# 2

# Review of Literature

The literature pertaining the overview of the organic amendment such as biocomposted manure, compost, vermicompost, FT-IR and microbial population of various organic manure and the influence of these manure on the vegetative, biochemical and yield parameters, leghaemoglobin, antioxidant, antibacterial activity and soil fertility were presented in this chapter.

## 2.1 Review on composting, vermicomposting, microbial count and physicochemical parameters

Organic farming includes tradition, innovation and science to benefit the shared environment and promoting pale dealings and a good quality of life for all involved, it has the most energy-efficient and cost-effective method for utilising agricultural machines and non-renewable natural resources and its process is gaining increasing popularity (Dangour *et al*., 2010; Dubey, 2013; Ganeshan *et al*., 2013).

Composting is a process of converting the bio-chemical organic matter into humus (Lignoproteins) by the help of mesophilic and thermophilic organisms. A composting process seeks to connect the natural forces of decomposition to save the conversion of organic waste into organic fertilizer. There are two main groups of organisms which decompose the organic matter a) Anaerobic bacteria which perform their work in the absence of oxygen b) Aerobic bacteria which perform their work in the presence of oxygen (Raza and Ahmad, 2016).

Reghuvaran and Ravindranath, (2010) reported that the application of composted coirpith with nitrogen fixing bacteria is an effective potting medium for cultivation of medicinal plants like *Phyllanthus amaranthus*, *Andrographis paniculata*, *Bacopa moneiri* and *Piper longum.*

Sangwan *et al*., (2010) reported that the vermicompost of sugar industry waste (Pressmud) with cow dung resulted in decrease in carbon, increase in nitrogen, phosphorus and calcium concentrations. The study indicated that vermicomposting could be used as an alternative technology for the management of Pressmud into useful fertilizing material, if mixed at maximum 50% with CD.

Composting includes different phase, the first phase (mesophilic phase) (25-45°C), is energy-rich easily degradable compounds such as sugars and proteins are degraded by fungi, actinobacteria and bacteria. The increase in a temperature higher than $45^0$C leads to another phase called the thermophilic phase, which is important for pathogen and parasites elimination, ensures maximal sanitary conditions. When the activity of the microorganisms decreases due to the exhaustion of the substrate then the temperature starts to decrease that leads to cooling or mesophilic phase. The mesophilic microorganisms such as bacteria, fungi and actinomycetes begins to grow again and predominate during these phase and maturation phase. In the maturation phase, the compost pile is stabilized for plant use and the proportion for fungi increases while bacterial numbers decline (Wichuk and McCartney, 2010; Ho *et al*., 2022).

Devi *et al*., (2012) reported that composting of fruit waste using *Eudrillus eugeniae* and *Eisenia foetida* resulted in reduction of TOC (Total Organic Carbon), Phosphorus and C: N (Carbon: Nitrogen) ratio but an increase of TKN (Total Kjeldhal Nitrogen), pH & EC (Electrical Conductivity) of the compost respectively. Manyuchi *et al*., (2012) stated that the vermicompost produced from waste corn pulp was dark brown, odourless and implementing vermicompost technology can be successful as a solid waste management system with corn pulp as the major organic waste.

Pandit and Maheshwari, (2012) stated that 25°C temperature, pH 7.0, 1-2 mm particle size, 80% moisture content were optimum parameters of vermicomposted sugarcane wastes through *Eisenia fetida*. It was also noted that vermicompost obtained by above method was rich in Nitrogen, Phosphorus, Potassium, Sodium, Calcium and Magnesium content including some micronutrients i.e. Iron, Zinc, Manganese, Copper, Boron and Aluminium.

Velmourougan and Raphael, (2012) reported vermicompost and vermicasts from native earthworms recorded higher functional microbial group's population as compared to the exotic worms.

Ghosh *et al*., (2013) reported that both total fungal and bacterial count per gram of sample were increased with increasing addition of vermicompost in soil. Soil fertility can be maintained adequately under organic management and the added benefits increased organic matter content and improved soil physical condition, which is also supported by a larger active soil microbial biomass community.

Selvamurugan *et al*., (2013) stated that application of biocompost (5t/ ha) enhanced bacteria ($25x10^6$ CFU $g^{-1}$), fungi ($14x10^4$ CFU $g^{-1}$) and actinomycetes ($8x10^3$ CFU $g^{-1}$) as compared to the biomethanated distillery spent wash.

Sarker *et al*., (2013) revealed that combined inoculation of Pressmud, bacterial consortia and cattle manure found to be the best decomposer resulting in reduction of organic carbon content (26.75%), C:N ratio (12.44%) while it increased the nitrogen (2.34%), phosphorous (1.15%) and potassium (1.37%) content. Highest microbial load was observed in pressmud inoculated with a bacterial consortium ($T_7$) with total bacterial population ($90.57\times10^4$ /gm), the fungal population ($72.72\times10^2$ /gm) and the actinomycetes population ($48.57\times10^2$ /gm) at 49 days.

Viji and Neelanarayanan, (2013) reported the vermicompost harvested from *Eudrilus eugeniae* experimental trays showed remarkable levels of chemical nutrients and higher density of microbial population *viz.,* Bacteria ($170 \times 10^{-6}$ CFU), Actinomycetes ($11 \times 10^{-6}$ CFU) and Fungi ($295 \times 10^{-6}$ CFU) followed by *Perionyx excavates* and *Lampito mauritii*.

Yadav *et al*., (2013) ascertained that the vermicompost harvested after 3 months showed lower pH, total organic carbon (TOC), organic matter (OM) and carbon/nitrogen ratio (C/N ratio) but higher electrical conductivity (EC), nitrogen, phosphorous and potassium (NPK) content than the raw substrate.

Prabhakaran and Manivannan, (2014) observed that among the different treatment inoculation of lignocellulolytic fungal consortium in poultry droppings and bagasse mixed at equal proportion (1:1) produced a superior quality compost with desirable C:N ratio and higher macro and micro nutritional status than uninoculated natural composting.

Sonowal *et al*., (2014) reported that pH values of the reactors after 45 days of vermicomposting increases with maximum pH value in R1 with 8.02 which range from 7.4-7.7 in the respective controls. The reactors R1 and R2 pH value was in increasing trend till the end of the vermicomposting period. The electrical conductivity (EC) values in the final product increased for the reactors R1 (58.3%), R2 (38.8%) and its CR1-controls (39.3%). The results indicated that 100% solid pulp and paper mill sludge (SPPMS) could be converted into good quality manure by vermicomposting if mixed with cow dung.

Song *et al*., (2014) showed reduction in C/N ratio, increase in total concentrations of N, P, K, increase in humic acid concentration, humification ratio and humification index due to earthworm activities.

Shamini and Fauziah, (2014) investigated the microbial population of vermicomposted banana stem waste combination with spent tea indicate that the population increases due to the introduction of the microbial consortium to each of the vermicomposting set-ups. The most active reaction can be observed in the set-up with the application of consortium 3I3 (*Pseudomonas alcaligenes*, *Flavobacterium johnsoniae* and *Bacillus licheniformis*) to all waste.

Albasha *et al*., (2015) studied on the potential of the African night crawler *Eudrilus eugeniae* in vermicomposting of Kitchen waste and noted that a mixture of Kitchen waste and cow dung in the ratio 1:1 was found to be the best ratio than 2 (Kitchen waste): 1 (cow dung) and 3 (Kitchen waste): 1 (cow dung). Increase in parameters like, total nitrogen (%), available phosphorus (%) and potassium (%) while a decrease in pH and C:N ratio was found as the timing of vermicomposting increased from 0 day to 6 days.

Bhardwaj *et al*., (2015) reported highest total microbial load in mixed-culture vermibed (*E. fetida* and *L. mauritii*) as compared to other vermibed. Bacterial population of vermicompost varied from 2.88 x $10^6$ to 6.68 x $10^7$ CFU /g and fungal colonies varied from 1.8 x $10^6$ to 5.5 x $10^6$ respectively.

Hanc and Vasak, (2015) reported the decreased in pH value and noted to be between 7.3 and 7.7 in the final vermicompost. Due to loss in organic matter, the total content of macro-elements increased at the end of vermicomposting with the exception of calcium. Similarly, the available contents of phosphorus and potassium increased, which was positive in terms of the use of vermicompost for agricultural purposes while the earthworm biomass increased from 282 to 896 % depending on the treatment after 5 months of vermicomposting. The best results were achieved during the vermicomposting of a mixture of straw (25 vol %) with separated digestate (75 vol %).

Hapsoh *et al*., (2015) reported the compost quality standards appropriate with Indonesia SNI 19-7030-2004 was a combination of rice straw + market waste that contains 1.12% nitrogen, 0.28% phosphorus, 0.63% potassium, ratio C/N 19.50, pH 7.42, and organic matters 37.65%. According to Haiba *et al*., (2014) vermicompost made from kitchen wastes contained 3.3% total nitrogen, 0.7% total phosphorous, 5.8% potassium and the vermicompost made from sewage sludge and sawdust noted 2.4% total nitrogen, 0.2% total phosphorous and 0.3% potassium. Small-scale vermicomposting of both household kitchen wastes and sewage sludge can be efficient, cost effective and eco-friendly.

Okareh *et al*., (2015) investigated on the physicochemical parameters of waste mixture (raw biomass) and vermicompost. The pH, proportions of OC, N, P, K and Carbon-Nitrogen (C-N) ratio of the waste mixture were: 5.6, 20.2 %, 0.9 %, 0.1 %, 0.3 %, and 23.4 while the pH, proportions of OC, N, P, K and C-N ratio of vermicompost was 7.3, 11.3 %, 1.3 %, 2.0 %, 2.5 % and 8.8 respectively.

Sequeira and Chandrashekar, (2015) reported that the highest bacteria count per gram of vermicompost was obtained from mixed organic garbage without cowdung slurry vermicompost (634 x $10^5$ CFU/$g^{-1}$) followed by garden trimming leaves vermicompost) 350 x $10^5$ CFU/$g^{-1}$), mixed organic garbage vermicompost (255 x $10^5$ CFU/ $g^{-1}$) and waste paper (110 x $10^5$ CFU/$g^{-1}$). Fungi count was observed in garden trimming leaves vermicompost (113 x $10^3$ CFU/$g^{-1}$), mixed organic garbage without cowdung slurry vermicompost (73 x $10^3$ CFU/$g^{-1}$), mixed organic garbage vermicompost (39 x $10^3$ CFU/$g^{-1}$) and waste paper vermicompost (17 x $10^3$ CFU/$g^{-1}$). The count of Actinomycetes was noted maximum in mixed organic garbage without cowdung vermicompost (699 x $10^4$ CFU/$g^{-1}$), garden trimming leaves vermicompost (649 x $10^4$ CFU/$g^{-1}$), waste paper vermicompost (570 x $10^4$ CFU/$g^{-1}$) and least was observed in mixed organic garbage vermicompost (167 x $10^4$ CFU/$g^{-1}$).

Tripathi *et al*., (2015) stated that vermicompost enhances the soil fertility by promoting beneficial microbial growth activities in soils and other organic substances are beneficial for the growth and development of crops in sustainable ways.

Viji and Neelanarayanan, (2015) reported that the physico-chemical and biological parameters of the vermicompost obtained from Experiment I (mixed leaves litter treated with cow dung in 1:2 ratio) showed better result followed by Experiment III (mixed leaves litter treated with cow dung and goat dung in 1:1:1 ratio) and Experiment II (mixed leaves litter treated with goat dung in 1:2 ratio).

Vermicomposting is one of the most feasible and environment friendly technique for the bioconversion of industrial wastes/sludges into a useful and high quality vermicompost (Bhat *et al*. 2016).

Hussain *et al*., (2016) concluded that the vermicomposting is the resourceful technique to renovate the vegetable market waste into a biofertilizer. It is a simple biotechnological process in which earthworm and microorganisms are employed to convert the organic waste or biological waste material into excellent biocompost.

