Review Article

Understanding of Organic fertilizersinIndian context:AReview

Abstract:

Today, Indian farmers have access to a wide variety of organic fertilizers. These fertilizers serve many agronomic purposes, including providing plant nutrition, controlling pests and diseases, and managing soil health. The most common organic fertilizers in India are compost, compost tea, earthworms, humus, meal blood and bone meal (MBBM), fish hydrolysate, seaweed extract, bio-inoculants, biomass and biochar. Many organic fertilizers contain nutrients in their organic molecular structure. These nutrients are not available to plants when they are mineralized in the first place. When the organic fertilizer is consumed by the microorganisms, minerals are released to stimulate the soil microbial activity. Providing organic fertilizers such as biomass, humus and seaweed extract can stimulate plant growth and development through the action of plant growth hormones such as cytokinins, auxins and gibberellins.However, despite these advantages, the use of organic fertilizers remains low in India. This is due to the high application rates required to produce agricultural crops, the lack of uniformity in the composition of some crops, and the lack of public awareness of these products' benefits.There is still a lack of significant scientific research on the agricultural potential of organic fertilizers.

keywords: Organic fertilizers, Plant nutrients, Compost, un-composted organic and vermicompost.

Introduction:

In India, many numbers of organic fertilizers are sold to farmers, but there is little scientific evaluation of their effectiveness in large-scale agriculture. Because these products are derived from natural organic ingredients, many are certified for use in organic farming systems. However, due to various factors, many of these organics remain invalid

Sources of organic matter used to make organic fertilizers include compostable and non-compostable waste from agricultural, industrial and municipal activities, seaweed, blood and bone meal, and humus (Curnoe et al.,2006; Nasti et al., 2006; Sivashankari et al., 2006;Hangreaves et al., 2008b; Mondini et al., 2008). Microorganisms are also used to improve plant performance and soil health (Flieabach et al., 2009), while earthworms are a key component of some organic fertilizers (Gutierrez-Miceli et al., 2007).

Nowadays, some organic fertilizers are used in horticulture and agricultural systems; in the past, many organic fertilizers were used in other agricultural systems. Synthetic fertilizers gained widespread use in developed countries duringthe first half of the 20thcentury and in developing countries during the early 21stcentury (Ghosh 2004). People relied on organic fertilizers to maintain soil fertility and crop yieldsas well asto control agricultural pests and diseases. Most fertilizer manufacturers report that the benefits of applying one or more synthetic inputs include increasing plant growth and yield by providing plant nutrients, controlling pests and diseases, increasing efficiency and improving the health of the soil. Despite the claims of the manufacturers and the few studies that show the possible effects of using organic fertilizers (Mondini et al., 2008). But little scientific research has been conducted on the use of this product in agricultural systems.

In India, there are many commercially available products that can be classified as organic fertilizers. Many of these stem from early human efforts to manage land for agriculture (Semple, 1928). However, since the beginning of the last century, the use of organic fertilizers has been largely restricted to intensive horticulture and organic farming systems. This is possible with the emergence of integrated improvements in agricultural systems. The transition from organic to synthetic inputs in European agricultural systems occurred from 1870 to 1914 due to falling prices and increasing synthetic inputs, as well as pressure from farmers to increase yields per hectare (Van Zanden, 1991). This period of agricultural change has been called "the first 'Green Revolution'" (Van Zanden, 1991). Since then, the use of synthetic fertilizers has increased dramatically (McGregor and Shepherd, 2000), and the use of organic fertilizers has declined. As a result of these changes, there is a general perception in society that the use of organic fertilizers has become part of organic or alternative farming systems, and has little or no practical use. Below we explain the different types of organic fertilizers available in India, including the basic materials and typical amendments as well as the benefits they claim for their application.

Compostedorganicmatter

Compost consists of biologically synthesized oxidative processes that lead to the formation of moisture, thereby increasing the stability and efficiency of very different organic materials for agriculture and horticulture (Hargreaves et al., 2008b). It has been used for centuries in agriculture worldwide (Chan et al., 2007a). For example, farmers in the Mediterranean region were composting animal waste as early as 800 BC, when the application of this organic fertilizer to agricultural land was thought to be beneficial for plant growth in later periods (Semple, 1928). Compost for agronomic purposes is made from plant residues, organic materials from urban and industrial wastes, and manure from animal production systems such as feedlots. Although the composition varies, organic manures generally serve as a source of macro and micronutrients for plants and add carbon to the soil (Monaco et al., 2008). These changes can also improve the structural conditions and increase the microbial biomass in the soil (Gopinath et al., 2008).

