanide content compared to inorganic fertilizer (NPK). Ibrahim *et al*., (2013) reported that the application (organic chicken dung; 10% N:10 % P_2O_5:10 % K_2O) inorganic fertilizer (NPK green; 15 % N, 15 % P_2O_5, 15 % K_2O) nitrogen at 90 kg N/ha improved the production of secondary metabolites in *Labisia pumila*. Higher rates at 90 kg N/ha reduced the level of secondary metabolites and antioxidant activity of this herb.

Singh *et al*., (2013) reported that the crude extracts of different parts (root, stem and leaf) of *Withania somnifera* screened for their antimicrobial activity in-vitro against one gram positive bacteria (*Bacillus subtilis*), one gram negative bacteria (*E. coli*) and it is observed that chloroform extract of stem (16.2 mm) showed highest minimum inhibitory concentration (MIC) against *B. subtilis*. According to Syed *et al*., (2013) preliminary phytochemical screening of different extracts of *Pisonea aculeata* leaf showed the presence of alkaloids, triterpenes, tannins, saponnins, glycosides, phenolic compounds and flavonoids.

Deepak *et al*., (2014) reported that the antioxidant activity of *Andrographis paniculata* with 3 extracts (Hexane, DCM and Methanol) showed the IC_{50} values 223.3 µg/ml, 69.32 µg/ml and 82.23 µg/ml in DPPH assay. The DCM extract of leaves showed the best antibacterial activity against the gram positive bacteria *Staphylococcus aureus* and *Streptococcus pyogenes at* 3 different concentrations (100, 200 & 500 µg/ml). Dharajiya *et al*., (2014) investigated the antibacterial activity of various solvent extracts of stem of *Withania somnifera* against gram negative bacteria *Escherichia coli, Serratia marcescens, Pseudomonas aeruginosa* and gram positive bacterium *Bacillus cereus* and the maximum antibacterial activity was recorded for methanol extract of *W. somnifera* stem against *E. coli* zone of inhibition (ZOI) of 17.67 ± 1.52 and Activity Index (AI) of 0.974 followed by *B. cereus* zone of inhibition (ZOI) of 15 ± 1.0 and Activity Index (AI) of 0.993.

Dwivedi *et al*., (2015) screened the leaves of *Andrographis paniculata* for phytochemicals and the extract of leaves with selected solvents petroleum ether and methanol showed the presence of alkaloids, steroids, flavonoids, tannins, triterpenoids, quinones, protein, sugars and gum. Patil *et al*., (2015) investigated the aerial parts (leaves and stem) of *Trigonella foenum- graecum* L. for the preliminary phytochemical analysis and it indicated the presence of proteins, starch, amino acids, fats and fixed oils, glycosides, tannins, alkaloids and flavonoids. Uckoo *et al*., (2015) evaluated the levels of phytochemicals of Meyer lemons (*Citrus meyeri* Tan.) cultivated on organic and conventional manner.the results indicated that organically grown lemons contain significantly higher levels of hesperidin, didymin and ascorbic acid than those cultivated in conventional system.

Zambrano-Moreno *et al*., (2015) reported that the antioxidant activity was found to be high between conventional (36.61 µmol trolox equivalents TE/g FW) and organically cultivated (5.60 µmol TE/g FW) egg plant, total soluble polyphenols (77.20 mg gallic acid equivalents GAE/100 g (fresh weight FW) of organically grown egg plant as compared to the conventionally grown egg plant (63.99 mg GAE/100 g FW).

Dangi *et al*., (2016) studied in *Trigonella* species for antibacterial activity against five plant pathogenic bacteria and five fungi. Three species showed strong antifungal activity against *Aspergillus niger* and *Fusarium solani* and three species namely *Trigonella coerulescens*, *T. suavissima* and *T. stellata* showed broad spectrum antibacterial activity inhibiting all the 9 test bacteria. Dharajiya *et al*., (2016) investigated the antibacterial activity of *Trigonella foenum-graecum* leaf extracts and found maximum on *Serratia marcescens* with a zone of inhibition (ZOI) (12.33 ± 0.57 mm) by aqueous extract followed by inhibition of *Bacillus cereus* (11.50±0.50 mm) by the methanol extract.

Gupta *et al*., (2016) evaluated phytochemical contents of 25 moth bean (*Vigna aconitifolia*) seed accessions. The studies revealed significant variation in the contents of phytochemical composition which is correlated with seed storage proteins like albumin and globulin. Lamma and Moftah, (2016) reported that application of vermicompost at different time intervals (20, 40 and 60 days) has positive effects on *Andrographis paniculata* and showed that the highest antioxidant levels compared with inorganic fertilizers.