Owis *et al*., (2016) reported that bulk density, water holding capacity and nutrient content (total and available forms of N, P and K) were greatly increased with progressing composting process, while the pH and EC were fluctuated among the heaps and different stages of composting process and the organic carbon, organic matter declined as the composting progress for all heaps. According to Sivakumar and Karthikeyan, (2016) the number of colony forming unit of the vermicompost was bacteria (185 x $10^6$), fungi (15 x $10^3$) and actinomyces (207 x $10^4$) when compare to the commercial vermicompost, bacteria (60 x $10^6$), fungi (9 x $10^3$) and actinomyces (103 x $10^4$) respectively.

The earthworms change the composition of waste, decreases organic carbon content, C:N ratio and retains macro and micronutrients (Bhat *et al*., 2017).

Gong *et al*., (2017) reported that the quality of the final vermicompost (in terms of electrical conductivity, nutrient content, C/N ratio, humic acid content, lignin and cellulose contents, and phytotoxicity to germinating seeds) was enhanced by addition of rhamnolipid and microorganisms.

Game *et al*., (2017) revealed that the bacterial and fungal population increased gradually and highest population was recorded in initial phase of composting i.e. between 60 to 90 days of composting in test consortium and commercial consortium treated pits, while uninoculated control pits took 90 to 120 days for reaching to its maximum. Thereafter a gradual decrease in bacterial, fungal population and increase in actinomycetes population was recorded with highest peak between 120 and 150 days of composting period.

Mousavi *et al*., (2017) stated that due to the high levels of nitrogen in raw material of some treatments, the concentration of N in mature compost was higher than other treatments such as total nitrogen content of the waste mixtures and single waste ranged from 0.97% and 0.92% (Cow dung), 0.97% (Food waste) and 1.03% (Foliage) respectively.

Patil *et al*., (2017) reported that the organic carbon content was recorded maximum in M1- Coir waste (100%) (28.48%) and minimum in M6- Cow dung (100%) (20.45%) after 180 Days After Inoculation and earthworm species E1- *Eudrillus eugineae* has minimum carbon content (22.95 %) after 180 DAI than E2- *Eisenia foetida* (23.64%). All the nutrient content in the treatment, M1 has minimum content of N (0.97%), P (0.39%) and K (0.57%), whereas, treatment M5 (Coir waste 20 : 80 cow dung) has recorded maximum content of N (1.30%), P (0.52%) and K (0.83%) which was followed by treatment M4 (coir waste 40 : 60

cow dung) having N content (1.23%), whereas for P content treatment M6 followed by M5 (0.50%) and K content (0.73%) in M4 on 180 DAI.

Arumugam *et al*., (2018) reported that total organic carbon (26.52 and 37.47%), total organic matter (36.01 and 33.13%) and C/N ratio (15.02 and 11.92%) are reduced in both Vermicompost (cowdung + paper cup waste + earthworm (*Eudrilus eugeniae*)) and Vermicompost with bacterial consortium (cowdung + paper cup waste + earthworm (*Eudrilus eugeniae*) + microbial consortia) with pH (8.01 and 7.56), EC (1.2–1.9 $\mu s^{-1}$ and 1.4–19 $\mu s^{-1}$), total phosphorus (46.1 and 51%), total magnesium (50.52 and 64.3%), total calcium (50 and 64%), total sodium (1.39 and 1.75%) and total potassium (1.75 and 1.86%) increases significantly.

Chander *et al*., (2018) reported that bacterial population observed highest under aerobic-composting (21.1–65.3 × $10^{10}$ CFU/g) as compared with vermicomposting (19.7–61.6 × $10^{10}$ CFU/g) while fungi comprised very little component of microbial population (5–9 × $10^3$ CFU/g on day 1, 5–10 × $10^3$ CFU/g on day 20 and 4–4 × $10^3$ CFU/g on day 55). Similarly, higher population (71–237 × $10^9$ CFU/g) of actinomycetes was observed under vermi-composting as compared with aerobic-composting (56–75 × $10^9$ CFU/g). The nutrient content noted high in aerobic-compost (1.55% N, 0.93% P and 1.00% K) content and stable C:N ratio (10.3) when compared to vermi-compost (1.11% N, 0.43% P, 0.96% K and C:N ratio of 11.7) respectively.

Elmahadi and Elamin, (2018) showed first season treatments resulted in a significant difference in the number of bacteria across the different sampling months (February, March and April). Aerobic preparation method recorded the highest bacterial concentration during February and April. In the second season, the aerobic method had the highest bacterial concentration in February while the anaerobic method recording the lowest value. Vermin method had lowest bacteria during March and April. During February, aerobic method had the highest fungi concentration, during March the vermin treatment recorded the highest concentrations, whereas the anaerobic method recorded the highest concentration during April.

Kim *et al*., (2018) stated that chemical properties such as pH (6.60–9.10), EC (1.36–2.86 dS $m^{-1}$), and organic matter content (49.40–64.04%) were within the ranges of typical composts while nitrogen content (1.76–2.28%) was increased when successive composting

technique was adapted. After finishing the second composting, average nitrogen content was increased at the range of 9.4–32.4% compared to the first cycle of vegetable waste compost.

Truong *et al*., (2018) revealed that the addition of VC significantly improved the physico-chemical media properties, increasing the EC and macronutrients in the media resulting in a substantial increase in the yield and quality of tomato fruits. Thyug and Kakati, (2018) reported that the cast of earthworms is labelled as biogenic structures consist of assemblies of organo-mineral aggregates and the earthworm influence on soil organic properties, altering soil profile and it ensure sustainable soil fertility by improving the physical, chemical and biological characteristic of the soil.

Blouin *et al*., (2019) indicate that meta-analysis used to prepare quantitative summary based on research studies for vermicompost showed maximum plant growth could be achieved when 30-50% of soil is replaced by vermicompost. Organic matter, cellulose, organic carbon, lignin, C:N ratio and C:P ratio was significantly lower than compost while N, P and K content were greater than the compost.

Dey *et al*., (2019) reported that vermicompost of MSW and *Phumdi* has highest nitrogen content (1.5) than that of compost (1.4) and soil (1.07), phosphorus has the highest value of 0.074, 0.081 in compost and Vermicompost of *Phumdi* than that of compost and vermicompost of MSW i.e. 0.065 & 0.069 and soil 0.01, potassium was recorded highest of 0.9 in vermicompost of *Phumdi* and MSW, second highest by compost of *Phumdi* (0.8), thirdly compost of MSW (0.7) least record in soil (0.1).

During the composting of vegetable, cowdung and sawdust, the pH and EC increase quickly from 6.8 to 7.1, 2.1 to 3.5 dS $m^{-1}$ in the thermophilic phase. The pH for end compost was recorded as 7.6. Nutritional properties such as nitrogen, phosphorus, and potassium were measured during 20-d composting process and noted that all nutritional parameters were observed to be increasing during the composting process with total potassium increased from 14.3 to 25.2 g $kg^{-1}$ and total nitrogen from the initial value of 1.5 to 2.2% during the composting process (Jain *et al*., 2019).

Karmegam *et al*., (2019) reported the use of paper mill sludge, green manure plant *Tephrosia purpurea* (TEP) and *Gliricidia sepium* (GLS) and cow dung to prepare vermicompost using *Eisenia fetida*. According to Ramnarain *et al*., (2019) pH was slightly acidic in the vermicompost, followed by the raw material and the cow manure, i.e., 6.5, 6.5

and 6.2, The electric conductivity in vermicompost, raw material and cow manure were 3.71 mS/cm, 3.00 mS/cm and 5.72 mS/cm, with slight decrease in the vermicompost compared to the cow manure. The total organic carbon was 18.53%, 42.96% and 21.02%, total nitrogen was 1.36%, 1.88%, 1.57%, total phosphorus was 0.58%, 0.26% and 0.78%, total potassium was 0.56%, 1.23%, 0.86% in the vermicompost, raw material and cow manure, C/N ratio in the vermicompost, and cow manure was the same (13:1) but quite high (23:1) in the raw material.

Aluko *et al*., (2020) studied on dewatered Faecal Sludge (DFS) and market waste (MW) which were mixed in ratios 1:3, 1:5 and 1:7, respectively with DFS and MW as controls, the N:P:K (%) in composts was noted as 9: 5: 4, 18: 7: 19 and 3: 3: 1 in the 1:3, 1:5 and 1:7 mixes at maturity of compost, while those of controls were: 19:12:12 (DFS) and 17:14:11(MW) respectively.

Biruntha *et al*., (2020) investigated the possibility of using earthworm species *Eudrilus eugeniae* for the vermiconversion of seaweed, sugarcane trash, coir pith and vegetable waste mixed with 1:1 ratio of cow dung into better vermicompost.

Bellitürk *et al*., (2020) investigated the physico chemical properties of raw material of goat manure, cowdung, sheep manure and their vermicompost product noted that percentages of EC, C:N ratio and organic matter decreased in vermicompost as compared to raw material while the proportion of pH, Ca, Mg, Fe, S, N, P, K increased in vermicompost as compared to livestock manures.

Bioconversion of *Lantana camara* a perennial weed species which threatens native ecosystems could be converted into vermicompost using earthworm species *Eisenia fetida* and *Eudrilus eugeniae* with mixture of cow dung (Devi and Khwairakpam, 2020).

Debernardi-Vázquez *et al*., (2020) stated that the final product has ideal characteristics to be used as a soil improver in the fields or to be marketed as a peat moss or compost substitute of coffee pulp and filter mud because the pH (9,1), C/N ratio (27,5), organic matter (65,5%), carbon (38%), macro and microelements show improved characteristics.

Esmaeili *et al*., (2020) stated that the combined compost-vermicompost process with pistachio waste mixed with cow dung could result in a good quality end product having low C:N ratio, total organic carbon, high total N and P. The MAB (Mesophilic aerobic bacteria)

counts in second week of the composting process for samples were 3.64 x $10^7$ CFU/g (S3), 8.28 x $10^7$ CFU/g (S2), and 1.08 x $10^8$ CFU/g (S1), respectively. The number of MAB decreased in the fifth weeks to 6.39 x $10^7$ CFU/g for S2, and increased for S3 (5.00 x $10^7$ CFU/g), 5.96 x $10^7$ CFU/g for S1 and then followed a downward trend until the end of composting respectively (Ghinea and Leahu, 2020).

Khandual and Satapathy, (2020) investigated the physico-chemical properties electro conductivity, pH and moisture content and better output was noted in both F2- 6:4 (Soil + CW) + FW (Floral waste) and F3- 4:6 (Soil + CW) + FW (Floral waste). Kalaivani *et al*., (2020) showed that the kitchen waste composting accelerates the process by adding a termite mound soil that led to increase in physico – chemical and microbial parameters of the composts which gave the better results from kitchen waste composts for the growth of terrace garden plant *Coriandrum sativum*.

Rini *et al*., (2020) indicated that cattle solid wastes generated from indigenous cow breeds were preferred by epigeic earthworm species *Eudrilus eugeniae* over exotic cow breeds for vermicomposting.

Treatment of *Eudrilus eugeniae, Eisenia foetida* and *Perionyx excavatus* on poultry waste (PW) showed a significant reduction in the pH whereas the control pH was 8.55 and reduced to 7.4 after treating with *Eudrilus eugeniae* similar trend was followed with *Eisenia foetida* and *Perionyx excavatus* treated soil as 7.41 and 6.88 respectively. Total organic carbon levels were decreased from 454.69 into 209.86 in the experimental group treating with *Eudrilus eugeniae*, 232.39 in the *Eisenia foetida* and 231.02 treating with *Perionyx excavatus* whereas the nitrogen content of the control soil was found to be 5.71, whereas the nitrogen content was 8.80, 17.71, 12.70 for *Eudrilus eugeniae*, *Eisenia foetida* and *Perionyx excavatus* respectively. Among the three earthworm species, *Eudrilus eugeniae* showed high efficiency of biodegrading poultry waste into an organic manure (Ramesh *et al*., 2020). As reported by Srivastava *et al*., (2020) municipal waste together with cow dung can be converted into valuable vermicompost using *Eisenia fetida*.

