2

REVIEW OF LITERATURE

The literature regarding the influence of organic amendments such as bio-composted groundnut shell and toddy palm shell on the growth, biochemical parameters and yield of various crops and the influence of these organic fertilizers on soil fertility as relevant to the present investigation are reviewed and presented in this chapter.

2.1 Review on composting, physico-chemical parameters and microbial populations

Organic manures not only supply nutrients to crops and act as a good mulching agent but also improves the texture of the soil. They protect crops against adverse temperature effects, improve seed germination, increase the water retention capacity of the soil and create the right micro-climate for the growth of beneficial soil microbes (Sharma and Mitra, 1991). Composting is a bio-oxidative process that involves the conservation of organic waste to a stabilized final product free of phytotoxicity and pathogens, by the process of mineralization and partial humification (Inckel *et al.,* 1996). Vermicomposting is an eco-biotechnological process that transforms energy-rich and complex organic substances into stabilized humus-like products (Benitez *et al.,* 1999).

Chaudhuri *et al.* (2000) studied the physical and chemical characteristics of kitchen waste compost as influenced by the presence and absence of earthworms at 0, 10, 20, 30 and 40 days. Vermicompost is an important organic source of plant nutrients and contains a high amount of N, P and K necessary for plant growth in readily available forms (Nagavallemma *et al.*, 2004). Mupondi *et al.* (2006) reported that the pine bark composted with the help of goat manure and sewage sludge with and without inoculation of effective microorganisms enhanced the physico-chemical parameters of the final compost. Compost improves the health of the soil, reducing loss of soil and increasing water infiltration and storage (Sally and Scott, 2007).

Suthar and Singh (2008) reported that the domestic waste vermicompost with the help of two epigeic earthworms such as *Perionyx excavates* and *Perionyx sansibaricus*. Parveen and Padmaja (2010) studied the changes in physical (color, appearance, odor,

pH and EC) and chemical (cellulose, organic carbon, organic matter, nitrogen and C:N ratio) parameters of raw and composted municipal solid waste and water hyacinth.

The influence of different levels (0, 50, 100, 250, 500, 750 and 1000g) of municipal solid waste compost increased the bacterial and fungal populations (Kasthuri *et al.*, 2011). Jayakumar *et al*. (2011) reported that the count of total bacterial, fungal, actinomycetes, fluorescent pseudomonads and phosphate solubilizing bacteria were enhanced by 1:1 ratio of soil amended with vermicompost prepared from turkey litter and cow dung. Selim *et al.* (2012) studied the total carbon, total nitrogen and C: N ratio of organic wastes such as corn stalks, cotton stalks, bagasse, cattle manure, poultry manure and mature compost. Chattopadhyay (2012) reported that the maximum microbial population was obtained from organic wastes (cow dung, sugarcane trash and horse manure) treated with earthworms.

Karmegam *et al.* (2012) observed that combined application of leaf litter with pressmud and sugarcane trash with pressmud vermicompost using *Perionyx ceylanensis* and concluded that vermicomposting of leaf litter with pressmud enhanced maximum bacterial, fungal and actinomycetes populations on 0, 15, 30, 45 and 60 days. Hegazy *et al.* (2013) studied the influence of different concentrations of recommended dose of garbage compost and compost extract increased the microbial populations of fungi, bacteria and actinomycetes in rhizosphere soil of fenugreek plants at 0, 15, 30 and 45 days after cultivation and also the physico-chemical parameters (pH, EC, total N, total P, total K, humic acid and fulvic acid) as influenced by the application of garbage compost extract. Jusoh *et al.* (2013) found that composting rice straw, goat manure and green waste along with effective microorganisms promotes the quality of compost.

Basheer and Agrawal (2013) reported that physico-chemical parameters of vermicompost prepared from waste paper and cow dung in different proportions such as 1:1, 2:1 and 3:1 and concluded that 1:1 is to be the best ratio. Sarker *et al.* (2013) estimated the nutrient status of compost prepared from sugarcane press mud by microbial consortium. At the end of the composting period, N was found to be 2.34% in press mud compost while phosphorus and potassium content was 1.15% and 1.37%. Khomami and Moharam (2013) observed an increase in the amount of nitrogen, phosphorus and potassium by increasing the level of sugarcane bagasse vermicompost in the growth medium. Chatterjee *et al.* (2014)

studied the initial and final concentrations of organic carbon, total nitrogen, total phosphorus, total potassium and carbon-nitrogen ratio as influenced by different vegetable waste vermicompost and observed that the OC and C:N ratio was considerably reduced and total N, P and P was significantly increased in final vermicompost.

Natarajan and Devi (2014) reported that pH, EC, organic carbon, total N, total P, total K, total Ca, total Mg, Mn, Zn, Cu and Fe were enhanced by the different ratios of poultry waste combined with *Eichhornia* and cow dung. Natarajan and Gajendran (2014) reported that different proportions (25%, 50% and 75%) of paper mill sludge vermicompost by *Eudrillus eugeniae* improve the physico-chemical parameters of the final compost. Paul *et al*. (2014) studied the physico-chemical parameters of various organic wastes such as municipal solid waste, mushroom spent substrate, vegetable market waste and bio-digested slurry used for vermiculture. Among them bio-digested slurry obtains less amount of organic carbon, C:N ratio and maximum percentage of N, P and K compared with other treatments.

The maize stover was vermicomposted with the help of the epigeic earthworm *Eisenia fetida* enhanced the maximum reduction of cellulose, hemicellulose and lignin than control group was reported by Chen *et al.* (2015). Rajeshkumar and Ravichandran (2015) the vermicompost prepared from biogas plant slurry mixed with cow dung enhanced the physico-chemical parameters of final compost. Oil palm empty fruit bunches mixed with cow dung in different ratios enhanced the physical and chemical parameters of final vermicompost as reported by Lim *et al.* (2015).

Karthikeyan *et al.* (2015) studied the physico-chemical characteristics of vermicompost prepared from different wastes such as vegetable waste, municipal waste, sago waste and dairy waste and concluded that the maximum total nitrogen and available phosphorus was obtained from vegetable waste vermicompost. Torkashvand *et al.* (2015) studied the efficacy of different proportions (15%, 30%, 45%, 60% and 100%) of peanut shell compost and reported an enhancement in the physico-chemical parameters of the growth medium. Hanc and Vasak (2015) reported that different proportions of straw and separated digested (separated biogas plant slurry) improve the total contents of phosphorus, potassium, magnesium, calcium and nitrogen in the final vermicompost.