Mohd Din *et al*., (2017) conducted an experiment to assess the effect of compost extracts on pak choi (*Brassica rapa* cv. *chinensis*) and higher antioxidant capacity was observed at non-aerated compost extract NCE + inorganic fertilizers. Petkova *et al*., (2017) analyzed 8 medicinal plants for antioxidants activity. Great difference in antioxidant activity was observed between species. The results for scavenging of DPPH radical were from 18.4 ± 0.6 to 334.1 ± 0.3 mM TE g^{-1}dw. The highest antioxidant activity possessed by *Arctium lappa* L 245.12 mM TE g^{-1}dw, followed by *Tussilago farfara* L. and *Mentha piperita* L extracts.

Polash *et al*., (2017) screened leaf and stem extracts of (water, and 70% ethanol and hexane) *Andrographis paniculata* (kalmegh) and found aqueous stem extract showed superior antibacterial effect against *E. coli* and *Bacillus subtillis*, (21 mm and 29 mm) on the other hand, the ethanolic stem extract showed the maximum antibacterial activity against *Salmonella typhi* (8.15 mm). Yaldiz *et al*., (2017) conducted experiment to determine essential oil yields, essential oil compositions, total phenolics, antioxidant and antibacterial activities of organic manure - treated medicinal plants of four Lamiaceae species cultivated in barnyard manure and it enhanced the total phenolics content, antioxidant activity in *Melissa officinalis* L. and essential oils of these plants exhibited antibacterial effects against *Staphylococcus aureus*, *Staphylococcus epidermidis, Enterococcus faecalis* and *Escherichia coli*.

Gholami *et al*., (2018) reported that the application of Humic Acid (HA) and vermicompost on chicory (*Cichorium intybus* L.). Results showed that humic acid (0.9 kg/hectare) and vermicompost (7.5 t/ hectare) improved the phytochemical properties of total phenolics and flavonoids. Karthiya and Vijayalakshmi, (2018) studied phytochemical analysis of *Millingtonia hortensis* L. and *Tecoma stans* L. leaves belonging to the family Bignoniaceae. The results revealed that ethanol, acetone, chloroform and water extracts showed the presence of carbohydrate, reducing sugar, protein, alkaloids, phenols, phytosterols and amino acids. Talei, (2018) investigated the impact of compost tea rates (0, 25, 50, 75 and 100 %) antioxidant reactions of *Andrographis paniculata* (Burm.f.) Nees. The results revealed that rates of compost tea significantly affected Ferric Reducing Antioxidant Power assay (FRAP) and total flavonoid contents ($P \leq 0.01$), while there was no significant difference on DPPH reduction, total phenolic contents and photosynthetic rate.

Salehi *et al*., (2019) studied the effect of organic fertilizers on antioxidant activity and bioactive compounds of fenugreek seeds in intercropped systems with buckwheat. It is found that harvested fenugreek seeds from plants that were intercropped with buckwheat and with the application of organic fertilizer enhanced the seed content of antioxidants and flavonoids. Antioxidant activity was analyzed of pineapple fruits grown on chemical fertilizer and vermicompost. The plants with vermicompost showed the IC_{50} values higher in DPPH scavenging activity (3.139 mg/mL), ABTS (7.290 mg/mL) and FRAP (0.276 mg FE/g dE) than plants grown on chemical fertilizer (Mahmud *et al*., 2019).

Alkooranee *et al*., (2020) evaluated the antifungal activity of leaves and roots parts of *Chenopodium album* against five phytopathogenic fungi (*Alternaria alternata, Fusarium solani*, *Rhizoctonia solani*, *Pythium aphanidermatum* and *Sclerotinia sclerotium*) and it is found that water extract of *C. album* showed reduction of fungi mycelia growth. Hassan and El-Azeim, (2020) conducted a field experiment with organic fertilizer (0, 5, 10 and 15 ton/fed), microbein biofertilizer (M.B.) at 50 ml/plant and antioxidant treatments (salicylic and ascorbic acids) on gladiolus (*Gladiolus grandifloras*) corm and cormels production and reported that compost (15 ton/fed) in combination with microbein biofertilizer (M.B.) at 50 ml/plant along with some antioxidant (salicylic and ascorbic acids) treatments each at 50 ppm significantly increased corms and cormels production.

Mai *et al*., (2020) studied the antioxidative response of *Glycine max* (L.) Merr. cv. Namdan to drought stress stated that high accumulation of enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT) and peroxidase (POX) detoxify the excess of O_2^- and H_2O_2 and decrease oxidative damages. Ramya *et al*., (2020) analyzed the phytochemical screening and antidiabetic potential of *Trigonella foenum-graecum* on alloxan induced diabetic rats concluded that antidiabetic potential of *Trigonella foenum graecum* can be attributed to wide range of active pool of secondary metabolites present in the seed part.

Shesharao *et al*., (2020) tested the alcholic extracts *Trigonella foenum graecum* and *Coccinia indica,* it was found to be positive for flavonoids, saponins, alkaloid, bitter principles, coumarines, anthracene and glycosides.