Chaudauri and Jamatia, (2021) reported that soil physico-chemical properties prior to experiment were pH (4.1), organic carbon (1.28 %), total nitrogen (0.13%), C/N ratio (9.43), available phosphorus (9.41 kg $ha^{-1}$), available potassium (32.14 kg $ha^{-1}$) and incorporation of vermicompost significantly increased the pH (5.49), organic carbon (2.33%), total nitrogen

contents (0.18%), C/N ratio (12.55), available phosphorus (56.56 kg $ha^{-1}$) and potassium (134.96 kg $ha^{-1}$) in $T_3$ (15 t $ha^{-1}$ $year^{-1}$) tea plantation soil.

Adding agro-wastes (RS- rice straw, SC- Sugarcane, BL- banana leaves) enhanced the nutrients status in the vermicompost and adding BL wastes enhanced K content while adding RS enhanced N content (Moustafa *et al*., 2021).

Olukanni *et al*., (2021) noticed a temperature range from $25^0$C to $56^0$C and pH level ranging from 6.6 to 8.1 during the composting process. The moisture content of the compost pile gradually reduced from 56% to 40% during the experiment. The NPK ratio of the final compost product was noted to be 0.61:0.40:0.73 which could be used for agricultural purposes to supply nutrients to growing plants and to enrich soil.

The pH, EC value and lignin content in raw groundnut shell and vegetable waste is 6.5, 2.96 millimhos $cm^{-1}$, 8.5% and as the decomposition started, it increased to 7.2, 16.22 millimhos $cm^{-1}$, 4.1% in composted groundnut shell and vegetable waste. The Initial nitrogen, total phosphorus, total potassium content of raw groundnut shell and vegetable wastes was 1.20%, 2.31% and 0.62% and there is a slight increase to 1.80%, 3.96% and 1.24% in composted groundnut shell and vegetable wastes while C:N ratio in raw and composted groundnut shell and vegetable waste showed a gradual decrease from 59.68:1 to 18:1 (Rajashri *et al*., 2021).

Sujatha *et al*., (2021) evaluated the various combinations of organic residues and found 100 per cent cow dung showed highest per cent recovery of vermicompost followed by 20:80 combination of Sugarcane bagasse and cow dung and pH of all organic residues decreased slightly and gradual increase in electrical conductivity of composting materials from 20 to 90 days of composting.

Thamizharasan *et al*., (2021) stated that the nutrient content was higher in the earthworm worked leaf litter than the control, nutrients were higher on the $30^{th}$ day from the start of the vermicomposting process and tend to reduce by the $60^{th}$ day with further fall on the $90^{th}$ day during vermicomposting of leaf litter of neem (*Azadirachta indica*).

During the first 10 days, pH value rised from 7.20 to 7.90 and the final pH value was in the range of 7.60, 7.99, 7.94, and 7.97 for VrEF (Vermicompost with *Eisenia fetida*), VrEE (Vermicompost with *Eudrilus eugeniae*), VrPC (Vermicompost with *Perionyx ceylanesis*), and VrC (without earthworm) in the reactor. The initial EC values were found to be

5.42 mS/cm, which was reduced to 5.08 mS/cm in the reactor whereas during vermicomposting the final values were reduced to 3.21, 3.78, 3.45, and 4.65 mS/cm in the reactor VrEF, VrEE, VrPC, VrC respectively (Kauser and Khwairakpam, 2022).

Pariyar *et al*., (2022) reported that the OC content for set 1 (Monoculture of *Eisenia foetida*), set 2 (Polyculture of local earthworm Species), and set 3 (Polyculture of *Eisenia foetida* and local earthworm species) were 3.48%, 3.46% and 3.29% respectively, total N content showed highest amount in set 1 (858 kg/ha), followed by set 3 (832.6 kg/ha) and set 2 (817.7 kg/ha) and highest levels of P and K concentration was noted in set 2 treatments (P: 70 kg/ha and K: 220 kg/ha) followed by set 3 (P: 64 kg/ha and 200 kg/ha) and set 1 (P: 59 kg/ha and K: 125 kg/ha).

Syarifinnur *et al*., (2022) stated that the application of 10t vermicompost/ha resulted in the highest yield of maize and highest increase in soil organic carbon, total phosphorus, available phosphorus, total potassium, pH and highest soil total nitrogen.

**2.2 Review on FT-IR**

Dai *et al*., (2013) point out that the 1000 $cm^{-1}$ band was due to C-O of alcohols derived from intact cellulose and hemicellulose. These functional groups may form part of the cellulose, partially mineralized. The increase of the oxygen-based functional groups (COO-, C-O aromatic and C-O aliphatic) was in line with the values of the H/O ratio which confirm the increase of oxygen base groups due to the composting process.

OH stretching was observed at 3685 $cm^{-1}$ and 3306 $cm^{-1}$ that signifies a strong bond that represents mainly phenolic compounds (Hussain *et al*., 2015).

Hussain *et al*., (2016) studied Fourier Transform Infrared (FTIR) Spectrometry and revealed that the phenols, the sesquiterpene lactones that are responsible for the negative allelopathic impact of parthenium were largely destroyed in the course of vermicomposting and it also indicate that lignin content of parthenium was reduced during vermicomposting.

Bhat *et al*., (2017) stated that FT-IR spectroscopy technique is used to confirm the decomposition of polypeptides, polysaccharides, aliphatic, aromatic, carboxylic, phenolic groups and lignin during vermicomposting process. The spectrum of initial and final vermicomposted samples are generally obtained in the mid-infrared area range of 4000–400 $cm^{-1}$. It is one of the most reliable techniques for determination of vermicompost maturity and different peaks/values show the presence or decomposition of their group in the sample.

According to Arumugam *et al*., (2018) FT-IR spectra comparison of cellulose (C), paper cup (PC), Vermicompost (VC) and Vermicompost with bacterial consortium (VCB) were studied and the stretch of vibration of region around 3100–3600 $cm^{-1}$ indicates the presence of hydrogen bonded (O-H) stretch, the intensity of peak at 3423 $cm^{-1}$ decreased in VC cowdung + paper cup waste + earthworm (*Eudrilus eugeniae*) and VCB- cowdung + paper cup waste + earthworm (*Eudrilus eugeniae*) + microbial consortia when compared to paper cup (PC).

Chávez-García *et al*., (2020) investigated the FT-IR spectra of biochars and reported to have few OH groups (~3600 $cm^{-1}$) in the composition. The ~1600 $cm^{-1}$ band, which corresponds to the aromatic C=C and to the COO-carboxylates are present in great intensity in the composted biochar and the band ~1700 which corresponds to the COOH region was absent.

Kauser and Khwairakpam, (2022) investigated the FT-IR spectra of vermicompost using earthworm species and without earthworm. The peaks in VrEF (Vermicompost with *Eisenia fetida*) reactor are shallower than in the other reactors after treatment, owing to degradation by various types of enzymes found in the earthworm gut and microflora which show a significant reduction during the vermicomposting process.

### 2.3 Review on biometric, biochemical analysis and yield parameters

Joshi and Vig, (2010) stated that application of vermicompost (15%) amended with soil enhanced the seed germination, growth, yield and quality of tomato plants under field conditions.

Chanda *et al*., (2011) suggested that combined application of $T_6$- vermicompost (50%) + NPK (50%) promote fresh and dry weight of leaves, no. of branches, no. of fruits/ plant, weight of fruits (g) and yield (Q/ha) of tomato.

Narkhede *et al*., (2011) reported that application of 20% concentration of vermicompost enhanced the plant height, leaf length, number of leaves per plant, chlorophyll content in leaves, fresh weight and dry weight of chilli pepper plant. According to Singh *et al*., (2011) combined application of nutrient dosage of N, $P_2O_5$, $K_2O$ fertilizer (8:13:10 kg) + vermicompost (3.75 kg/ha) enhanced shoot length, number of primary branches, shoot fresh weight and shoot dry weight increased by 28-63% and by 5-50% in organic mulching treatments in French bean.

Shadanpour *et al*., (2011) stated that combined application of vermicompost (40%) + sand (30%) + soil (30%) enhanced the fresh weight (230.5 g) and dry weight (19.7 g) of marigold. The use of vermicompost tends to increase in nitrogen, potassium and calcium concentration of plant as compared with peat and perlite.

Arvind *et al*., (2012) concluded that combined application of vermicompost with soil mixture enhanced the chlorophyll content (1.996 mg/g) and yield (42.416 q/ha) of wheat crop.

Kumar *et al*., (2012) revealed that combined application of (80%) effluent of painting industry + vermicompost enhanced the chlorophyll 'a', chlorophyll 'b' and 'total' chlorophyll content in *Solanum melongena* (L.). Mathivanan *et al*., (2012) reported that application of 200g vermicompost in 10kg of soil increased chlorophyll 'a' (0.764 mg/g), chlorophyll 'b' (0.544 mg/g), 'total' chlorophyll (1.313 mg/g) and carotenoid content (1.570 mg/g) in groundnut seedlings.

Upadhyay *et al*., (2012) reported that combined application of NPK (40: 20: 20 kg/ha) + farmyard manure (5 t/ha) + vermicompost (2 t/ha) recorded the highest fresh yield (240.5 q/ha) and quality of mint (*Mentha arvensis* L.).

According to Befrozfar *et al*., (2013) shoot dry weight (28.28%), shoot wet weight (13.77%), essence yield (24.84%), plant height (13.2%), leaf area (17.17%), chlorophyll a (17.17%), chlorophyll b (17.37%), and chlorophyll a+b (17.35%) was enhanced by application of vermicompost when compared to control of basil (*Ocimum basilicum* L.).

Kavitha *et al*., (2013) experimented on different combinations of biofertilizer (*Azospirillum)*, chemical fertilizers and reported vermicompost would have an impact on the growth of a green leafy vegetable, *Amaranthus tristis.* After the growth period of 40 days the biometric and biochemical analysis was done and it shows that there is significant change in biometric parameters and increase in the biochemical constituents.

Mishra and Jain, (2013) suggested that combined application of biofertilizers (250 g) + NPK (50%) + vermicompost (5t/ha) promoted the chlorophyll (3.8, 4.8, 5.1, 5.9 mg/g) and protein (5.0, 5.9, 6.6, 7.2 mg/g) content on 45 DAS, 75 DAS, 105 DAS and 135 DAS stage of *Andrographis paniculata*. According to Naveen *et al*., (2013) combined application of NPK (78.06 kg/ha nitrogen), (15.28 kg/ha phosphate) and (101.67 kg/ha potassium) with *Azospirillum brasilense* + *Bacillus megasterrum* + vermicompost promoted the growth and nutrient uptake of rice.

Rahbari *et al*., (2013) evaluated the effects of cow manure vermicompost rates (10%, 20%, 30% and 40%) in growing medium on growth of marigold transplants. The maximum shoot fresh weight, shoot dry weight, root fresh weight and root dry weight were achieved on 40% vermicompost rate.

Dhanalakshmi *et al*., (2014) concluded that when treated with 50% of vermicompost + soil significant increase in the root length of okra (7.07, 9.13, 13.03 cm) and chili (5.80, 7.60, 10.90 cm) on 30, 60 and 90 days after planting. The influence of vermicompost on branch and leaf number was high when compared to control.

Jahanshahi *et al*., (2014) concluded that seed sowing in early April along with vermicompost (32 t/ha) increased the growth and chlorophyll content of dill (*Anethum graveolens* L.). Singh *et al*., (2014) stated that combined application of vermicompost (2.5 t/ha) + FYM (12.5 t/ha) + biofertilizer (2.5 kg/ha *Azospirillum* + 2.5 kg/ha phosphate solubilizing bacteria) enhanced the number of leaves (96.12), number of fruits (17.97), fresh weight of fruits (37.86 g), dry weight of fruit (18.02 g), chlorophyll 'a' (0.59 mg/g), chlorophyll 'b' (0.92 mg/g) and protein content (0.25 mg/g) of chillies.

Vermicomposting of various waste such as cow dung, leaf litter, flower waste and onion garlic waste using earthworm were used for plant growth. The final vermicompost provide better growth and influences chlorophyll content of *Vigna unguiculata* L. (Saravanan *et al*., 2014).