When compost is used in agriculture, the application rate is 2-30 t/ha, but in agricultural systems the application rate is more than 30 t/ha. Compost is often spread on the soil surface and then incorporated into the top-soil to improve soil texture and provide nutrients for plants (Eghball and Power 1999). Some farmers and growers produce their own compost, but there are also many commercially produced compost products in India. Problems and risks associated with composting and application include the contamination of grass seeds, heavy metals, salts and pathogens, as well as different compositions (Hargreaves et al., 2008b). Although the use of compost produced from municipal waste and biomass is increasing, there is still concern that these compost materials contain heavy metals and salt residues (Hargreaves et al., 2008b). Of all composts, compost from animal waste poses the greatest risk to beneficial weed seeds; composting reduces the risk but does not eliminate it (Larney and Blackshaw, 2003).

Composttea/extract

Compost tea or extract is a liquid organic fertilizer that is used as a source of macro and micro nutrients for plants, as a carrier for beneficial microorganisms, and to control pests and diseases (Hargreaves et al., 2009a, 2009b). Making compost tea involves steeping the compost in water for a long time, often with other ingredients added to the mix such as seaweed extract, fish compost or molasses. The resulting water is applied as a foliar spray or soil wash at a rate of 50 to > 1000 L/ha, and is used to completely cover the plant's foliage when used for pest control. Compost tea does not contain a lot of plant macro or micro nutrients. However, this material can be useful as a source of nutrients when given in high doses (eg: 1000 litres/ha). The researchers investigated the potential of compost tea made from a variety of compost sources, including municipal solid waste.

Vermicasts:

Vermicomposting is a method of composting organic matter using earthworms to decompose organic matter. When earthworms digest organic matter, they produce worms or maggots (Padmavathiamma et al., 2008). This natural process has been commercially adapted to produce compost from municipal and industrial waste (Campitelli and Ceppi, 2008) and animal and plant waste (Padmavatiamma et al.,2008). Organic fertilizers were made of solid earthworms, vermicompost and liquid earthworm extract. These crops are a source of macro- and microbial growth as well as moisture and micro-organisms that inhabit the earthworm nest (Sinha et al., 2010). Manufacturers of earthworm products recommend 10-100 litres/ha for liquid amendments and 2-50 t/ha for solid amendments.

Humicsubstances

Humus occurs naturally in soil and water and is formed during the decomposition of organic matter (Hayes and Clapp, 2001; Smidt et al., 2008). Due to the diversity of humic substances, the definition is controversial (Hayes and Clapp, 2001), but they can be divided into three main categories: humic acids, fulvic acids, and humins. The nature of this group is that it is soluble in solutions of strong acids and bases. Fulvic acid is soluble at all pH values, humic acid is soluble only in strong acids, and humin is insoluble at all pH values (Hayes and Clapp, 2001).

Commercially, humus is extracted from materials such as compost and vermicompost, charcoal and peat. Humus is extracted from weathered lignite to produce organic fertilizers (Brownell et al., 1987). Humic acid fertilizers are available in both liquid and solid suspension forms; liquid suspensions are usually mixed with water and applied to the soil or plant foliage, whereas solid granular products are spread and incorporated into the soil or mixed with synthetic materials before mixing. Manufacturer application rates for liquid products are typically 1 to 30 liters/ha as a foliar spray or soil drench, while granular humus can be applied at rates of 25 to >400 kg/ha.

Meat,blood,andbonemeal

Around 700 BC, Greek and Roman farmers noticed that when large numbers of dead were left on the battlefield, crops increased in the following season (Semple, 1928). Today, meat, blood and bone meal (MBBM), a by-product of the food processing industry, is widely used as a fertilizer and other feed source for livestock. The outbreak of mad cow disease in Europe in the late 1990s, and its subsequent emergence in other parts of the world, led many countries to ban the feeding of MBBM to livestock (Mondini et al., 2008). Therefore, MBBM products are also receiving attention as organic fertilizers for soil crops. MBBM products are usually sold in solid form (pellets or pellets) and are spread over the soil and incorporated. Although to a lesser extent, liquid MBBM products can also be used as soil conditioners through fertilization or foliar spraying. MBBM products are used as an important source of plant nutrients (Mondini et al., 2008), for the control of pests and diseases in the soil (Tenuta and Lazarovits, 2004), and as an input for the rehabilitation of contaminated soil (Hodson et al., 2001).