Sivakumar and Karthikeyan (2016) reported that bioconversion of vermicompost weed plants waste using *Eudrilus eugeniae* Kinberg enhanced the physicochemical parameters (pH, temperature, EC, OC, N, P, K, C:N%) and microbial populations (bacteria, fungi and actinomycetes) of end product. Anike *et al.* (2016) reported that the *Pleurotus ostreatus* enhanced the biodegradation of peanut shells and cornstalks. Game *et al.* (2016) studied the bacterial, fungal and actinomycetes populations during composting of different substrates such as wheat straw, sorghum straw, chickpea straw, vegetable waste and sawdust using cellulolytic microbial consortium.

Thilagar *et al.* (2016) reported that the influence of microbial consortium and NPK fertilizers enhanced the bacterial population in rhizospheres soil of chilly under a microplot study. Haseena *et al.* (2016) reported that ayurvedic herbal waste increased the microbial population of bacteria, fungi and actinomycetes than weed compost, tea waste compost, coir pith and sawdust. Ravindran and Mnkeni (2017) studied physicochemical characteristics of different proportions of chicken manure and shredded paper waste and concluded that mixture of 9.4 kg of chicken manure along with 15.6 kg of shredded paper waste enhanced reduction of C:N ratio. The composting of rural and urban waste treated with test consortium improves the total phosphorus, total nitrogen and total potassium level was reported by Game *et al.* (2017).

Gopal *et al.* (2017) studied the percentage of total nitrogen, total phosphorus and total potassium during vermicomposting of coconut leaves with *Eudrilus sp*. assistance on 15, 45, 75 and 105 days and the changes of pH during composting and vermicomposting of different paper wastes (newspaper waste, newspaper waste + earthworm, written paper waste and written paper waste + earthworm) on 15, 30, 45 and 60 days (Paul and Joseph, 2017).

Karimi *et al.* (2017) studied the physico-chemical properties of moisture level, EC, organic carbon, nitrogen and pH enhanced with the application of wastewater treatment plant sludge and cow manure. Omidi *et al.* (2017) reported that application of composted peanut shells enhanced the physicochemical parameters (pH, EC, total nitrogen, phosphorus, potassium, organic carbon and C/N ratio) of the growth medium. Premalatha *et al.* (2017) reported that total bacterial population during composting of different crop residues such

as paddy straw, sugarcane trash and leaf litter by microbial consortium and conventional method was maximum with the application of leaf litter + microbial consortium.

The application of 30% nanozeolite in soil with alfalfa straw enhanced the fungal and bacterial populations (Aminiya *et al.,* 2018). According to Khomami *et al.* (2019) the different concentrations (15%, 30%, 45%, 60% and 100%) of peanut shells and azolla mixed compost as a substitute for peat enhanced the physicochemical properties of *Dieffenbachia amoena*. Mbarek *et al.* (2019) studied the physicochemical parameters of date palm compost and sheep manure and concluded that the maximum reduction of total organic carbon (18.59%) and carbon nitrogen ratio (11.40) observed in final compost of date palm than sheep manure. Sharma *et al.* (2019a) studied the physico-chemical parameters of aerobic compost from two different municipal solid waste dumpsites located in the cities of Solan and Mandi in Himachal Pradesh and concluded that the municipal solid waste compost of Solan cannot be used as fertilizer due to its low fertilizing potential.

Usmani *et al.* (2019) investigates the changes in physico-chemical and microbial population during composting and vermicomposting of coal fly ash under aerobic condition and concluded that the physico-chemical parameters and total microbial population (bacteria, fungi and actinomycetes) was improved with the application of vermicompost. Kaur *et al.* (2019) stated that bio-composting of rice straw, rice bran and fruit waste in different combinations with the standard fungal culture of *Trichoderma harzianum* MTCC 8230 significantly decrease the percentage of lignin from 20-25% to 13-15%. Kutu *et al.* (2019) observed that the maximum bacterial, fungal and actinomycetes population in soil was higher in cattle manure than poultry manure.

Jagadabhi *et al.* (2019) investigated the physico-chemical characteristics of sorghum straw, finger millet straw, soybean straw saw dust and cow dung. Among them cow dung showed a maximum level of N and P. Vermicomposting of rice straw and dry grass clipping using the epigeic earthworm *Eisenia fetida* increased the micro and macro nutrients levels (Ramnarain *et al.,* 2019). The composting of tomato plant residues with sheep manure integration at different proportions enhanced the organic matter mineralization, humification, nitrogen dynamics and agronomic value of the final compost (Tabrika *et al.,* 2020).

The influence of different combinations of coir, biochar, perlite, pine bark and municipal solid waste enhanced the physical and chemical parameters of the end product was reported by Machado *et al.* (2022). Nobile *et al.* (2022) reported that compost with different amendments (rapeseed biochar, miscanthus biochar and green waste residues biochar) enhanced the organic carbon, total N, P, K, Ca, Mg and C: N ratio. Aslam *et al.* (2023) reported that considerable reduction of C:N ratio and improvement of N, P, K, Ca and Mg as influenced by the application of vermicomposted cow dung as compared with raw, composted and vermicomposted wheat straw, rice straw and cow dung respectively.

2.2 FT-IR, XRD AND SEM analysis

Reddy *et al.* (2009) studied the FT-IR, XRD and SEM analysis of untreated and alkali-treated borassus coarse and fine fibers and the FT-IR, XRD and SEM analysis of different concentrations (2%, 5%, 10%, 15% and 20%) of alkali-treated borassus fine fibers compared with untreated fibers was reported by Reddy *et al.* (2012). Fourier transform infrared spectroscopy, X- Ray diffractograms and scanning electron micrographs of untreated and 1 h, 4 h, 8 h and 12 h alkali-treated borassus fine fibers were reported by Reddy *et al.* (2013).

Durairaj *et al.* (2015) studied the SEM image and XRD pattern of Titanium dioxide nanoparticles (N-TiO_2) synthesized with the help of *Aspergillus niger* and scanning electron micrographs of oil palm empty fruit bunches and final vermicompost in the ratio of 2 part of empty fruit bunches and 1 part of cow dung were reported by Lim *et al.* (2015).