Badar *et al*., (2015a) investigated the effects of composted and uncomposted organic wastes on growth of chickpea plants. Peanut shells and saw dust were used as organic wastes as treatments at the rate of 10 tons/ha. Composted organic materials enhanced more growth as compared to uncomposted materials and organic soil amendments can improve soil fertility and plant growth.

Badar *et al*., (2015b) stated that composted tea waste in combination with coal ash showed better results as compared to other treatments. Biochemical constituents such as % carbohydrate, % protein and total chlorophyll contents were also increased non-significantly by all treatments, except treatment with composted tea waste with bottom ash significantly improved total chlorophyll content of cow pea plants.

Gopinathan and Prakash, (2015) concluded that application of Vermiculture of (*Perionyx ceylanensis*) + cowdung (T4) increased shoot length, root length, number of root

nodules and yield of green gram. According to Chavan *et al.* (2015) the highest plant height was noticed with vermicomposting treatment on $7^{th}$ day (4.1 cm), $30^{th}$ day (8.9cm) over the control and other fertilizers. The weight of pod yield was 106.78 g/100 pods in the set of vermicompost treatment indicating drastic increase than the other sets. Significantly increased growth and pods yield in cluster bean was noted with the application of vermicompost, followed by chemical fertilizers when compared with control field.

Gayathri *et al*., (2015) studied the morphological characters such as, number of leaves, shoot length and root length in plants treated with different concentrations of panchagavya solution (5%, 6%, 7% and 8%) and revealed that panchagavya solution with 8% showed the highest growth parameters in Tomato, French bean and Lady's finger.

Joshi *et al*., (2015) reported application of vermicompost increased seed germination, stem height, number of leaves, leaf area, leaf dry weight, root length, root number, total yield, number of fruits/plants, chlorophyll content, pH of juice, TSS (total soluble solid) of juice, micro and macro nutrients, carbohydrate (%) and protein (%) content hence improved the quality of the fruits and seeds. Studies concluded that treatments of humic acids, plant growth promoting bacteria and vermicompost can be used for a sustainable agriculture discouraging the use of chemical fertilizers.

Kashem *et al*., (2015) revealed highest dose of vermicompost of 20 t $ha^{-1}$ + NPK fertilizer (200%) increased dry weight of shoot and root, number of fruit(s)/plant and mean fruit weight of tomato plant. Karimi *et al*., (2015) reported that fungal compost treatment with 6 tons per hectare had the highest height (28.66 cm), weight of fresh yield (464.66 gr per $m^2$), weight of dry yield (174.389 gr per $m^2$) and chlorophyll content (63.63 mg per $cm^2$). However, the highest crown cover diameter (33.33 cm) and crown spread (10.5 cm) were observed in vermicompost treatment with 9 tons per hectare in *Ziziphora clinopodioides*.

Samadhiya *et al*., (2015) recorded shoot length of plants (4.51±0.07 cm, 4.57±0.10 cm and 4.59±0.10 cm) in TR-1, TR-2 and TR-3 treatments respectively, while in control it is 4.23±0.08 cm. Hence, it can be concluded that the effect of vermiwash and vermicompost on the growth and development of leaves and stem of brinjal plants is more significant than control (Soil and dung only).

Varghese and Celine, (2015) studied the yield and quality characters of long bean varieties under naturally ventilated polyhouse. Super Green recorded the highest pod length (85.07 cm) and pod weight (64.77 g) whereas highest pod girth was noticed in NS - 634.

Neyyattinkara Local recorded highest number of pods per plant and highest yield per plant was noted in Anad Local (1627.12g) followed by NS-634, Githika and Hari Rani.

Alwaneen, (2016) reported that use of cow manure vermicompost has a lot of potential for the development of landscape and house hold plants. The study concluded that cow manure vemicompost showed significant effect on plant growth both for the *Alfalfa* and *Vinca rosea*.

Anisa *et al*., (2016) reported the yield attributing characters were best in the treatment where combined application of all the three biofertilizers *(Azospirillum,* Arbuscular Mycorrhizal Fungi *and Frateuria)* along with double dose of FYM was given ($T_8$) while it was closely followed by the treatment where full dose of FYM, ¾ of inorganic fertilizers and biofertilizers ($T_{10}$).

Gayathri *et al*., (2016) studied the growth parameters namely shoot length, root length and leaf diameter after 15 days and 25 days of growth of the plants and showed a higher growth rate in vegetable compost treated plants than control plants of Tomato, French bean and Lady's finger.

Joshi *et al*., (2016) reported application of recommended dose of fertilizer 20-40-0 NPK kg $ha^{-1}$ recorded significantly higher green pod, stover yield and yield contributing characters *viz.,* number of green pods $plant^{-1}$, number of seeds $pod^{-1}$ over different organic sources.

Kamble *et al*., (2016) reported application of $T_3$- 100% NPK+ poultry manure @ 5 t $ha^{-1}$, recorded maximum plant height (37.30 cm), and yield attributing characters such as pod length (12.83 cm), pod diameter (0.93 cm), number of pods/plant (42.18). The lowest value of growth characters was recorded in treatment $T_{16}$ - FYM @ 25 t $ha^{-1}$ in French bean.

Mudalagiriyappa *et al*., (2016) indicated that spraying of water-soluble fertilizer (19:19:19) at 1.5 % concentration at flowering and pod development stage along with basal application of fertilizers (13.5: 25: 25 kg N, $P_2O_5$, $K_2O$) significantly increased growth attributes, yield and benefit cost ratio in chickpea cultivation. Meena and Ram, (2016) reported that application of RDF + 16.6 kg K + 20 kg S + 3 kg Zn /ha along with seed inoculation with *Rhizobium* + *PSB* noted significantly taller plants, higher number of branches/ plants, pods/plant, higher seed yield, net return and benefit: cost ratio over control of Black gram.

Sakthivigneswari and Vijayalakshmi, (2016c) conducted a pot culture experiment with black nightshade (*Solanum nigrum*) reported that the treatment $T_6$- compost 6 (Raw coirpith predigested by using *Pleurotus sajor-caju* and *Eudrilus eugeniae* (5t $ha^{-1}$)) and $T_3$- compost 3 (Raw corncob predigested by using *Pleurotus sajor-caju* and *Eudrilus eugeniae* (5t $ha^{-1}$)), significantly increased the vegetative and yield parameters of black nightshade.

Vipitha and Geethakumari, (2016) revealed that T1 (coir pith compost – 50g, ground nut cake – 35g and ash – 15g) treatment recorded the highest number of leaves per plant and highest dry matter production (25.6 $plant^{-1}$ and 1481.92 kg $ha^{-1}$) respectively. Among the treatments, maximum yield was obtained in treatment T5 and it was on par with T1 and T2 (poultry manure- 50g, ground nut cake – 30g, rock dust- 20g).

Anhar *et al*., (2017) noticed that the application of organic fertilizer from decomposition influences the plant height, number of leaves, leaf area, fresh weight and dry weight of spinach plants.

Omidi *et al*., (2017) recorded significant increased on plant height, fresh and dry weight of the canopy, root fresh and dry weight, root length and nitrogen in comparison to control as increased levels of composted peanut shells was incorporated in *viola* spp.

Premalata *et al*., (2017) reported that recommended dose of leaf litter compost with 75% of the RDF showed higher germination rate (95%), plant growth (27.7 cm) and number of pods (31 pods per plant) of Black gram compared to the application of 100% RDF and compost. The study illustrated that the leaf litter compost developed by the microbial consortium mediated decomposition could reduce the fertilizer usage by 25% without compromising the yield.

The *Lycopersicon esculentum* which were grown in African vermicompost soil showed significant plant stem height (9.0 cm), length of the root (2.5 cm), number of leaves (5) and length of the leaves (3.0 cm) than the control and Indian vermicompost (8.7 cm, 3.8 cm, 4 and 2.7 cm) on $4^{th}$ week (Sophi and Krishnaswamy, 2017).

Soobhany *et al*., (2017) concluded that both MSW composts and vermicompost have substantial capacity for promoting plant growth significantly the germination rate, shoot length, marketable yield, shoot and root dry weights when compared to the control (soil). Green beans which are grown in 40% vermicompost/soil mixtures and compost/soil mixtures yielded 78.3–89.5% higher fruit weights as compared to control.

Sahu *et al*., (2017) showed maximum plant height (41.86cm), number of branches (6.85) root length (15.27cm), fresh weight (13.00g) and dry weight (5.55g) in T1- kitchen waste compost (KWC) decomposed by *Pseudomonas sp.* followed by other treatment. The minimum plant height (29.56cm), number of branches (4.28), root length (11.22cm), fresh weight (10.00g) and dry weight (4.14g) was noted in T9- control (without compost).

Trupiano *et al*., (2017) reported that compost amendment had clear and positive effects on plant growth, yield and soil chemical characteristics. However, the biochar alone stimulated lettuce leaves number and total biomass, improving soil total nitrogen and phosphorus contents, as well as total carbon, enhanced related microbial communities.

Vijayalakshmi and Gayathri, (2017) revealed plant growth parameters such as shoot length, root length, number of leaves, fresh weight and dry weight better in vermicompost treated with 19g ($T_3$) when compared to control of chilli plant.

Vaidyanathan and Vijayalakshmi, (2017) revealed that significant results were observed in growth parameters on $30^{th}$ day, $45^{th}$ day and $60^{th}$ day. The yield was also significantly higher in soil treated with optimum concentration of vermicompost in tomato plant.

Akoijam *et al*., (2018) reported that an increase of 11.7 cm in height, 13 number of leaves, 5 cm in root length and 3.4 g of biomass in the flower waste amended pots of *Solanum melongena*. Soil moisture, organic C and N increased in all types of amendments. Available K increased only in flower and pineapple wastes amendment.

Ananth and Kumar, (2018) recorded the highest growth parameters with 5 t Vermicompost $ha^{-1}$ + 75% RDF + CBF and it was on par with 5 t Vermicompost $ha^{-1}$ + 100 % RDF + CBF. The highest yield parameters and pod yield (15.5 t $ha^{-1}$) were noted in combination of 5 t Vermicompost $ha^{-1}$ + 75 % RDF + CBF (2 kg Rhizobium $ha^{-1}$ + 2 kg VAM $ha^{-1}$ + 2.5 kg PSB $ha^{-1}$) whereas the lowest values of growth, yield parameters of dolichos bean were recorded with 25 t pressmud $ha^{-1}$ + 75 % RDF + no CBF (Consortium biofertilizers).

Birla *et al*., (2018) reported a significant improvement in protein and N content in seed, Stover yield and N uptake by cowpea with the application of 50% N through FYM + 50% N through vermicompost + PSB ($T_8$), whereas, higher N content in stover and P content in seed were recorded in the treatment $T_9$ (50% N through castor cake + 50% N through vermicompost + PSB).

Celes *et al*., (2018) studied the use of vermicompost, ordinary soil and garden compost for the plant growth and noted that the vermicompost applied plant was more efficient than other plants.

Dhanraj *et al*., (2018) recorded the maximum plant height (13.50, 24.08, 46.25 and 60.07 cm), number of branches (4.55, 6.45, 8.35 and 10.37) on 30, 60, 90 DAS and at harvest, the maximum number of pods per plant (46.43), length of pod (9.76 cm), test weight (4.11g), seed yield (13.53 $Qha^{-1}$) and crude protein content (7.47 %) in $T_4$ treatment of Shankapushpi.

Ferreira *et al*., (2018) indicate that cattle manure can be replaced by household food waste as organic material used in compost piles. Fertilization with organic compost from household food waste positively influenced the growth and nutrient assimilation in the leaf tissue of cherry tomato.

Gupta *et al*., (2018) reported that combination of organic fertilizers, Vermicompost and vermiwash greatly influenced okra plants growth parameters when compared with control. Among the five treatments, Treatment $T_3$ (Soil + vermicompost + ½ recommended dose of NPK) was effective.

Gayathri and Malathi, (2018) studied the growth parameters such as root length, shoot length, number of leaves, fresh weight and dry weight and noted significant results with the combination of bio-fertilizers (*Azospirilium* + VAM + *Phosphobacteria*) on $30^{th}$ and $45^{th}$ day. On the $60^{th}$ day, the fresh weight and dry weight was found to be higher in *Phosphobacteria* ($T_3$) treated plants.