The nutrients in MBBM are found in fats and proteins, and when these compounds are mineralized in the soil, they become available to plants (Cayuela et al., 2008b). Manufacturers claim that MBBM is a source of nitrogen (N), and this claim is supported by the findings of Mondini et al., (2008) and Cayuela et al., (2009). Manufacturers of solid MBBM products recommend a use rate of 0.1-1 t/ha, while liquid forms recommend a use rate of 30 liters/ha. Researchers found that the best response rates of the plant usually reached 0.5 t/ha (Jeng et al., 2006).

Fishhydrolysates:

Until the early 1800s, by-products from the fishery industry were often used to increase soil fertility in coastal areas of Europe and the United States (Fussell and Goodman, 1941). Currently, bio-degradates are produced by distillation or enzymatic digestion of by-products of the fish processing industry, such as tuna and mackerel (Andarwulan and Shetty, 1999). Taking wild fish from waterways and subsequent processing is another production method in India. Manufacturers recommended application methods for fish hydrolysate, which include spraying, foliar spraying, and soil drenching. Recommended rates for fish hydrolysate products are generally 10-30 litres/ha when used as a foliar spray and 20-60 litres/ha when used as a soil drench. The main benefit of hydrolysates is the addition of phytonutrients (Blatt, 1991), but hydrolysates are also used to increase plant resistance (Abbasi et al., 2003) and to increase germination and growth.

Seaweedextracts

In England, from the late 1800s to the 1900s, seaweed was collected from beaches, applied directly to farmland, burned or composted, often mixed with other chemical factors (Sherman, 1979). In the United States in the early 1900s, seaweed was harvested and burned to provide a source of potassium for agriculture (Cameron, 1913). No longer is raw seaweed processed or burned for processing, but seaweed extract is now found in the organic fertilizer market. Seaweed extracts are produced using seaweed species such as Ecklonia maxima and DurvillaeaPotrum (Stirk and van Staden, 1996), often with extracts designed to enhance more than the levels of enzymes and hormones in the final liquid product. Therefore, seaweed extracts containing the growth hormone cytokinin are considered to improve plant performance (Sivasankari et al., 2006). Seaweed extract can be used as a foliar application at a dose of 0.5 to 5 liters/ha and as a soil conditioner at a dose of 5 to 20 liters/ha.

Otheruncomposedorganicwastematerials

Although composting is often used to stabilize organic waste and reduce the variability of raw materials, many municipal, industrial and agricultural wastes are used or have been used as organic fertilizer. Olive waste and paper mill waste (Curnoe et al., 2006; Brunetti et al., 2007), sewage sludge and bio-solids (Pedra et al., 2007) and non-compostable animal waste (Liu et al., 2009) are used as amendments to improve soil conditions and planting practices. Industrial, agricultural and municipal solid waste materials are being used as raw materials for energy production through the pyrolysis process. However, some of these wastes are also used to produce biomass, biodiesel, and bio-ethanol, these products are also used as organic fertilizers (Moore et al., 2010). This includes waste from corn waste, corn, sugar beets, and other crop residues, as well as algal biomass used to produce biodiesel (Moore et al., 2010). These improvements can provide plant nutrients and organic matter to the soil, potentially improving soil health and plant growth (Moore et al., 2010).

Bio-inoculants

A bio-inoculant is an organic fertilizer that contains live microorganisms that are considered beneficial to agronomic or agricultural production systems. These products are mainly composed of microorganisms in water suspension, which include organisms such as arbuscular mycorrhizal fungi (Gianinazzi et al., 1995), Azospirillum (Okon and Itzigsohn, 1995) and Pseudomonas (Walsh et al., 2001), increasing crop yields by increasing the nutrients collected by plants and, removing nitrogen from the air. Although there is a lot of scientific literature on the effectiveness of microbial control in agricultural soils, the main focus is on microorganisms that form symbiotic relationships with plant roots, such as rhizobia removeatmospheric nitrogen in legume agroecosystems (Deaker et al., 2004) andarbuscular mycorrhiza (Parniske, 2008). There is little research in India on the potential of biomass, which involves introducing non-living microbes (species that do not interact directly with plant roots) into the soil to improve microbial diversity, nutrient cycling and soil health.