X-Ray diffractograms, scanning electron micrographs and FT-IR spectra of palmyra palm fruit fiber and extracted cellulose microfibers and XRD pattern and SEM morphological structure of *Borassus flabellifer* shell activated carbon before and after adsorption of naphthalene was reported by Reddy *et al.* (2016); Kumar *et al.* (2016a). Usman *et al.* (2016) studied the FT-IR and SEM micrographs of untreated and alkaline treated groundnut shell powder recycled polyethylene composites.

Kamaraj and Umamaheswari, 2017 studied the FT-IR spectra and FESEM analysis of activate carbon prepared from groundnut shell and FT-IR spectra of extracted humic acid from the initial feedstock (food waste + rice bran + dried leaves) and final

compost (compost with effective microorganisms) were reported by Fan *et al.* (2018). Mbarek *et al.* (2019) studied the infrared spectrum of humic acids extracted from the initial mixture (34% oasis palm and 66% sheep manure) and final compost.

FT-IR, XRD and SEM analysis of municipal solid waste compost on 20^{th}, 40^{th} and 60^{th} day at Mandi and Solan region by Sharma *et al.* (2019a) and field emission scanning electron micrographs and X-Ray diffraction of washed hard carbon samples derived at 500℃, 700℃ and 900℃ was reported by Damodar *et al.* (2019). Scanning electron micrographs of borassus fruit fibre, tamarind fibre and tamarind/borassus fruit fine fibre with cashew nut shell liquid epoxy matrix-based composites were experimented by Nayak *et al.* (2019).

Scanning electron micrographs of untreated borassus fibre and initially treated with sodium hydroxide for the duration of 1h, 2h and 3h and were later treated with potassium permanganate were reported by Baby *et al.* (2019) and SEM micrographs of toddy palm fruit fiber bundle and coir fiber bundle were studied by Graupner *et al.* (2019).

The influence of 5 kg of feedstock mixed with 2.16 kg of shredded waste paper and 2.84 kg of cow dung enriched with (1% P) rock phosphate, triple superphosphate, phosphoric acid and calcium chloride vermicompost at 56 days and the scanning electron micrograph of vermicomposted samples was reported by Unuofin and Siswana (2019) and microstructure of commercial and processed activated carbon from toddy palm fruit husk using scanning electron micrograph was reported by Khaing *et al.* (2020). Scanning electron micrograph of bovine blood-rumen digest mixture was reported by Bhunia *et al.* (2021).

Sharma *et al.* (2023) studied the spectrochemical characterization of *Tectona grandis* leaf litter compost and concluded that scanning electron microscopy revealed irregularities of the compost with a higher porous texture and fourier transform-infrared spectroscopy showed excellent compost maturity.

2.3 Influence of composts on biometric and yield parameters

Increased yield of chilli, okra, tomato and brinjal by the application of organic manures was reported by Gaur *et al.* (1984). Sheorant *et al.* (2000) reported that planting date had a significant effect on the growth and yield of fenugreek. Atiyeh *et al.* (2000) have

reported an increase in the number of germinated seeds of tomato in Metro-Mix 360 with 20% vermicompost addition. Negassa *et al.* (2001) found that corn yield was increased with the application of the mixture of 35% organic and inorganic nutrients.

The application of different types and rates of vermicompost promotes the growth and yields of field-grown strawberries under field conditions (Arancon *et al.*, 2004). Leaf area, plant vigour, plant height, stem girth, plant weight, dry matter percentage and marketable yield were increased in red amaranth (*Amaranthus tricolor* L.) when it was cultivated with 10 tons of vermicompost in combination with 100% of NPK (Alam *et al.*, 2007).

Formowitz *et al.* (2007) experimented the influence of effective microorganisms in the compost of banana residues and observed an enhancement in shoot and root dry matter of young banana plants. Karmegam and Daniel (2008) stated that the impact of the vermicompost individually and in combination with chemical fertilizers increased the growth and yield parameters of the vegetable crop *Lablab purpureus* (L.) sweet. Darzi *et al.* (2008) concluded that organic nutrients could enhance the vegetative growth and yield of seed spices like fennel. Ali (2008) reported that the addition of date palm compost enhances plant growth and germination of ornamental plants such as *Dahlia, Tagetes, Zinnia and Cosmos.*

Microbial consortium enhances plant growth, nutrient uptake and biomass of crops (Akhtar and Siddiqui, 2008). The positive effect of rice yield observed from rice straw compost (Goyal *et al.*, 2009) and the application of inorganic and organic fertilizers improved the growth and yield related attributes in cotton and maize (Shisanya *et al.*, 2009). Pirlak and Kose (2009) reported an increase in the yield of strawberry plants after inoculation with the microbial consortium.

Ayub *et al.* (2010) studied the efficacy of different nitrogen levels (0, 25, 50 Kg ha^{-1}) on the growth and yield of three cluster bean varieties namely; cluster bean 2/1, BR-90 and BR-99 and concluded that BR-99 showed a maximum increase in plant height, stem diameter, number of branches and green fodder yield. Manures prepared from different weeds increased the yield and quality of maize were reported by Naikwade and Jadhav (2011). According to Kasthuri *et al.* (2011) the influence of municipal solid waste

compost amendments (0, 50, 100, 250, 500, 750 and 1000g) promotes the growth and yield characteristics of green gram (*Vigna radiata* (L) and fenugreek (*Trigonella foenum-graecum* L.)

Ayub *et al.* (2011) observed that different nitrogen levels (0, 30 and 45 Kg ha^{-1}) and seedling rates (30, 40 and 50 Kg ha^{-1}) increased the forage yield and quality parameters of cluster bean. Jayakumar *et al.* (2011) studied the growth and yield of paddy influenced by soil amended with farmers practice and the different concentrations (40, 30, 20 and 10 kg) of vermicompost prepared from turkey litter + cow dung using *Perionyx ceylanensis* and concluded that farmers practice with 40 kg of vermicompost enhanced the growth and yield of paddy. Darzi *et al.* (2012) reported that the application of vermicompost and phosphate solubilizing bacterium improves the morphological traits and seed yield of anise (*Pimpinella anisum* L.).