Krishnaraj *et al*., (2018) applied neem cake as soil application before 3 – 4 weeks of sowing/transplanting and the data revealed that the neem cake treated plot showed good results in both vegetative characters and also in the productivity of the crop. Neem cake + *Trichoderma* + *glucose* and Neem cake + *Pseudomonas fluorescens* + *glucose* treated tomato crop recorded about 22 % of yield increase compared to untreated control plot. The other treatments like Neem cake, Neem cake + *Trichoderma viridi* and Neem cake + *Trichoderma* + *glucose* recorded yield increase of 18.76, 17.99 and 19.47 % respectively compared to untreated control.

Morales-Corts *et al*., (2018) studied the growth effect of the tea compost on tomato plants and indicated that both ACT (Aerated compost tea) and AVT (Aerated vermicompost

tea), when applied weekly, produce a positive effect on shoot and root dry weight, chlorophyll content and stem diameter compared to untreated plants. The results support that uses of ACT and AVT as potential alternatives for application of synthetic fungicides, and as plant promoters in crop production, for attaining environmental sustainability for farming and food safety.

Nalluri and Karri, (2018) investigated on 2:1 ratio of soil to chemical fertilizer as a control whereas chemical fertilizer was replaced by 50, 75 & 100 % v/v of groundnut shell compost and highest yield was observed in 50 % groundnut shell compost treatment. Results suggest that groundnut shell compost can be used as an effective alternative to chemical fertilizer to enhance the growth and yield of vegetable plants (Bitter gourd and brinjal) and also an appropriate method to manage environmental pollution.

Rekha *et al*., (2018) reported significant improvement in all the parameters, like length of shoot, length of inter node, number of leaves and number of branches was observed in plants treated with 50% vermicompost in *Capsicum annum* (Linn.) Hepper than Gibberellic acid (GA) and Indole acetic acid (IAA) treatment.

Shaheen *et al*., (2018) emphasized that the highest values of vegetative growth, dry seed yield and the quality attributes of common bean plants were fluctuated between the application of soil drenched diluted chicken manure tea 1:2 incorporated with effective microorganisms at 5 cm/l and soil applied inorganic fertilizers at recommended doses (45 N : 60 $P_2O_5$ : 90 $K_2O$ kg/ha).

Annapoorani and Sindhu, (2019) reported that application of tea dust significantly increased the growth parameters and enhanced the photosynthetic activity when compared to control.

Coulibaly *et al*., (2019) reported in maize number of leaves under the ear was 6.43 for pig compost, 7.25 for chicken compost and 6.23 for the control. The highest numbers of branches per tassel were obtained with pig compost (17.0) and chicken compost (16.2) and the lowest with the control (9.83). At 45 days, the tallest plant (70.19 cm) was measured in compost from pig waste, followed by the chicken compost (51.4 cm) and the shortest was noted with control (22.45 cm). Similar trends were reported at day 60 and 75 pig compost show superiority over the chicken compost and the control.

Chaudhary and Mishra, (2019) showed that KWC- Kitchen waste compost has a potential to improve the physical growth of tomato plants with KWC 60% + 40% soil (T3)

showed positive result for plant height, number of leaves on 25, 50, 75, 110 and 135 days, Number of flowers on 50, 75 and 110 days followed by T(1)- KWC 20% + 80% soil , T(2)- KWC 40% + 60% soil and C1 (Control)- 100% soil due to the presence of optimum level of primary and secondary level of plant's vital nutrients in tomato.

Dey *et al*., (2019) revealed highest average shoot length in S4- vermicompost of *Phumdi* (86.6cm) followed by the average shoot length 81.6 cm in S3- vermicompost of MSW and 81.3 cm in S2- compost of *Phumdi*, 68.3 cm in S1- compost of *Phumdi* and 49.6 cm in S- soil, the maximum average root length was noted in S4 (42.3 cm) and least in S (21.3 cm) which indicates that applications of vermicompost of MSW and *Phumdi* (S3 and S4) had a significant effect on the shoot and root length of King chilli.

Gayathri and Sowntharya, (2019) found the shoot length to be higher in $T_4$ i.e., combination of VAM + Vegetable compost + Phosphobacteria on the 30$^{th}$ day and 45$^{th}$ day. Similar to shoot length, the root length was more in $T_1$ on 30$^{th}$ day. On the 45$^{th}$ day, 60$^{th}$ day and 75$^{th}$ day, the fresh weight and dry weight of the plant was more in plants treated with VAM fungus in Lady's finger.

Gayathri and Malathi, (2019) reported that in *Amaranthus viridis* L. growth parameters such as root length, shoot length, fresh weight and dry weight was estimated to be higher in plants treated with *Azospirillum* on the 30$^{th}$ and 45$^{th}$ day but the fresh weight and dry weight were found to be more in plants treated with a combination of *Azospirillum*, VAM fungi and Phosphobacteria.

Karagöz *et al*., (2019) reported that treatment E (Autoclaved vermicompost (60 kg da$^{-1}$) + PGPB (Plant growth promoting rhizobacteria) formulation) promoted overall performance as compared to other treatments on number of leaves per plant, number of florets per spike, stem diameter, spike length, fresh and dry weight of flowers, number and diameter of corm (*Gladiolus grandiflorus* L).

The highest growth of chilli pepper was at the 2x (double rate of organic manure) application whereas the highest yield was found at the 1x (livestock manure compost) of organic manure application. The application of organic manure at the 1x rate in the greenhouse increased root, shoot, and fruit dry weights of chilli pepper by 21.4%, 52.4%, and 79.7% respectively as compared to the control values (Khaitov *et al*., 2019).

Soil biological properties showed improvement in the soil microbial counts over its initial values at the end of 2-years cropping sequence and reported that $T_9$- Poultry manure

applied @ 150% RND (recommended nitrogen dose) showed the higher counts of bacteria ($82.45\times10^3$), fungi ($37.82\times10^3$) and actinomycetes ($58.23\times10^3$) closely followed by the treatments where PM was applied with reduced rates ($T_8$- PM @ 120% RND & $T_7$- PM @ 100% RND) respectively (Meena *et al*., 2019).

According to Olle, (2019) the basil vegetative parameters like shoot length, root length, number of leaves was noted highest in Treatment 1- 30% vermicompost, peat, sand and dolomite stone (7.3 cm, 6.8 cm and 5.9) and Treatment 2- 25% vermicompost, peat, gravel, perlite (5.9 cm, 6.5 cm, 5.9) respectively.

Pandey *et al*., (2019) investigate on plant height, no. of leaves, no. of branches and noted maximum increase in $T_3$- (75% NPK+5t FYM $ha^{-1}$+bio-fertilizers (PSB + rhizobium) followed by $T_4$- (50% NPK+5t FYM $ha^{-1}$+ Bio-fertilizer than $T_2$- (100%NPK) on 30, 45 and 60 DAS in green gram.

Sharma *et al*., (2019) reported the highest shoot and root length was noted in T7- Spinach + Mustard oil cake (MOC) @ 5t/ha + Sesame oil cake (SOC) @ 5t/ha + NPK@30kg/ha (17.33 and 7.16cm) treatment followed by T5- Spinach + Sesame oil cake (SOC) @10t/ha + NPK @60kg/ha (16.90 and 5.76cm), and T8- control (9.66cm and 4.46cm) while the fresh and dry weight of plants were maximum in T7 (3.44 and 1.40g) treatment followed by T6 (2.43 and 0.35g) and T1 (1.76 and 0.15g) in *Spinacia oleracea*. The biochemical parameters such as chlorophyll 'a', chlorophyll 'b', total chlorophyll, protein and carbohydrates was observed in T7 treatment which is followed by other treatments and control.

Senevirathne *et al*., (2019) revealed that combined application of 25% compost with 75% biochar (T4) significantly increase the plant height, number of nodules per plant, leaf area on 2, 3, 4, 5 and 6 Week After Plantation and decrease chlorophyll content of the leaves from 2 to 6 Week After Plantation of *Glycine max* (L.).

Sutar *et al*., (2019) recorded that application of jeevamrutha @1000 l $ha^{-1}$ has higher plant height (65.60cm), number of branches (8.89), number of leaves (26.50), leaf area (1039.56 $cm^2$) and yield attributing characters like number of pods per plant (20.57), pod length (19.8cm), number of seeds per pod (15.58), seed weight per plant (9.53g) and 100 seed weight (11.82g) when compared to control in cowpea.

Aslam and Ahmad, (2020) stated that the foliar application of vermi-tea ($F_{VT}$) significantly enhanced the shoot length, shoot fresh, dry weight, root length, root fresh and

dry weight when compared to other treatments and control. Number of leaves and leaf length increased significantly in solid vermicompost ($F_{VC}$), chemical fertilizer ($F_C$) and vermi-tea ($F_{VT}$).

Al-Sabbagh *et al*., (2020) reported that plants height and number of leaves were recorded highest in Ecodrum compost (44 cm and 13.66) with the control plants displaying the lowest value (31.16 cm and 8.66) while maximum fresh weight was noted in market compost (0.276 gm) grown plants followed by Ecodrum composter (0.271 gm), when compared to control (0.133 gm) in Chinese kale.

Devkota *et al*., (2020) reported the maximum plant height and leaves size was observed in T5 (½ NPK+ 2 ton/ha PM) and yield per plot, yield per ha was noted in T6 (¾NPK+ 1 ton/ha PM). Similarly, highest leaf nitrogen, phosphorous, and potash were found in the treatment T7 (1/2 NPK+ 6 ton/ha Compost), T5 (1/2 NPK+ 2 ton/ha Poultry Manure) and T2 (¾NPK+ 2 ton/ha VC) respectively.

Dlamini *et al*., (2020) stated that increased plant growth and yield was noted in treatment fertilized with stillage followed by kraal manure in terms of performance in amaranthus. El-Goud and Amal, (2020) revealed that the application of chicken manure and kitchen waste converted into vermicompost treatment, T1- high rate (6.5 t/fed.) of vermicast + organic liquid (vermitea) 4 times as a soil drench led to significant increase in vegetative parameters e.g., plant height, number of leaves/ plant, number of branches, leaf area index, total chlorophyll (SPAD- Soil Plant Analysis Development) number of flowers and fruit length & diameter when compared to control.

Merlin *et al*., (2020) reported that highest protein content (14.92% DM) with NPK fertilizer as compared to control and other fertilizers in the *New Kuroda* variety. In the *Madona* variety, two high protein contents were recorded with compost and NPK fertilizer as compared to control. Combined application of compost + NPK fertilizer gave the lowest protein content in both *Madona* and *Amazonia* varieties when compared to control whereas highest total carbohydrates were obtained with compost and chicken manure with lowest content being noted in NPK fertilizer, compost + NPK fertilizer and chicken manure combination as compared to control in *New Kuroda* variety.

Mawussi *et al*., (2020) studied the growth parameters including plant height, stem girth, leaf area and number of leaves per plant in maize and highest growth were obtained

from plots treated with compost submitted to irrigation at two days interval while the lowest values were recorded from control plots.

Nurcholis *et al*., (2020) reported that composted NS (Neem Seeds) at 2 kg per plant increased the plant height and pseudo stem diameter traits compared with the control treatment. The application of composted GL (Guava leaves) + (Neem seeds) at 2 and 4 kg per plant significantly increased the leaf length and number of shoots while all treatments showed unchanged leaf width and number of leaves of java turmeric (*Curcuma zanthorrhiza* RoxB).

In Dolichos bean [*Lablab purpureus* L. (Sweet)], maximum number of pods per plant, number of seeds per pod, dry pod yield per plant, dry pod yield per plot, seed yield per plant, pod length, seed yield per plot and seed yield per hectare was recorded in *rabi* season than *kharif* whereas among the plant growth regulators, it was recorded in $G_3$- NAA @ 40 ppm, followed by $G_6$- nitrobenzene @ 200 ppm (Pramoda *et al*., 2020).