A series of biological digesters, called residue digesters, are used to increase the rate of decomposition of plant residues. These products were developed to meet the need for improved crop residue management practices as farmer's transition from conventional farming systems to reduced tillage and non-productive practices (Davis et al., 2008). Inoculations are usually applied by soil injection or spraying on the stump. The soil inoculation rate is 20-30 litres/ha, whiles 15-25 litres/ha is the recommended application rate for straw applications.

Biochar

Biochar or agricultural charcoal is basically a type of black carbon, produced by the slow pyrolysis of biomass, usually from the agricultural or forestry industry. Biochar manufacturers claim that it improves soil fertility, increases the efficiency of synthetic inputs, and increases soil carbon content. Research has shown that biochar can increase the efficiency of synthetic nitrogen fertilizers (Chan et al., 2007b; Steiner et al., 2007; Van Zwieten et al., 2010) and the potential for biological nitrogen fixation in rhizobia-legume systems (Rondon et al., 2007), and improve soil structural conditions (Chan et al., 2007b) and increase carbon content in soil (Lehmann et al., 2006). The energy produced during the pyrolysis of low-energy biomass is used to create biomass that can be used to generate electricity. However, despite its potential benefits, biochar is not widely used in India, due to the difficulty of producers in obtaining large quantities of biomass for the pyrolysis process, and changes in the availability of biomass in the meantime. The biochar application rate used in this study ranged from 10 to 140 t/ha.

Utilizationoforganic fertilizerasasourceofplantnutrients

Many organic fertilizers are produced to provide macro and micro nutrients for plants. Some of these nutrients are in pure form (Hargreaves et al., 2009a). However, unlike synthetic fertilizers, most of the nutrients are contained in organic molecular structures (e.g., amino acids) and are therefore not available for plant uptake (Jeng et al., 2006; Sudhanshu Verma et al., 2017). These nutrients become available when soil organic matter is mineralized, usually by microorganisms (Dilly, 2001; Cayuela et al., 2008b; Mondini et al., 2008).

Many studies show that organic fertilizers can provide nutrients to plants and maintain yields at the same level as inorganic fertilizers (Jeng et al., 2006; Mondini et al., 2008). Using MBBM as a nitrogen source, Jeng et al., (2006) found that wheat (*Triticum aestivum)* yields increased linearly with increasing application rates (500, 1000 and 2000 kg/ha), but barley (*Hordeum vulgare*) remained at the level of the bid rate. The Kurojiru, which is an organic fertilizer, has some positive effects on tomato growth in soil-less systems under the middle level of P (Murakami K et al., 2021)

Jeng et al., (2006) found an increase in plant-available phosphorus in soil amended with MBBM and concluded that an organic fertilizer application of 500 kg/ha can provide sufficient phosphorus for barley and ryegrass (*Loliumperenne*) for a long time. Padmavatiamma et al., (2008) reported that increasingrate of application of nitrogen and phosphorus available to plants in vermicompost by adding nitrogen-fixing microorganisms (Azatobacter, Azospirillum, and Rhizobium) during the vermicomposting process. The vermicompost contained higher levels of NH_4^+ and NO_3^-, and higher levels of phosphorus>1.5%, compared to 0.5% in conventionally processed products. A study conducted by Ghosh et al., (2008) found an increase in the concentration of available nitrogen and phosphorus in soil treated with 50 l/ha of vermicompost. They concluded that organic fertilizers stimulate microbial biological activity, thereby increasing nitrogen and phosphorus mineralization in the soil.

Industrial and municipal wastes can also provide nutrients for crop production. These wastes include paper factory waste (Curnoe et al., 2006), olive factory waste (Nastri et al., 2006;

Sierra et al., 2007), sewage sludge, biomass (Moritsuka et al., 2006; Chan et al., 2007a), municipal solid waste (Tognetti et al., 2007), a byproduct of biofuel production (Moore et al., 2010) and fly ash (Jala and Goyal, 2006) are used as organic fertilizers because of their high consumption. The use of municipal and industrial waste in organic fertilizers can offer recycling opportunities, increase the waste value and provide farmers with access to synthetic inputs.