The plant height of green gram was significantly enhanced due to the inoculation of microbial consortia at the graded levels of nitrogen, phosphorus and Sulphur (Kamlesh and Dubey, 2012). According to Ahmed *et al.* (2012) the influence of organic and bio-fertilizer improves the growth and yield characteristics of two fenugreek cultivars (Giza 2 and Giza 3) grown in sandy soil in 2009-2010 and 2010-2011 seasons. Sharma and Agarwal (2017) concluded that impact of farmyard manure, vermiculture, vermicompost and chemical fertilizer improves the growth, yield and quality of spinach.

Saxena *et al.* (2013) studied the growth parameters of coriander genotypes (RCr 41 and Acr 1) at 45, 75 and 90 DAS and concluded that Acr 1 obtain maximum fresh weight, root weight, number of branches, root length, shoot length and dry weight of coriander on 90 DAS. Growth and yield parameters of okra improved with the application of 100% recommended dose of fertilizers (N, P and K) + vermicompost (5t ha^{-1}) + biofertilizers (*Azotobactor*, *Azospirillum* and PSB) than other combinations (Mal *et al.*, 2013). The efficacy of garbage compost and compost extract improves the plant height and number of leaves of fenugreek seedlings under greenhouse conditions (Hegazy *et al.*, 2013).

Kavitha *et al.* (2013) studied the individual and combined effect of biofertilizer, chemical fertilizer and vermicompost and reported an enhancement in root and shoot length, fresh and dry weight, number of leaves and moisture content of *Amaranthus tristis*

at 40th day of growth. Inoculation of rhizobium and phosphate solubilizing bacteria enhanced the growth and yield attributing characteristics of chickpea genotypes (Tagore *et al.,* 2013).

Shahid *et al.* (2013) studied the yield of okra as influenced by different concentrations (0, 50, 100 & 200 ppm) of gibberellic acids (GA_3) and naphthalene acetic acid (NAA) alone / in different combinations and concluded that T_{15} (200 + 200 ppm GA_3 + NAA) showed the maximum number of pods, pod length, pod fresh and dry weight of okra. Hu and Qi (2013a) studied the biomass and yield of wheat as influenced by the application of NP fertilizer, traditional compost and effective microorganisms compost treatments and concluded that the highest wheat biomass (39.45 g/10 plants) and wheat yield (6.09 t ha^{-1} m^{-2}) was obtained in effective microorganisms compost treatment. The maximum root dry biomass, stem and leaf dry biomass, root, stem and leaf dry biomass in wheat at seedling stage, jointing stage and maturity stage as influenced by effective microorganisms compost than traditional compost and control (Hu and Qi, 2013b).

The application of cow dung, poultry droppings and NPK fertilizer promotes the plant height, leaf area, fresh and dry weight of okra (Uka *et al.,* 2013) and the influence of microbial enriched phosphocompost (rock phosphate + vermicompost) improves the growth parameters of *Trigonella foenum-graecum* L. (Biswas and Anusuya, 2014). Chatterjee *et al.* (2014) reported that the growth, yield and quality of carrots increased significantly by different vegetable waste vermicompost.

Osoro *et al.* (2014) studied the efficacy of water hyacinth (*Eichhornia crassipes* [mart.] solms) compost prepared using different combinations of effective microorganisms, cattle manure and molasses. Improvement in growth and yield characteristics of common bean grown under greenhouse conditions were reported. Bio-fertilizing efficiency of seaweed liquid extracts of brown algae *Sargassum wightii* increased the growth and yield attributes of cluster bean (Vijayanand *et al.,* 2014).

The application of Jeewamirta increased the number of fruits, weight of fruit and yield of oriental pickling melon (Vemaraju, 2014) and the application of vermicompost promotes the maximum number of fruits and yield of fruits in okra, tomato and chilli has been reported to by Dhanalakshmi *et al.* (2014). The integrated nutrients management enhanced the growth performance of bottle gourd as influenced by different combinations of organic manure, chemical fertilizers and biofertilizers (Das *et al.,* 2015).

Rajeshkumar and Ravichandran, (2015) reported that germination of seeds, root length, shoot length, number of root hairs and leaves enhanced with the application of compost prepared from biogas plant slurry and cow dung mixture. Deka *et al.* (2015) studied the growth and yield attributes of cluster bean as influenced by different sowing dates (1st July, 15th July, 1st August and 15th August) and spacing distances (45 × 30, 60 × 30 and 45 × 45 cm) in the subtropical climate of Assam and concluded that 1st July sowing date and 45 ×30 cm spacing was suitable for cluster bean production under agro climatic condition of Assam. Biologically synthesized Titanium dioxide nanoparticles (N-TiO_2) enhanced the root length, shoot length, germination percentage and seed vigor index of fenugreek seedlings (Durairaj *et al.*, 2015).

The influence of organic manures and bio-inoculants increased the vegetative and yield attributing characters of gymnema (*Gymnema sylvestre* R. Br) was reported by Manigandan and Manivannan, (2015) and the seed germination and growth of okra as influenced by different organic amendments such as farmyard manure, vermicompost and biochar by Sarma and Gogoi (2015). Muhmood *et al.* (2015) reported that bio slurry and inorganic fertilizers improves the yield of okra and carrot. Karthikeyan *et al.* (2015) reported the growth characters (plant height and plant diameter) enhanced by different vermicomposts such as vegetable waste, municipal waste, sago waste and dairy waste and the efficacy of different proportions of peanut shell composts (15%, 30%, 45%, 60% and 100%) enhanced the growth of *Dracaena marginata* (Torkashvand *et al.*, 2015).

Said-Al Ahl *et al.* (2016) reported that the effect of indole acetic acid and humic acid increased the growth characteristics (plant height, number of branches, number of umbels) and yield characters (seed weight, seed yield, straw weight and straw yield) of dill (*Anethum graveolens*) in 2010-2011 and 2011-2012 in two different locations such as Giza and Sinai in Egypt. Sivakumar and Karthikeyan (2016) studied the bioconversion of vermicompost weed plants waste using *Eudrilus eugeniae* Kinberg which promotes the germination efficiency, shoot length, root length, total fresh weight, total dry weight and vigour index of brinjal (*Solanum melongena*).

Ravimycin (2016) experimented the effects of vermicompost (VC) and farmyard manure (FYM) and reported an enhancement in the germination percentage, root length,

shoot length, fresh weight and dry weight of coriander (*Coriander sativum* L.). and the influence of fertilizers and microbial consortia alone and microbial consortia with varied level of NPK increased the plant height, stem girth and biovolume index of chilly at 70 and 140 days after transplant under microplot study (Thilagar *et al.*, 2016).