Purna *et al*., (2020) recorded significant increase in plant height (164 cm), leaf number (80 nos./plant), leaf area (3360 $cm^2$/plant), fresh weight (49.03 gm/plant), dry weight (24.54 gm/plant), fruit length (9.4 cm), fruit number per plant (5 nos. /plant) of soyabean were recorded in Zn 1 kg/ha + VC 5 ton/ha treatment.

Ropo *et al*., (2020) investigated the growth and yield parameter of tomato and revealed that application of poultry dung as soil amendment significantly supported higher plant height and stem girth (All through the growth period examined), number of fruits (8.75±1.49), fruit weight (25.30±4.75g), fruit length (6.60±0.31 cm) and fruit diameter (1.93±0.38 cm).

Silpa and Vijayalakshmi, (2020) observed that a significant increase in shoot length was recorded in $T_4$- (Cocoa shell waste + *Pleurotus eous* + *Pleurotus florida* + *Eudrilus eugeniae*) (67.933 cm, 112.133 cm and 119.300 cm) on 25, 35 and 45 DAS when compared to control (13.933 cm, 35.233 cm and 50.233 cm), gradual increase in root length and number of leaves was noted from 25 to 45 DAS in all treatments maximum in $T_4$ treatments and minimum in control. A significant increase in fresh weight and dry weight content was observed in $T_4$ treatment followed by other treatment and control.

Sekhar *et al*., (2020) reported that treatment $T_5$ N (20Kg/ha) + K (20Kg/ha) + PSB (I) was found to be the best treatment for obtaining higher growth and yield attributes *viz.*, plant height (46.47 cm), dry weight (16.930 g), crop growth rate (9.78 g $m^{-2}$ $day^{-1}$), number of

branches/plant (5.88) at 60 DAS, number of nodules/plant (30.89) at 45 DAS, number of pods/plant (16.33) and test weight (40.33 g) in green gram.

Segatelli *et al*., (2020) reported that control plot presented the lowest values of the HD- Head Diameter, LG- Leaf Growth and LN- Leaf Number parameters compared to the others treatment showing that only the nutrients contained in the soil are not enough for the good growth of the plants whereas influence of organic compost on the plots using composts 1 (Pruning tree + Dairy Sludge + Coffee Ground) and Compost 2 (Grass + Dairy Sludge + Coffee Ground) observed higher HD values.

According to Venkatakrishnan and Manimaran, (2020) the highest no. of millable cane, individual cane weight, cane yield of sugarcane was noted in vermicompost @ 5 t $ha^{-1}$ + Seasoned pressmud @ 25 t $ha^{-1}$ (T3) which was comparable with the treatment T2- Seasoned pressmud @ 25 t $ha^{-1}$ + Lignite flyash @ 25 t $ha^{-1}$ and the lowest no. of millable cane, individual cane weight, cane yield was registered in T8 (Recommended Dose of Fertilizer).

Biswas *et al*., (2021) studied the agronomic parameters such as plant height (91.75 cm), leaves number per plant (39.25) and leaf length (30.25 cm) was significantly increased at T5 treatment (a combination of CFPH and VC) then in T2 treatment (90.58 cm) at 50 days. In field experiment, tomato plant-growth, the order of best treatment efficacy for improvement of parameter estimates was as follows: CFPH (Chicken Feather Protein Hydolysate) and VC (vermicompost) > CFPH > VC > Recommended Dose of Fertilizers (RDF) > control.

Chitra *et al*., (2021) studied the vegetative parameters like length of shoot, length of root, number of leaves/ plants, leaf area and yield characters such as number of pods, number of seeds/pod, fresh and dry weight of the pod was found to be maximum in T1- 100% Vermicompost followed by T2- 75% Vermicompost + 25% fertilizer (N, P, K) in dolichos bean.

Duraisamy *et al*., (2021) observed that whole plant height (38 cm), fresh weight (182.33g), dry weight (60.41 g), number of leaf (21), root length (13 cm) and fresh weight of root (87.39 g) was higher in the plots treated with DSV (Industrial Sludge Vermicompost) when compared with others treatment and minimum value was noted in WOF (control) in radish.

Gokulakannan and Muthuveeral, (2021) who reported that among the cropping system, maize + cowpea intercropping system satisfyingly influenced the growth and yield components of maize such as plant height, cob length, cob diameter and grain yield. The maize + cowpea (S2) intercropping system with the addition of vermicompost @ 5 t $ha^{-1}$ + RDF (M3) recorded the highest grain yield of 6141 kg $ha^{-1}$ while lowest values of all growth and yield characters was noted in maize alone (S1).

Gobi *et al*., (2021) reported that application of 50% RDN + 50% N through vermicompost + 0.5% Zn-EDTA foliar spray ($T_9$) on 30 and 45 DAS showed a significant increment in the yield attributes viz. pod length, number of pods $plant^{-1}$ and number of seed $pod^{-1}$ followed by $T_{10}$- 50% Recommended Dose of Nitrogen through fertilizer + 50% N through FYM + 0.5% Zn-EDTA (Ethylene Diamine Tetra Acetic Acid) foliar spray and least was noted in control ($T_1$) in both crop of cowpea while $T_9$ treatment recorded higher NPK uptake at harvest stage of cowpea.

Khan and Junaid, (2021) showed that inoculation of plants with the strains of *Rhizobium* species RB1, RB6 and RB9 increase the shoot, root dry matter and also the nodule number significantly by 19, 14, and 25% over the uninoculated plants. The shoot length increased by 50%, root length by 40%, shoot dry weight by 35% and root dry weight by 60%. The pod number was increased significantly by 30% due to inoculation and yield up to 50%, as compared to the control plant.

Karthiya and Vijayalakshmi, (2021) reported that application of biocompost T3 significantly increased the growth parameters like root length (cm), shoot length (cm), no. of leaves, diameter of leaf (cm), fresh weight (g), dry weight (g) and yield attributes like length of fruit (cm), diameter of fruit (cm), no. of seeds/fruit, fruit yield/plant (g), fruit yield/ bed (kg), fruit yield/three beds (kg), fresh weight (g) and dry weight (g) of bhendi followed by T2.

Meher *et al*., (2021) studied the development parameters such as plant tallness, number of leaf per plant, leaf region, number of branches per plant, chlorophyll content and yield parameters like number of fruits per plant, weight of fruit, diameter, length of fruit and number of seed per fruit was noted highest in vermicompost and chicken fertilizer in chilli plant. According to Muthukumararaja and Sumithra, (2021) the application of RDF + Zinc (Zn) @ 50 kg ha-1 + Rice straw compost (RSC) @ 14.5 t $ha^{-1}$ achieve the highest tiller

productivity, leaf area index, root dry weight and root length, grain yield and straw yield of rice.

Manivannan *et al*., (2021) reported that application of vermicompost (50% N) + mineral nitrogen (50% N) in Clay loam and Sandy clay loam recorded highest plant height (97.5, 99.3cm), no. of tillers/hill (14.1, 13.9), LAI (4.78, 4.67), chlorophyll content (2.99 and 2.98 mg $100g^{-1}$) and highest nutrients uptake *viz*., N (50.4 and 43.7 kg $ha^{-1}$), P (14.7 and 10.7 kg $ha^{-1}$), K (40 and 59.8 kg $ha^{-1}$) respectively.

Mahto and Dutta, (2021) recorded maximum pod length, pod weight (14.50 cm, 7.00 g) in HAFB-4 ($V_4$) under organic intervention, whereas, it was only 8.93 cm and 4.36 g under absolute control growing condition, number of pods per plant recorded a non-significant differences among varieties under both organic and absolute control growing condition, green pod yield showed significant differences among varieties under both growing conditions culminated with the highest yield (17.55 t $ha^{-1}$) in HAFB-4 ($V_4$) while the lowest (15.40 t $ha^{-1}$) being observed in Swarna Priya ($V_2$) under organic intervention (FYM @ 3.0 t $ha^{-1}$ + Vermicompost @ 1.0 t $ha^{-1}$ + Shasyagavya @ 10% concentration @ 1.0 litre $m^{-2}$) + organic plant protection measures .

Palia *et al*., (2021) reported that the combination of organic manure and inorganic fertilizers were beneficial for increasing growth such as plant height, number of leaves per plant on 30, 60, 90 Days After Transplantation and yield parameters like average fruit weight, length of fruit, diameter of fruit, fruit per plot, fruit per plant and fruit per hectare in brinjal.

Purba *et al*., (2021) reported the highest mean percentage of crude protein content is in the N2 treatment (once every two weeks), which is 8.64 %, while in N1 treatment (once every four weeks), the average percentage of crude protein was lower (7.86%) because of the right time interval for fertilization that have an incredible impact on the availability of sufficient N for *Clitoria ternatea* plants to help improve their quality.

Rajashri *et al*., (2021) stated that the treatment T3- compost 3 consisting of vermi-composted groundnut shell and vegetable waste (75g) showed significantly increased chlorophyll ‘a’, ‘b’, Total chlorophyll, protein, and carbohydrate content followed by $T_2$-compost 2 (Vermicomposted groundnut shell and vegetable waste (50g) and control.

The growth characters of lady finger (*Hibiscus esculentus*) such as plant height and number of leaves per plant were observed at $15^{th}$ day, $30^{th}$ day, and $45^{th}$ day from the date of

planting with maximum value of growth parameters observed in leaf litter vermicompost followed by Eichhornia vermicompost, cow dung vermicompost and control (Sellappan *et al*. 2021).

Srinivasan *et al*., (2021) stated that among all the treatments, application of 100 % RDF (N: $P_2O_5$: $K_2O$ @ 40:30:50 kg $ha^{-1}$) ($T_2$) recorded the highest number of productive tillers $pot^{-1}$ of 6.54, ear head $plant^{-1}$ (4.50), ear head length of 10.11, ear head weight of 30.37 g, grain yield of 166.15 g and straw yield of 306.15 g $pot^{-1}$ on the growth of barnyard millet.

Shafique *et al.,* (2021) reported that incorporation of 35% vermicompost showed a significant increase in all vegetative growth like plant height (26.0 cm), root volume (15.66 $cm^3$), number of lateral shoots per plant (9.00) and floral parameters like number of open flowers (2.66), number of floral buds (7.00), diameter of flower (9.00 cm), fresh weight (16.66 g), and dry weight of flower (7.33 g) in marigold.

Senthilkumar and Gokul, (2021) reported significantly higher finger millet plant height (122.9 cm), number of tillers (9.4) and dry matter production (12806.5 kg $ha^{-1}$) at harvest stage in $T_{10}$- soil application of 50% RDN + foliar spray of 50% RDN + 100% P and K through water soluble fertilizer + foliar spray of humic acid 0.1% followed by $T_5$- soil application of 50% RDN + foliar spray of 50% RDN and 100% P and K through water soluble fertilizer (on 20 and 40 Days After Transplantation) and control respectively.

Sandeepani *et al*., (2021) reported highest plant height, no. of leaves, no. of pods/plant and no. of seeds/pod at 8 weeks after planting in *Vigna radiata* L. planted in Maxicrop™ foliar application with the soil application of Department of Agriculture fertilizer and followed by the plants on Maxicrop™ foliar application with the soil application of Jeewamirtha. While the highest number of root nodules per plant and number of flowers per plant at 6 and 8 weeks after planting were recorded in *Vigna radiata* L. planted in Maxicrop™ foliar application with soil application of Jeewamirtha and it was followed by the plants on Maxicrop™ foliar application with the soil application of DOA fertilizer.

Treatment T16- 125 kg Di Ammonium Phosphate (DAP) along with Phosphate Solubilizing Bacteria (PSB) + VC produced the tallest plant height when compared to other treatment. A maximum of 2 mg $g^{-1}$ chlorophyll content was recorded under T16 treatment followed by 1.93 mg $g^{-1}$ under T15 treatment on 30 DAS while on 45 DAS, application of 125 kg DAP along with VC + PSB (T16) gave the maximum of 2.85 mg $g^{-1}$ chlorophyll

content followed by 1.93 mg $g^{-1}$ by application of 100 kg DAP accompanied with VC + PSB (T15). Maximum nodule count was recorded with the application of 125 kg DAP along with PSB + VC (T16) when compared to the rest of the treatments on 30 DAS and 45 DAS in mungbean (Samsurahman *et al*., 2021).