Although Biochars do not provide a significant source of plant nutrients, they can increase the efficiency of synthetic fertilizers (Van Zwieten et al., 2010) and nitrogen-fixing capabilities of Rhizobium spp. in legume pasture and cropping systems (Rondon et al., 2007). Van Zwitten et al., (2010) reported that the addition of paper mill waste biochar and synthetic fertilizer increased plant biomass, an effect not seen if only synthetic fertilizer was used. They also found that this effect was more pronounced in alkaline soils than in slightly alkaline soils, and attributed it to the lime strength of the biochar mill waste. The findings of Van Zwieten et al., (2010) showed that although biomass may not provide a significant source of plant nutrients, it can increase the nutrient uptake capacity of plants by having a positive effect on the soil environment. Since most organic fertilizers contain plant nutrients in the organic molecular framework and minerals first (Jeng et al., 2006; Mondini et al., 2008), many questions arise to this process thatmust be answered in order to use it well.

Currentlimitationstotheadoptionoforganic fertilizer andtheirfutureinIndia

The slow progress in the application of organic fertilizers in large-scale agriculture in India at present can be attributed to the following factors: Lack of scientific information on the agronomic effectiveness of organic fertilizers in this agricultural sector and the need for high levels of implementation. Organic fertilizers are relatively in-expensive, some of these products can maintain and improve agricultural soil health(Bulluck et al., 2002). Organic fertilizers can provide an alternative and renewable nutrient source and, in some cases, increase economic and resource efficiency for industry, governments and cities through reduction and recycling waste materials.

Although many studies investigating the use of organic fertilizers have focused on horticultural crops, there is still little scientific information on their use in general agriculture. Research in this area has been hampered by many factors since the late 19thcentury. Initially, the introduction of synthetic fertilizers and pesticides drove farmers away from using natural resources.According to Cassman et al., (2009) and Li et al., (2009)the Green Revolution in the mid-1900s introduced varieties of rice and wheat that were bred to produce high yields through the use of synthetic fertilizers (Khush, 1999).

This event reduced the need and demand for organic inputs in agriculture. The lack of scientific information on the application of organic fertilizers in large-scale agriculture may be due to the unstable composition of some crops and the high application rates required toachieve good results. According to Edmeades (2002), research results on the use of organic fertilizers vary widely, some of which are due to differences in product composition. Hargreaves et al., (2009b) applied urban waste compost to crops for two consecutive years, and the N-P-K concentrations of the crops changed from 18, 0.4 and 10 g/kg in the first year to 23, 6 and 6 g/kg in the second year. This variability presents a significant challenge for researchers trying to accurately predict the impact of organic fertilizer applications on different cropping systems. Lack of knowledge about the effectiveness of these seasonal adjustments may cause farmers to underuse these products.

The conflicting findings may be due to differences in soil conditions, soil water content, temperature, microbial species, mineral composition, pH, texture, and OC content have been shown to influence the yield of organic fertilizers (Varadachari et al., 1991; Engelking et al., 2007). In studies related to the use of organic fertilizers in relation to the soil, it is necessary to investigate deeply the environment of the soil in order to fully understand the relationships of these products with the environment. Estimated yields of some organic fertilizers in agricultural systems only meet application levels that may be considered uneconomical for field cultivation such as 5 t/ha MBBM proposed by Mondini et al., (2008), or the provision of 5500 L/ha of pig manure by Lazarovits et al., (2001). However, with practical and proper implementation, this number can be reduced. Technologies available in precision agriculture, such as variable fertilizer rates and soil injection methods, can reduce the amount of organic fertilizer needed per hectare. Some products, such as vermicompost, humus and seaweed extract, have been shown to be effective when applied at rates suitable for agricultural production in large areas.

Conclusion

Organic matter has been successfully used to maintain crop yields and soil health, and to control pests and agronomic diseases, supporting agriculture without dependence on fossil fuels and external inputs of current traditional agriculture (Pimentel et al., 2005). However, due to the increasing demand for food from the world's population, we conclude that organic fertilizers are unlikely to replace organic fertilizers or become more common than organic fertilizers. Pimentel et al., (2005) suggest that many types of organic products can be gradually integrated into modern agriculture to help improve and maintain those production systems.