The efficiency of vermicompost, mineral fertilizers increased the morphological parameters (plant height, leaf number, internode length, fresh and dry weight of plant) and yield attributes (number of pod, pod yield and harvest index) of okra in 2011, 2012 and 2013 (Oroka and Oke, 2016). Maity *et al.* (2016) reported the plant growth regulators such as gibberellic acid and indole-3-butyric acid increased the growth and yield of okra (*Abelmoschus esculentus* L.).

Baliah *et al.* (2016) reported that plant growth regulators such as IAA, BAP, GA, Spic Cytozyme and Aminos improved the shoot length, root length, fresh weight and dry weight of bhendi. Sambangi and Rani (2016) studied the germination percentage, root and shoot length of seven different cluster bean varieties (HG365, JJ1, JG2, GL1031, REC1025, RGC963 and RGC936) in net house under pot culture. Among them RGC963, HG365, JJ1, REC1025 varieties showed better germination percentage and length of root and shoot.

Schoebitz *et al.* (2016) studied the combined application of microbial consortium and humic substances and reported an improvement in the growth performance of blueberry seedlings and the effect of different combinations of NPK, sheep manure, poultry manure and farm yard manure enhanced the leaf area index, 1000-grain weight, grain yield, biological yield and harvest index of maize (Mahmood *et al.*, 2017). The effects of vermicompost, vermiwash, vermicompost + vermiwash increased the growth and yield characteristics of fenugreek under greenhouse at the University of Guilan, 2012 (Alaghemand *et al.* (2017).

Lal *et al.* (2017) stated organic madules (M_1, M_2 and M_3) on varieties (AFg-1 and RMt-305) improves the plant height, number of primary branches/plant, number of pods/plant, number of seeds/pod, seed yield of fenugreek in 2009-2010 to 2012-2013. Cultivation of fenugreek variety AFg-1 with the application of M_1 (vermicompost @ 5t/ha, foliar spray of 5% garlic extract @ 2.0 kg/ha + 2% neem oil @ 5 litre/ha) exhibited

maximum values for all the growth and yield parameters. The effect of different level of recommended dose of fertilizers, farmyard manure, vermicompost and bio-fertilizers promotes the yield components such as fruit yield and bulb yield of *Abelmoschus esculentus* and *Allium cepa* cropping system in the semi-arid zone of Haryana (Jat *et al.,* 2017).

Vaidyanathan and Vijayalakshmi (2017) concluded vermicompost increased the growth and yield parameters of tomatoes and the effect of microbial inoculants in seeds enhanced the shoot length, root length, number of leaves/plant, number of branches/plant, number of flowers/plant, number of fruits/plant, fruit weight, fruit length, fruit girth, number of seeds/fruit and average fruit yield/plot of bhendi in field trial (Sundari and Gandhi, 2017). Pampuro *et al.* (2016) studied the potential pig slurry solid fraction pellets as fertilizer improved the growth of maize.

Satyavathi and Vanaja (2017) stated that the growth and yield performance of cluster bean genotypes (RGC-1017, RGC-936, RGC-986, RGC-1025 and HGS-365) under different environmental conditions Season 1 (S1), Season 2 (S2) and Season 3 (S3). Among the genotypes RGC-936, RGC-986 recorded highest total biomass and seed yield during S2 while the genotypes RGC-1017 and HGS-365 during S3 whereas genotype RGC-1025 recorded its highest biomass during S2 while seed yield during S3. The growth and yield attributing characteristics of cluster bean crop as influenced by different dosages of fertilizers and concluded that T_3 (RDF (100%) + PSB + Zinc (5 Kg/ha) enhanced the growth and yield characters of cluster bean (Anuradha *et al.,* 2017). Omidi *et al.* (2017) reported that the influence of 25% of the soil + 75% peanut shell compost enhanced the growth parameters such as plant height, root length, fresh and dry weight of canopy and root of the violet plant.

Integrated nutrient management increased the yield and growth characteristics of bottle gourd was reported by Baghel *et al.* (2017) and the effect of foliar application of some chelates micronutrients (Fe, Cu, Zn, Mn) and compost tea significantly enhanced the growth, yield and productivity of fenugreek plant during two seasons (2017-2018) (Hegab, 2018). The combined application of plant growth regulators and organic fertilizers improved the growth attributes of fenugreek (Balakrishnan and Arunprasath, 2018). Srivastava *et al.* (2018) observed the morphological and yield response of lady's finger and found an enhancement in the varying ratios of municipal solid waste vermicompost.

Meena *et al.* (2018) studied the different sowing dates (15th October, 30th October and 15th November), NPK levels (30:30:15 kg/ha (F1), 40:40:20 kg/ha (F2) and 50:50:25 kg/ha (F3) and weedicides (Pendimethalin @ 1.0 kg/ha, Oxadiargyl @ 75g ai/ha) on growth and yield of fenugreek under semi-arid conditions. Significantly improved plant height, primary branches, secondary branches, nodules, seed yield and biological yield were recorded in 30th October sown crop, NPK level (F3) 50:50:25 kg/ha and Oxadiargyl @ 75g a.i/ha. The influence of. Singla *et al.* (2018) studied the okra genotypes for growth and yield parameters under Punjab condition and concluded that okra genotype OH 2324 performed well for various growth and yield.

Singh *et al.* (2018) studied that the integrated nutrient management on growth, flowering and yield attributes of cucumber and the effect of mycorrhiza and vermicompost fertilizers improves the growth and physiological traits of vetiver grass was reported by Akhzari *et al.* (2018). Benabderrahim *et al.* (2018) stated that palm trees compost increased the growth of alfalfa crop and the impact of poultry feather waste as compost promotes the growth of the vegetable crop *Ipomoea aquatica* (Joardar and Rahman, 2018).

Kakade *et al.* (2018) studied the biometric parameters of okra in different shade net houses such as green shade net house, white shade net house and green and white shade net house and concluded that the green and white strip shade net house was significantly increased the growth attributes viz., plant height, number of primary branches, canopy area and stem diameter of okra. The growth, yield and quality of seeds as influenced by sowing dates (15th October, 1st November, 15th November, 1st December and 15th December) and varieties (Hissar sonali, Rmt-1, Co-1, Rajendrakanthi and Co-2) in fenugreek. The maximum values in respect of many of these parameters was recorded by Co-1 and Co-2 by sowing on 15th October (Anitha *et al.,* 2018).