Sulaiha and Anburani, (2021) states that chlorophyll content index (62.77 and 66.10) in first and second season was recorded to be superior in T15 which received EM 1 t $ha^{-1}$ + Consortium of Biofertilizers 2 kg $ha^{-1}$ + Se (20µg $L^{-1}$) as foliar application respectively. The increased chlorophyll content index in leaves might be due to the favourable response of enriched manure from which efficient assimilation of nitrogen takes place. As a result of boosted nitrogen which serves as an essential component of chlorophyll, plant photosynthetic activity continues to improve leading to increased chlorophyll content index.

Thakur *at al*., (2021) indicated that the improvement in growth, yield parameters and seed yield of wheat was observed with the application doses of 100% NPK + 100%VC as compared to plots under control treatment. However, application of 100% NPK + 50% VC also showed remarkable progress in the growth and yield of the wheat.

Uçar, (2021) stated that application of vermicompost was found significantly effective on the plant height, pod height, number of pods per plant, number of seeds per pod, 100 grain weight and grain yield by applying of 800 kg $ha^{-1}$ and 120 kg $ha^{-1}$ vermicompost along with *Rhizobium leguminosarum*.

Upadhyay and Kaushal, (2021) observed the highest plant height at maturity (100 cm) in T10 (FYM + Vermicompost + Urea) application at all the growth stages which was significantly superior to other treatments and minimum plant height of wheat was recorded in treatment T1 (control).

Veeral and Kalaimathi, (2021) revealed that the growth and yield components of groundnut *viz*., plant height, DMP- dry matter production and LAI- leaf area index at flowering stage, number of pods per plant, hundred kernel weight, pod yield and kernel yield were recorded highest in pressmud @ 12.5 t $ha^{-1}$ + *Rhizobia* @ 2 kg $ha^{-1}$ + 50% RDF ($T_7$) followed by the application of distillery spentwash @ 100 $m^3$ $ha^{-1}$ + *Rhizobia* @ 2 kg $ha^{-1}$ + 50% RDF ($T_8$) and least was noted in control treatment in both Rabi, 2016 and summer, 2017.

Yadav, (2021) reported that the treatment Fungal Mediated Vegetable Waste Compost and green manure gave maximum response at the end of 30 days followed by vermi compost

treatment as compared to control in paddy. According to Zohaib *et al*., (2021) application of T4 (all PK at sowing, ½ N at sowing and ½ at tillering) shown maximum improvement in plant height, fertile tillers, grains per spike, biological yield, grain yield and $NUE_A$ (agronomic nutrient use efficiency of nitrogen) of intercropped wheat in cotton.

Silpa and Vijayalakshmi, (2022) noted that $T_8$ – Raw Jack fruit peel + 10 g *Pleurotus eous* + 10 g *Pleurotus florida* + *Eudrilus eugeniae* 5t/ha$^{-1}$ treatment showed maximum root length (20.63 cm, 32.73 cm and 39.23 cm), shoot length (70.73 cm, 167.50 cm and 175.83 cm), number of leaves/plant (26.46 cm, 33.53 cm and 37.50 cm), number of flowers/plant (12), number of nodules (14, 21.20 and 11.34), fresh weight (10.076 g, 12.146 g and 14.047 g) and dry weight (1.744 g, 1.854 g and 2.827 g) on 25, 35, 45 DAS while on 65 DAS, the number of pods/plant (21), length of pod (16.50 cm), number of seeds/pod (20), weight of the seed/pod (1.68 g), pod fresh weight (5.711 g) and pod dry weight (2.398 g) followed by $T_4$ treatment when compared to control in *Vigna unguiculata* (L.) Walp.

Maximum plant height and number of leaves was recorded with 100% RDF at all stages of crop growth and application of 100% RDF noted significantly superior length of pod, number of pods plant$^{-1}$, number of seeds pod$^{-1}$ and 100 seed weight (g) over 75% and 50% RDF (Sakpal *et al*., 2022).

Senarath *et al*., (2022) reported that *Vigna unguiculata* L. planted in loose soil with the application of amuthakaraisal showed significantly highest values in biomass of shoot, root, length of lateral roots, no. of nodules, effective nodules and yield with lower values observed in compact soil amendments.

**2.4 Studies on leghaemoglobin content**

Sharma *et al*., (2011) stated that inoculation with IRG–6 strain enhanced the number of pink coloured nodules, leghaemoglobin and nitrate reductase enzyme activity in *Arachis hypogaea.*

Singh and Vijayalakshmi, (2013) found 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 DAS.

Tagore *et al*., (2013) states that the leghaemoglobin content in chickpea root nodules increased with the advancement of crop age, maximum at 55 DAS and decline at 75 DAS. Among the genotypes, IG- 593 possessed the highest nodule leghaemoglobin of 2.10, 2.55,

and 2.47 mg $g^{-1}$ of fresh nodule and lowest 1.07, 1.23, and 1.45 mg $g^{-1}$ of fresh nodule in IG-370 at 35, 55 and 75 DAS respectively.

Kannan *et al*., (2015) tested leghaemoglobin content for root nodules of four tropical legumes. Among them, leghaemoglobin concentration is high in the nodules of *Arachis hypogaea* GN7, *Mymosa putika* TN3, *Vigna radiata* GG3 and *Vigna mungo* BG2 with the absorbance value of 0.088, 0.044, 0.024 and 0.020 µg/ml.

Singh and Vijayalakshmi, (2016) analyse the conjugative effect of composted coirpith, composted pressmud, farmyard manure and NPK on leghaemoglobin content in the nodules of black gram and cluster bean and a significant increase in leghaemoglobin content of both the crops was noted in T12 (Composted coirpith (6.5t $ha^{-1}$) + composted pressmud (6.5t $ha^{-1}$) + farmyard manure (6.5t $ha^{-1}$)) followed by T9 (Composted coirpith (12.5t $ha^{-1}$) + 25% NPK) when compared to control.

Sakthivigneswari and Vijayalakshmi, (2016b) reported that leghaemoglobin content was increased from 25 to 50 DAS and it gradually decreases up to 75 DAS. The treatment T6- compost 6 (Raw coirpith predigested by using *Pleurotus sajor-caju* and *Eudrilus eugeniae* (5t $ha^{-1}$)) significantly increased leghaemoglobin content followed by T3 as compared to the control on 25 to 50 DAS.

Abd-Alla *et al*., (2017) recorded a significant increase in leghaemoglobin content in legumes grown at South Sinai and Nile Region while highest leghaemoglobin content and nitrogen-fixing activity were estimated in *Trifolium resupinatum* respectively.

Kumari *et al*., (2017) reported that leghaemoglobin content significantly decreased with the increase in salinity levels in both the varieties of fenugreek (cv. NDM-17and Pusa Kasauri) except at 3 EC level whereas the content was higher in the rhizobium inoculated treatment on 90 DAS. Pande, (2017) investigated the leghaemoglobin content in cowpea of both healthy and infected nodule samples with the age of the plants and found that nodules of healthy plants had higher leghaemoglobin content than those of diseased ones on 20, 30, 40 and 50 days after inoculation.

Pagare *et al*., (2019) recorded $T_7$ (Liquid consortium + 100 % N) to be significantly superior in Leghaemoglobin content in soyabean nodule over rest of the treatments and it was at par with treatment $T_6$ (Liquid consortium + 75 % N). The treatment absolute control

recorded the least Leghaemoglobin content in nodule at 45 and 60 days. According to Anjali *et al*., (2021) liquid biofertilizer treatment LGR33+RB1+0.1% CMC recorded maximum chickpea plant height, chlorophyll content, number of nodules and dry weight of nodules as well as leghaemoglobin content, soil enzyme activity, total N and P content of shoot, soil and grain yield over uninoculated control.

**2.5 Soil status**

Pathak *et al*., (2011) stated that Municipal solid waste (MSW) compost is increasingly used in agriculture not only as a soil conditioner but also as a fertilizer. Proponents of this practice consider it an important recycling tool since MSW would otherwise be landfilled and critics are concerned with its often-elevated metal concentration.

Subbulakshmi and Thiruneelakandan, (2011) stated that vermicomposting improves the soil structure, enhancing soil fertility and moisture holding capacity which in term increase the crop yield. It also becomes an important tool for waste recycling.

Garg *et al*., (2012) reported that after 15 weeks vermicomposting of food industry sludge (FIS) significant increase in total nitrogen (60–214%), total available phosphorous (35.8–69.6%), total sodium (39–95%) and total potassium (43.7–74.1%), while decrease in pH (8.45–19.7%), total organic carbon (28.4–36.1%) and C:N ratio (61.2–77.8%) was recorded.

Othman *et al*., (2012) showed that vermicomposting has reduced the mass of tested sample and the concentration of N, P and K for the soil is greater than the chemical fertilizer. Therefore, vermicomposting is a promising alternative treatment of food waste as it is more ecofriendly.

Punde and Ganorkar, (2012) measured the parameter such as pH, electrical conductivity, C/N Ratio, N, P and K during the specific intervals of time and reported that nutrient content at the end of 45 day increased its content.

Hanc and Pliva, (2013) reported that vermicomposting increased the total content of N, P, K, Ca and Mg and the availability of P, K and addition of used paper into kitchen bio-waste proved to be a suitable feed for earthworms.

Ananthakrishnasamy and Gunasekaran, (2014) concluded that integrated application of $T_1$ - 20% + 80% (Bedding Material + MSW) 200g BM + 800g MSW + 200g soil promote

the nutrient content of organic carbon, nitrogen (N), phosphorus (P) and potassium (K) in the compost which can be utilized for organic farming.

Huang *et al*., (2014) studied the physicochemical properties and microbial profiles during vermicomposting of fresh fruit and vegetable wastes which showed an increase in total nitrogen content during the first 2 weeks and then followed by a progressive decrease of total nitrogen in the vermicomposting system was linked to the loss of substantial nutrients in the form of leachate.

Aswhini *et al.*, (2018) reported that $T_6$ treatment (FYM at 6 t/ha + RDF + Biofertilizers) recorded significantly higher uptake of nitrogen, phosphorus and potassium (143.76, 22.68 and 36.17 kg $ha^{-1}$) over other treatments and lowest uptake of nitrogen, phosphorus and potassium (92.27, 12.31 and 22.49 kg $ha^{-1}$) were recorded with Recommended Dose of Fertilizers ($T_9$) alone at harvest.

Khalil *et al*., (2019) concluded that all the treatments receiving alone or integration of organic and inorganic fertilizers in diverse ratios have significantly affected the chemical properties of post-harvest soil of maize crop such as pH, EC, total nitrogen content and organic matter content.

Dhillon *et al.*, (2020) observed that significant variation in organic carbon, available macro (N, P, K and S) and micro (Fe, Mn, Zn and Cu) nutrients status when organic manures were integrated with inorganic fertilizers as compared to sole use of inorganic fertilizers and initial status of soil. The maximum available nutrient status was recorded with treatment T12 {25% Recommended Dose of Nitrogenous Fertilizers + 25% N (Farm Yard Manure) + 25% N (Vermicompost) + 25% N (Poultry Manure)} whereas lowest was recorded with treatment T1 (control) after harvest of onion crop.

Senthilvalavan and Ravichandran, (2020) observed that the soil pH and EC of the post-harvest soils of rice – black gram varied within a narrow range among the treatments and the differences were not statistically significant while microbial population (Bacteria, Fungi, Actinomycetes) was counted for two years, where System of Rice Intensification plots were found to be superior by registering higher microbial population (50.61, 13.64 and 9.98) and lower microbial population was noticed with conventional method (44.51, 11.18 and 7.89).

Zonayet and Paul, (2020) reported that post-harvest soil of field-I and II contain higher organic matter (2.86%), organic carbon (1.70%), total nitrogen (0.087%),

exchangeable K (0.14 meq 100 $g^{-1}$) and available Zn (0.66 µg $g^{-1}$) in 100% NPK briquette (267.5 kg $ha^{-1}$). Organic matter (2.65%), organic carbon (1.61%), total nitrogen (0.080%), exchangeable K (0.10 meq 100 $g^{-1}$), available Zn (0.41 µg $g^{-1}$) were found in control.