Chaturvedi and Pandey, (2021) observed the effect of bioinoculant and vermicompost on *Mentha arvensis* L. and it showed improved plant growth, secondary metabolites, total phytoconstituents and total antioxidant capacity in bioinoculant - treated plants as compared to the control with carrier vermicompost. Hariharan *et al*., (2021) analyzed *Andrographis paniculata* for phytochemicals. Saponins, tannins, phlobatannins, hydrolysable tannins, phenols, alkaloids, terpenoids, flavonoids and glycosides were present in aqueous extract. Ethanol extract also showed similar results with the exception of cardiac glycosides. Uthirapandi *et al*., (2021) reported that application of seaweed (*Sargassum wightiiGreville*) liquid extracts enhanced the andrographolide (34.92 mg g^{-1}) production and antioxidant activity in *Andrographis paniculata* (Burm f.) Nees 53.94 μg/ml DPPH activity and 44.94 % inhibition of nitric oxide activity.

Das *et al*., (2022) analyzed the antimicrobial activity of *Moringa oleifera* against *Pseudomonas aeruginosa, Bacillus subtilis, Staphylococcus aureus* and *Proteus mirabilis* the results exhibited a broad - spectrum antimicrobial activity due to the presence of various phytochemicals like phenols. Sahrawat *et al*., (2022) studied the antifungal and anti oxidant activity of whole part of *Dactyloctenium aegyptium* weed on bengal gram and concluded that excess concentration of the extract of *Dactyloctenium* reduce the growth of all the soil borne fungal phytopathogens and antioxidant activity was shown in stem (67.10 %), root (64.15 %) and seed (59.1 %) by FRAP method.

Hamedi *et al*., (2022) observed the influence of different fertilizers and weather conditions on flowers of damask rose (*Rosa damascena* Mill.) the results showed the maximum total flavonoids from horse manure, NPK, and vermicompost along with of Zn, Cu, Fe and Mn in the flowers at highest concentrations and recommended that use of organic fertilizers especially horse manure and vermicompost at the semiarid climate gives good results.

Hashempoor *et al*., (2022) studied the effect of different fertilizer sources on soil nutritional status and physiological and biochemical paramenters of cone flower (*Echinacea purpurea* L.), *Azospirillum* + *Pseudomonas* enhanced superoxide dismutase (SOD) and peroxidase (POD) activity along with highest content of protein, total phenol and total flavonoids in the leaves of cone flower. Lahbouki *et al*., (2022) grew prickly pear cactus (*Opuntia ficus-indica*) under the arbuscular mycorrhizal fungi and vermicompost supplementation and observed the enhancement of phenolic and antioxidant activity by inhibition of the free radical 2, 2-diphenyl-1- picrylhydrazyl (DPPH) activity by 58, 52 and 33%.

Libutti *et al*., (2023) found an enhancement of yield, phytochemical content and biological activity of a leafy vegetable (*Beta vulgaris* L. Var. Cycla) by using organic amendments as an alternative to chemical fertilizer the results are found to increase antioxidant activity with vermicompost treatment. Aydi *et al*., (2023) reported that the date palm compost with animal manure when used as soil less substrate improved phytochemical composition and antioxidant activity of melon (*Cucumis melo* L). Chandukishore *et al*., (2023) reported that the application of plant extract-based vermiwash (VW2) on *Capsicum annum* (bell pepper) has showed a notable inhibition zones against *Pseudomonas aeruginosa* (5.14 mm), *Klebsiella pneumonia* (5.91 mm), *Escherichia coli* (5.15 mm), *Staphylococcus aureus* (5.11 mm) and *Candida albicans* (4.18 mm).

El-Hefny *et al*., (2023) observed that the combined application of compost (50 and 25 %) and metallic nanoparticles (30 mg/L) on *Asclepias curassavica* has showed highest antimicrobial activity in leaf methanolic extracts LMEs (4000 mg/L) inhibition zones (IZs) 2.43 and 2.2 cm, against the growth of *Dickeya solani* and *Pectobacterium atrosepticum* (2.76 and 2.73 cm) as well as it showed several phytochemical productions.

Verrillo *et al*., (2023) reported that humic substances (HS) and compost teas (CTs) extracted from artichoke (ART) and coffee ground (COF) recycled biomasses when employed on *Ocimum basilicum* plants showed HS-ART and CT- COF antioxidant capacity (55 and 49 µmol) at the maximum concentration (100 mg L^{-1}). Inhibition zones (mm) of methanol extracts from basil plants treated with humic substances and compost teas from artichoke residues (HS-ART, CT-COF) showed larger effect at (100 mg L^{-1}) concentration against *Staphylococcus aureus* (11.4 and 17.1 mm), *Enterococcus faecalis* (12.4 & 9.2 mm), *Escherichia coli* (10.2 & 9.7 mm), *Pseudomonas aeruginosa* (9.8 & 8.7 mm), *Salmonella typhi* (8.6 & 7.9 mm) and *Listeria monocytogenes* (112 & 10.1 mm).