Szparaga *et al.* (2018) reported that bio-stimulant increased the number of pods per plant in soybeans and the microbial consortium of *Funneliformis mosseae* and *Bacillus sonorensis* added to the substrate in pro-trays enhanced the seedling height, stem diameter, biovolume index, plant strength, vigour index and dry weight of tomato and capsicum (Desai *et al.,* 2019). Parul (2019) reported that nanochitosan and nanozeolite along with PGPR improved the yield of maize under field conditions as compared to the control.

Foliar application of liquid organic fertilizer, compost water extract, combined with micronutrients solution promotes the growth of fenugreek plants under sandy soil condition (Ibrahim, 2019) and the organic fertilizers improves the growth and mineral properties of *Moringa oleifera* under greenhouse conditions (Christophe *et al.,* 2019).

Different ratios of soil and poultry litter vermicompost such as V1 (100% soil + 25% vermicompost), V2 (100% soil + 50% vermicompost), V3 (100% soil + 75% vermicompost) and V4 (100% soil + 100% vermicompost) improves the plant growth parameters of okra (Yuvaraj *et al.,* 2019). Erana *et al.* (2019) stated that agro industrial wastes compost and inorganic fertilizers improves the shoot girth, shoot weight and bulb weight of onion (*Allium cepa* L.) under field condition.

The different varieties (MDU 1, Pusa Navbahar, Pusa Sadabahar and Farmers practice (local check)) of cluster bean (*Cyamopsis tetragonoloba*) improve the growth and yield characteristics and concluded that MDU1 recorded the highest number of fruits, weight of fruit, length of fruit, a girth of fruit and fruit yield per hectare (Rajamanickam, 2019) and the different level of urea and Jeewamirta enhanced the growth and yield of *Abelmoschus esculentus* L. (Fazeel *et al.,* 2019).

The different concentrations of peanut shells (15%, 30%, 45%, 60% and 100%) and azolla mixed compost enhanced the final height, trunk diameter, fresh and dry weight of stem and leaves of the tropic snow plant (*Dieffenbachia amoena*) was reported by Khomami *et al.* (2019) and the variety GF-12 and AF-1 performed better in growth and yield attributing characters of fennel under organic production system (Lal *et al.,* 2019).

The studies of Sharma *et al.* (2019b) showed an increase in growth, yield and quality of cluster bean as influenced by integrated nutrient management under an alley cropping system and the effect of inoculation of microbial consortia improves the growth parameters of green gram (*Vigna radiata* L.). (Badiger *et al.,* 2019). The results of Sikder and Joardar (2019) revealed the preparation of biochar from poultry litter enhanced the plant growth performance of *Gima kalmi*.

Zhao *et al.* (2020) stated that the different size fractions (the whole compost, 1.6 mm compost and 0.8-1.6 mm compost) of municipal solid waste improved the plant height on 20, 40 and 60 days of *Lolium perenne* L. Sukeerthi *et al.* (2020) reported that the

influence of a microbial consortium of the arbuscular mycorrhizal fungus and plant growth promoting rhizobacterium enhanced the growth parameters of flowering plants Zinnia and Balsam in pro-trays under poly house conditions.

Ameziane *et al.* (2020) studied the value of olive pomace compost from a traditional system as soil amendment enhanced the germination rate of the fenugreek plant and the plant height, root length, fresh and dry weight of okra (*Abelmoschus esculentus* L.) as influenced by *pseudomonas spp*. under soil salinity condition was reported by Vimal *et al.* (2020). Kumari *et al.* (2020) reports a significant increase (1.5 to 2 folds) in plant height, leaf number, leaf area and fresh weight in fenugreek plants when treated with nano compounds and plant growth-promoting rhizobacteria (PGPR) than control.

Moretti *et al.* (2020) reported different combinations of beneficial bacteria with and without microbial secondary metabolites increased the growth and yield of two soybean cultivars (BRS 317 and TMG 1264 RR) in three cropping seasons (2016-2017, 2017-2018 and 2018-2019) under tropical field conditions. Sankar *et al.* (2021) studied the effect of different proportions of dried rumen content blood with coir pith enhanced the growth and yield of Okra.

Asghar and Kataoka (2021) stated that inoculation of *Trichoderma sp*. with poultry compost, cattle compost, rapeseed oil cake and inorganic fertilizer enhanced the fresh and dry biomass of *Brassica rapa* and *Lactuca sativa* and the solid phosphate sludge composted with organic horticultural residues (tomato plant) improved the plant height and diameter of citrus and forest seedlings (Eg. *Carrizo citrange*, Argan and Carob) (Baiz *et al.,* 2021). Singh *et al.* (2021) stated that morphological parameters of okra under different microbial inoculation (T1 - control, T2 – *S. rolfsii* inoculation, T3 – *T. viride* BHU-V2 VOCs treatments and T4 – *T. viride* BHU-V2 VOCs + *S. rolfsii* inoculation) and concluded that T3 is the best combination.

The planting date and compost fertilization enhanced the plant height, leaves number, pods number and seed yield of fenugreek (Abdou and Abdel-Fatah, 2021) and the physical and chemical parameters of millicomposts prepared from different vegetable residues such as *Bauhinia sp.* leaves, grass clippings, *Musa sp*. leaves and shredded cardboard and its efficacy on growth parameters of curly lettuce was reported by Antunes *et al.* (2021).

The integrated application of biochar, compost, fruit and vegetable waste and *Bacillus subtilis* enhanced the growth (plant height, root length, fresh and dry biomass of root & shoot) and yield (number of fruits, fruit length, average diameter of fruit, fresh and dry biomass of fruit) characteristics of okra (Anwar *et al.,* 2021). Paler and Alcantara (2021) using different concentrations (25%, 50%, 75% and 100%) of Azolla as a bio-stimulant enhanced the nutrient uptake and yield performance of mungbean.

Kumar *et al.* (2021) reported diazotrophic plant growth promoting rhizobacterial strains enhanced the growth and yield of wheat under pot and field conditions and the effect of different substrates such as coir, biochar, perlite, pine bark and municipal solid waste in different concentrations enhanced the shoot dry weight, leaf area and fresh yield of spinach (Machado *et al.,* 2022). Mowafy *et al.* (2022) stated that different bacterial strains increased the shoot length, root length, shoot dry weight, root dry weight and the number of nodules of *Vicia faba* plant during the pre-flowering stage and Cheng *et al.* (2023) reported that the application of biochar and compost stimulated the plant growth and biomass of ryegrass.