Bhuyan *et al*., (2021) reported that combinations of different organic manure significantly influence soil physico-chemical properties. Maximum improvement in terms of soil physico-chemical parameters such as EC, available nitrogen, available phosphorus and available potassium was noticed in application of 100% poultry manure ($T_{10}$).

Post-harvest residues of barley undersown with catch crop and stressed with water shortage accumulated the same or higher amounts of N, P, K, and Mg than residues of barley grown alone under sufficient water supply (Jastrz ębska *et al*., 2021).

**2.6 Antioxidant and antibacterial activity**

De Britto *et al*., (2011) reported that the methanol extracts of *Solanum nigrum, Solanum torvum* and *Solanum surattense* exhibited clear zone of inhibition against the tested microorganisms. The Minimum Inhibitory Concentration value of *Solanum surattense*, determined by serial dilution technique, was found to be 32 µg/ml and 64 µg/ml against *Xanthomonas campestris* and *Aeromonas hydrophila* respectively.

Deshpande *et al*., (2011) concluded that the methanolic extract of the fruit of *Coccinia grandis* showed significant hydrogen peroxide scavenging, reducing power and DPPH activities. The antioxidant activity of the fruit may be attributed to the presence of flavonoids and anthraquinone glycosides.

Prabhu *et al*., (2011) showed that the minimum inhibitory concentration (MIC) of the methanolic extract of *Eclipta alba* at the concentration of 250 µg/ml as compared with standard drug tetracycline (100 µg/ml). The study concluded that *Eclipta alba* was found to better antioxidant in DPPH radical scavenging activity and significant antimicrobial activity.

Parameswari *et al*., (2012) studied anti-bacterial activity of ethanolic and methanolic extracts of stem, berries and whole plant of *Solanum nigrum* against *Bacillus subtilis, Escherichia coli, Klebsiella pneumonia* and *Pseudomonas aeruginosa*. The methanolic extracts showed highest antibacterial activity than ethanolic extracts. In both extracts, whole plant extract showed potential anti-bacterial activity than stem and berries.

Antimicrobial efficiency of *Melia azedarach* L. leaf extracts were evaluated using Methanol, Ethanol, Petroleum ether and water, as solvents and tested against 4 bacterial

pathogens like *Bacillus cereus, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa.* The minimum zone of inhibition and comparatively greater inhibitory concentration were determined in petroleum ether and aqueous extract of *M. azedarach* showing less antimicrobial activity against all the experimental strains (Sen and Batra, 2012).

Aminifard *et al*., (2013) reported that fruit antioxidant activities and quality of pepper was affected by different compost levels and suggest the usage of compost as bio-treatment for improvement of fruit antioxidant activities and quality of pepper.

Aires *et al*., (2013) reported that the percentage of scavenging radicals of DPPH from 1 mg $mL^{-1}$ showed high antiradical activity (81.4%) compared to the positive control (83.3%). The antioxidant activity measured by reducing power method was (0.437) in Watercress as compared to positive control (0.487).

Borguini *et al*., (2013) reported that the 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%) respectively. Organic tomatoes had higher antioxidant potential probably due to its higher ascorbic acid and total phenolic values.

Ibrahim *et al*., (2013) reported that the DPPH values were found to be highest under organic fertilization and lowest under inorganic fertilization. The DPPH antioxidant activity recorded the highest value (63.18%) at 90 kg N/ha followed by the 0 kg N/ha (57.12%), 180 kg N/ha (47.22%), and the least in the 270 kg N/ha treatment (38.99%) leaf tissue of *Labicia pumila*.

Indumathy and Aruna, (2013) screened for antioxidant activity using DPPH, nitric oxide radical scavenging activity and hydroxyl radical scavenging activity. The maximum DPPH activity was noted in n-hexane, chloroform, ethyl acetate and methanol extracts of *Lepidium sativum* whereas least was noted in rutin (standard) at 1000 µg/ml. The highest nitric oxide radical scavenging activity was observed in n-hexane, chloroform, ethyl acetate and methanol extracts of 32.13%, 39.31%, %, 61.83% and 78.23% whereas ascorbic acid (standard) exhibited 64.37% at 1000µg/ml. The n-hexane, chloroform, ethyl acetate and methanol extracts exhibited a maximum hydroxyl radical scavenging activity of 37.65%, 62.72%, 77.64% and 83.82% while ascorbic acid (standard) exhibited 75.23% at 1000µg/ml respectively.

Moorthy *et al*., (2014) revealed that the aqueous extracts of *Adiantum lunulatum* showed significant inhibitory activity against *Salmonella paratyphi* B, *Pseudomonas aeruginosa* and *Vibrio parahaemolyticus*. Ethanolic extract showed inhibitory activity against *Pseudomonas aeruginosa*, *Staphylococcus epidermidis* and *Salmonella paratyphi* B. The petroleum ether extract showed significant inhibitory activity against *Shigella flexneri*, *Salmonella typhimurium* and *Klebsiella pneumoniae*.

Nur *et al*., (2013) recorded the total phenolics, total flavonoid, 1, 1-diphenyl-2-picryl-hydrazyl (DDPH) scavenging assay and ferric reducing antioxidant capacity (FRAP) scavenging assay for cassava tuber and leaves in vermicompost. Application of vermicompost showed the highest DPPH scavenging activity in tuber of Pontian variety but with other fertilizer sources such as NPK and EFBC- Empty fruit bunch compost, Medan variety exhibits a higher value.

Seasotiya *et al*., (2014) tested the DPPH free radical scavenging ability for *Trigonella foenum graecum* seeds extracts, the ethyl acetate extract at 100 µg/ml showed highest radical scavenging activity (69.7%) followed by methanol (67.9%), chloroform (57.5%) and hexane extracts (50.9%). These findings suggest that all fenugreek extracts exhibit antioxidant activity and could act as potent source of antioxidants.

Mary and Nithya, (2015) revealed a similar trend of higher mean values for organic fertilizer when compared with inorganic fertilizer. DPPH and reducing power assay of *Solanum nigrum* leaf sample in organic fertilizer were 64.21±15.81 mg/100g and 42.12±14.72 mg/100g while mean values for inorganic leaf sample were 35.42±12.80 mg/100g and 25.42±7.90 mg/100g respectively.

Khyade and Jagtap, (2016) reported the highest antioxidant activity in terms of % DPPH inhibition (40.09 ± 3.63%) in cowpea, followed by (35.683±0.69%) in yellow mustard, (26.214±0.88%) in black gram dry seed whereas least inhibition was noted (25.669±0.48%) in chickpea. The highest total phenol content was noted in yellow mustard sprouts (58.45 ±6.67 mg/100g).

Mohamed *et al*., (2016) screened the free radical scavenging properties using 2, 2-diphyenyl-1- picrylhydrazyl (DPPH) and propyl gallate assays. The water extract of the seeds and honey combination showed the highest radical scavenging activity (RSA) 91±0.04% and the control propyl gallate gave RSA 93±0.01%.

Demirkol, (2018) reported that all the seed and shoot extracts showed antibacterial activity against *Clavibacter michiganensis*. The shoot ethyl acetate extract of *Lotus aegaeus* and shoot extracts of *Lotus corniculatus* against *C. michiganensis* and shoot extracts of all solvents of *Lotus angustissimus* against *Pseudomonas phaseolicola* showed high antibacterial activity.

Noorjahan and Saranya, (2018) studied the antioxidant activity of tulsi plant and observed that an increase in percentage of inhibition as the concentration of plant leaves extract increases. The highest percentage of inhibition was recorded as 52±1.93% in 500 µg/ml and lowest percentage of inhibition was recorded as 12.98±3.57% in 100 µg/ml of sample. They concluded that tulsi leaves extract has a good free radical scavenging ability and $IC_{50}$ value was found at 500 µg/ml tulsi leaves extract.

Gayathri and Anuradha, (2020) investigated an antimicrobial activity of acetone mace extract (*Myristica fragrans* Houtt) against *Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa*, using agar disc diffusion technique. Acetone mace extract was potentially effective with variable efficiency against the tested bacterial strains. Acetone mace extract can be used as natural alternative antibacterial agent against synthetic antimicrobial drug.

Machado *et al*., (2020) noted that the addition of inorganic N led to a dramatic decrease in leaf-blade ferric reducing antioxidant activity and was higher with ammonium sulfate application. Antioxidant activity (DPPH and FRAP) was higher in plants grown with ammonium nitrate than those grown with ammonium sulfate of spinach.

Among the eight vermicompost mixtures, the studied samples had antagonistic activity against the four identified *pathogenic bacteria* (*Citrobacter freundii, Enterobacter cloacae, Pseudomonas aeruginosa* and *Klebsiella pneumonia*) except sample (CD- cowdung + BL- Banana leaves) against (*Pseudomonas aeruginosa* and *Klebsiella pneumonia*) and sample (FS- fish sludge + SC- sugar cane) against (*Pseudomonas aeruginosa*). The CD, CD+SC, CD+BL and FS- fish sludge + RS- rice straw had higher antimicrobial activity to *Enterobacter cloacae* and the inhibition zone diameter was (29, 25, 25 and 24 mm) while FS+RS, CD+RS and FS were higher antagonist with *Citrobacter freundii, Pseudomonas aeruginosa* and *Klebsiella pneumoniae* with 22, 21 and 18 mm diameter, respectively (Moustafa *et al*., 2021).

Naik *et al*., (2021) studied the antimicrobial activity of both Cinnamon leaf oils and extract by disc diffusion assay and it showed that essential oils and extracts exhibited the highest zone of inhibition (ZOI) against *Staphyllococcus aureus* and *Escherichia coli*. Minimum inhibitory concentration (MIC) of both oils and extracts ranged from 0.156 mg/ml to 5mg/ml and the antioxidant properties of oils and extract of cinnamaldehyde type Cinnamon possessed the highest antioxidant activity than linalool type.

Das *et al*., (2022) investigated the antibacterial activity using agar well diffusion and found that *Peudomonas aeruginosa, Bacillus subtilis, Staphylococcus aureus* and *Proteus mirabilis* was significantly susceptible to ethanol extracts. The ethanol extract had the maximum (17 mm) antibacterial activity against *S. aureus*, while minimum (7 mm) antibacterial activity against *P. mirabilis*. The *Moringa oleifera* seed extract of ethanol was found to be effective against all the four pathogenic organisms showing a zone of inhibition ranging from 10-17 mm.

Kazi *et al*., (2022) reported the highest antioxidant activity was noted in T1, T19 and T29 (84.95%, 81.41% and 80.53%) respectively. To conclude, finger millet landraces are highly nutritious and need to be conserve as potential source of nutrients, antioxidant as well as for nutritional traits. Lubiana *et al*., (2022) studied the antibacterial potentiality of ferulic acid isolated from pineapple peel exhibited varied susceptibility against *Escherichia coli, Klebsiella pneumonia, Bacillus cereus and Staphylococcus aureus.* Ferulic acid showed inhibitory effects against the all four tested bacterial strains. Among the tested pathogens *Bacillus cereus* and *Staphylococcus aureus* were the most resistant species. The increased bactericidal activity was observed in 1000 μg of ferulic acid against *Bacillus cereus* followed by *Staphylococcus aureus.*

Rani *et al*., (2022) evaluates the antimicrobial activity of aqueous, chloroform, and ethanol extracts of *Moringa oleifera* and *Citrus maxima* medicinal plants against two Gram-positive bacteria and two Gram-negative bacteria and revealed that ethanolic leaf extract of all the plants showed potential activity against all the microbial cultures of *Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli* and *Bacillus subtilus.*

Recycling of organic wastes have beneficial effects for producing bio-energy, reducing the need for inorganic fertilizers and minimizing the volume of contaminants in the environment. From the review and from our work, it is clear that physico-chemical factors like temperature, pH, particle size, moisture content, aeration and CN ratio regulate the breakdown process. Microorganisms convert the organic matter into high quality compost during which majority of the materials is broken down, temperature steadily drops and composting process is completed. From the previous work, it is well evident that majority of the material are broken down during composting hence the nutrients are in the available form for the growth of plants