2.4 Studies on biochemical content

Parthasarathi and Ranganathan (2001) noticed higher chlorophyll, sugar and protein contents in vermicompost + NPK application and the effect of plant growth regulators increased the chlorophyll content and fruiting nodes in cotton was reported by Norton *et al.* (2005). The application of biodegraded sunflower extract at 2.5% to 10% increased the growth, protein and chlorophyll content of green gram and chickpea (Kaya *et al.,* 2006).

Karmegam and Daniel (2008) studied the influence of vermicompost individually and in combination with chemical fertilizers and reported increased total chlorophyll content in leaf of *Lablab purpureus* on 60^{th}, 120^{th} and 180^{th} day after sowing and the different levels of municipal solid waste compost enhanced the total chlorophyll, protein, amino acids, carbohydrates and reducing sugars of green gram (*Vigna radiata* (L) and fenugreek (*Trigonella foenum-graecum* L.) was reported by Kasthuri *et al.* (2011).

Ahmed *et al.* (2012) noted the efficacy of cultivars (Giza 2, Giza 3), organic and bio-fertilizers enhancing the carbohydrate and protein content of fenugreek grains and individual and combined application of biofertilizer, chemical fertilizer and vermicompost

enhanced the chlorophyll, carotenoids, protein, carbohydrates, vitamin A & C, phosphorus and iron content of *Amaranthus tristis* at 40th day of growth (Kavitha *et al.,* 2013).

Saxena *et al.* (2013) observed chlorophyll a, chlorophyll b and total chlorophyll content in seeds of coriander genotypes (RCr 41 and ACr 1) at 75 & 100 DAS. Leghaemoglobin content of root nodules of five genotypes of chickpea (IG 226, IG-370, IG-379, JG-412 and IG-593) was studied by Tagore *et al.* (2013) and concluded IG-593 had a higher value of leghaemoglobin content.

Vijayanand *et al.* (2014) studied the biochemical parameters of cluster bean (*Cyamopsis tetragonoloba* L.) as influenced by the different concentrations (0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 5.0%) of seaweed (*Sargassum wightii*) liquid extracts and concluded that 1.5% increased the chlorophyll a, chlorophyll b and total chlorophyll content in leaves of cluster bean. The protein, carbohydrate, reducing sugar, chlorophyll content in leaves of fenugreek enhanced with the application of Titanium dioxide nanoparticles (N-TiO_2) synthesized with the help of *Aspergillus niger* (Durairaj *et al.,* 2015).

Sivakumar and Karthikeyan (2016) studied chlorophyll a, chlorophyll b, total chlorophyll, carotenoid and anthocyanin content of brinjal influenced by weed plants waste vermicompost using *Eudrilus eugeniae* Kinberg. The effects of vermicompost and farmyard manure increased the total chlorophyll, carotenoids and protein content of coriander (*Coriander sativum* L.) was stated by Ravimycin (2016). The chlorophyll content, nodule number and nodule weight of green gram was enhanced due to the application of microbial consortia (Kumar *et al.,* 2016 b).

Sambangi and Rani (2016) studied the biochemical content in leaves of different cluster bean varieties (HG365, JJ1, REC1025, RGC963, GL1031, RGC936 and JG2) and concluded that maximum total protein content was found in RGC963, HG365, JJ1, REC1025 followed by JG2, GL1031 and RGC936. The plant growth regulators such as IAA, BAP, GA, Spic Cytozyme and Aminos improved the biochemical characteristics such as total chlorophyll, protein, glucose and free amino acid of bhendi (Baliah *et al.,* 2016).

The effects of organic fertilizers such as vermicompost, vermiwash (combination and alone) improves the biochemical characteristics (total phenol, seed protein and nitrogen in seed) of fenugreek in 2012 (Alaghemand *et al.,* 2017) and the application of

75% chemical fertilizer with *Azospirillum brazilense* and *Pseudomonas fluorescens* isolates enhanced the chlorophyll a, chlorophyll b and total chlorophyll content in leaves of bhendi was reported by Sundari and Gandhi (2017). Balakrishnan and Arunprasath (2018) the different combination of plant growth regulators (IAA, IBA and NAA) and organic fertilizer improves the total chlorophyll, carotenoid, sugar, starch, amino acids and protein content of *Trigonella foenum-graceum*.

Akhzari *et al.* (2018) studied the effect of different concentrations of vermicompost and mycorrhizae increased the chlorophyll a, b and carotenoids content of *Chrysopogon zizanioides* and the application of different proportions of nitrogen fertilizers and Jeewamirta enhanced the chlorophyll content of *Abelmoschus esculentus* L. (Fazeel *et al.,* 2019). The different size fractions (the whole compost, 1.6 mm compost and 0.8-1.6 mm compost) of municipal solid waste enhanced the chlorophyll a, b and total chlorophyll content in leaves of *Lolium perenne* L. (Zhao *et al.,* 2020)

Vimal *et al.* (2020) reported that chlorophyll a, chlorophyll b and total chlorophyll content of okra (*Abelmoschus esculentus* L.) was increased by *pseudomonas sp*. under soil salinity conditions and the effect of compost, planting date and their combinations enhanced the protein and saponin content in fenugreek seeds during 2018-2019 and 2019-2020 seasons (Abdou and Abdel-Fatah, 2021).

Singh *et al.* (2021) stated that under different microbial inoculations T3 (*T. viride* BHU-V2 VOCs treatments) showed a higher amount of chlorophyll in okra and the effect of composted phosphate sludge with proportions of 41%, 29%, 35% and 10% mixed with tomato waste enhanced the chlorophyll content of *Carrizo citrange* (Baiz *et al.,* 2021). The influence of different bacterial strains such as *Bacillus* MP3, *Brevibacillus* MP4, *Pseudomonas* MP5 & MP8 and *Rhizobium* MP7 enhanced the chlorophyll a, chlorophyll b and carotenoids content of *Vicia faba* during the pre-flowering stage (Mowafy *et al.,* 2022). Alhammad and Seleiman (2023) reported that the combined application of biogas digestate + biofertilizers improves protein (27.67%) and carbohydrate (59.68%) content in seeds of feba bean.

2.5 Fertility status of soil

Organic amendments improve the soil quality, crop growth and yield (Dahama, 1997) and the application of organic manures in the soil enhanced phosphorus availability (Toor and Bahl, 1997). Crop residues when incorporated directly into the soil accelerate the biochemical and biological components of the carbon cycle in soil (Maithani *et al.,* 1998).

Date palm compost enhances the life of N and P in soil, improve soil aggregates and stimulate plant respiration in soil (Hernandez *et al.,* 2001). Renato *et al.* (2003) reported that organic fertilizers in soil can increase element uptake and vermicompost used as manure for improving the physical, nutritional and biological properties of soil was reported by Chaoui *et al.* (2003). Organic manures affect the soil biological activity (Araujo *et al.,* 2007) and better soil aggregation by the application of bulky organic manures that ultimately improved soil porosity and water holding capacity (Gangwar *et al.,* 2006).

Savy and Banzatto (2006) reported that the application of castor crop residues to the soil increased the organic matter, N, P and K and the organic manure can serve as an alternative to mineral fertilizer for improving soil structure (Dauda *et al.,* 2008). The application of organic amendment improved soil N, P and K concentrations when applied with inorganic fertilizers (Hao *et al.,* 2008) and the incorporation of organic manures improves soil physico-chemical properties that may have a direct or indirect effect on plant growth and yield attributes (Lima *et al.,* 2009).

The application of organic manure from different sources enhanced the soil porosity, soil moisture contents and water holding capacity (Papini *et al.,* 2011) and the influence of different levels (0, 50, 100, 250, 500, 750 and 1000g) of municipal solid waste compost promotes soil physical and chemical parameters were reported by Kasthuri *et al.* (2011). Jayakumar *et al.* (2011) reported that pH, organic carbon, available N, P and K content in soil was enriched by farmers practice with 40 % vermicompost prepared from 1:1 ratio of turkey litter and cow dung.

Organic manure increases soil aggregation, aeration, water holding capacity and supply roots with an extended source of nutrients (Rani and Nishana, 2012) and the soil

fertility is influenced by individual and combination of rhizobium and phosphate solubilizing bacteria in chickpea genotypes (Tagore *et al.,* 2013). Soil organic matter, total N, alkaline N, available P, available K, pH and bulk density as influenced by effective microorganisms compost and traditional compost (Hu and Qi, 2013b).

Bhuvaneshwari and Kumar (2013) reported that the incubation of Azolla into the soil leads to an increase in the soil pH, organic matter, nitrogen, phosphorus and potassium level and the application of municipal solid waste compost can significantly improves soil physicochemical properties, increase soil nutrients and enhance soil fertility, thereby promoting plant growth (Papafilippaki *et al.,* 2015). Muhmood *et al.* (2015) recommended a dose of nitrogen, fresh and dry bio-slurry, farmyard manure and inorganic fertilizer to improve the post harvest soil of carrot and okra.

Thilagar *et al.* (2016) chemical properties of soil as influenced by 100% NPK and 50% NPK with microbial consortium in field trial of chilly was analyzed on 140 days after transplanting and concluded that maximum soil nitrogen (266 kg/ha) and phosphorus (47 kg/ha) found in 50% NPK with microbial consortium. Schoebitz *et al.* (2016) studied the chemical and physical soil properties of blueberry seedlings in response to the addition of microbial consortium and humic acids. Ravimycin (2016) studied the nutrient contents (pH, EC, organic carbon, N, P, K, Ca, Mg, Fe, Zn, Cu, Mn and boron) of vermicompost, farmyard manure and soil.

Said-Al Ahl *et al.* (2016) experimented the physical and chemical properties of soil in two different seasons (2010-2011 and 2011-2012) in two different locations (Giza and Sinai) in Egypt and concluded that maximum value of EC, nitrogen and potassium content was found in 1st season of Giza and Sinai. The efficacy of organic manure and inorganic fertilizers improves the available NPK (124.85, 15.85 & 176.05 kg ha^{-1}) in the soil after the harvest of okra and onion cropping system (Jat *et al.,* 2017). Mahmood *et al.* (2017) reported the soil total organic carbon, total N, P and K contents were increased when inorganic fertilizer was applied alone or combination with organic manure.

Lal *et al.* (2017) studied the effect of organic madules (M1, M2 and M3) and varieties (V1 and V2) enhanced the organic carbon, nitrogen, phosphorus and potassium level of soil after four cycles of fenugreek crop and the available K (219 mg/l soil extract),

available P (65.6 mg/l soil extract), total N (0.168%) and organic carbon (1.08%) of pre-harvest soil of fenugreek plant was studied by Alaghemand *et al.* (2017). Khati *et al.* (2018) reported that the application of 50 mg L^{-1} of nanozeolite improved soil health under maize cultivation.

Srivastava *et al.* (2018) reported that the physico-chemical properties of different levels (20%, 40%, 60%, 80% and 100%) of municipal solid waste vermicompost amended soil and unamended soil and the application of nitrogen not only increase the growth and fruit yield but also improves soil characters due to soil fauna and flora (Fazeel *et al.,* 2019). Soil nutrients status after harvest of fennel varieties under organic production system was improving the level of nitrogen, phosphorus and potassium (Lal *et al.,* 2019).

Sikder and Joardar (2019) studied the different concentrations of poultry litter (PL) and poultry litter biochar (PLB) on the nutrient status of post-harvest soil of Gima kalmi (*Ipomoea aquatica*) and concluded that 10 t/ha and 4 t/ha of poultry litter (PL) and poultry litter biochar (PLB) increased the N, P and K content and the effect of agro-industrial waste compost increased the soil physicochemical quality, soil microbial population of onion (*Allium cepa* L.) under field condition was reported by Erana *et al.* (2019).

Christophe *et al.* (2019) reported that, the physicochemical parameters of before and after inoculation of different levels of poultry manure, cow manure, goat manure compost and the mixture of fertilizer with 0.8 kg of soil and the integrated application of biochar, compost, fruit and vegetable waste with *Bacillus subtilis* enhanced the soil EC, pH, nitrogen, phosphorus, potassium and carbon level under pot trial of okra (Anwar *et al.,* 2021). Cheng *et al.* (2023) reported that combined application of biochar and compost improves the soil pH, soil organic carbon, total nitrogen, available phosphorus, and potassium concentration.