Disclaimer (Artificial intelligence)
Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References:

1. Abbasi PA, Cupples DA, Lazarovits G (2003) Effects of foliar application ofneem oil and fish emulsion on bacterial spot and yield of tomatoes andpeppers.*CanadianJournalofPlantPathology***25**,41–48.doi:10.1080/07060660309507048

2. AndarwulanN,ShettyK(1999)Improvementofpea(*Pisumsativum*)seedvigourresponsebyfishproteinhydrolysatesincombinationwithacetylsalicylic acid. *Process Biochemistry* **35**, 159–165. doi:10.1016/S0032-9592(99)00047-3

3. Blatt CR (1991) Comparison of several organic amendments with a chemicalfertilizerforvegetableproduction.*ScientiaHorticulturae***47**,177–191.doi:10.1016/0304-4238(91)90001-F

4. BrownellJR,NordstromG,MarihartJ,JorgensenG(1987)Cropresponsesfromtwonewleonarditeextracts.*TheScienceoftheTotalEnvironment***62**,491–499.doi:10.1016/0048-9697(87)90544-4

5. Brunetti G, Senesi N, Plaza C (2007) Effects of amendment with treated anduntreated oliveoilmillwastewatersonsoilproperties,soilhumicsubstances and wheat yield. *Geoderma***138**, 144–152. doi:10.1016/j.geoderma.2006.11.003

6. Bulluck LR, Brosius M, Evanylo GK, Ristaino JB (2002) Organic andsynthetic fertility amendments influence soil microbial, physical andchemical properties on organic and conventional farms. *Applied SoilEcology***19**,147–160.doi:10.1016/S0929-1393(01)00187-1

7. CameronFK(1913)Kelpandothersourcesofpotash.*JournaloftheFranklinInstitute***176**,347–383.doi:10.1016/S0016-0032(13)90379-3

8. Campitelli P, Ceppi S (2008) Chemical, physical and biological compostand vermicompost characterization: a chemometric study. *ChemometricsandIntelligentLaboratorySystems***90**,64–71.doi:10.1016/j.chemolab.2007.08.001

9. Cassman KG, Dobermann A, Walters DT (2009) Agroecosystems, nitrogen-use efficiency,

and nitrogen management. *AMBIO: A Journal of theHumanEnvironment***31**,132–140.

10. Cayuela ML, Sinicco T, Fornasier F, Sanchez-Monedero MA, Mondini C(2008*b*) Carbon mineralization dynamics in soils amended with meatmeals under laboratory conditions. *Waste Management* **28**, 707–715.doi:10.1016/j.wasman.2007.09.028

11. Cayuela ML, Sinicco T, Mondini C (2009) Mineralization dynamics andbiochemicalpropertiesduringinitialdecompositionofplantandanimalresiduesinsoil.*AppliedSoilEcology***41**,118–127.doi:10.1016/j.apsoil.2008.10.001

12. Chan KY, Dorahy C, Tyler S (2007a) determining the agronomic value of composts produced from gardenorganicsfrommetropolitanareasofNewSouthWales,India.*IndianJournalofExperimentalAgriculture***47**,1377–1382.doi:10.1071/EA06128

13. ChanKY,vanZwietenL,MeszarosI,DownieA,JosephS(2007*b*)Agronomicvaluesofgreenwastebiocharasasoilamendment.*Indian Journal of Soil Research* **45**, 629–634. doi:10.1071/SR07109

14. CurnoeWE,IrvingDC,DowCB,VelemaG,UncA(2006)Effectofspringapplication of a paper mill soil conditioner on corn yield. *AgronomyJournal***98**,423–429.doi:10.2134/agronj2005.0041

15. Davis RA, Huggins D, Cook RJ, Paulitz TC (2008) Can placement of seedaway from relic stubble limit Rhizoctonia root rot in direct-seededwheat? *Soil & Tillage Research* **101**, 37–43. doi:10.1016/j.still.2008.05.014

16. Deaker R, Roughley RJ, Kennedy IR (2004) Legume seed inoculationtechnology – a review. *Soil Biology & Biochemistry* **36**, 1275–1288.

17. DillyO(2001)Microbialrespiratoryquotientduringbasalmetabolismandafterglucoseamendmentinsoilsandlitter.*SoilBiology&Biochemistry***33**,117–127.doi:10.1016/S0038-0717(00)00123-1

18. EdmeadesDC(2002)Theeffectsofliquidfertilisersderivedfromnatural products on crop, pasture, and animal production: a review.*IndianJournalofAgriculturalResearch***53**,965–976.doi:10.1071/AR01176

19. EghballB,PowerJF(1999)Compostedandnoncompostedmanureapplicationtoconventionalandno-tillagesystems:cornyieldandnitrogen uptake. *Agronomy Journal* **91**, 819–825. doi:10.2134/agronj1999.915819x

20. El-TarabilyKA,NassarAH,HardyGESJ,SivasithamparamK(2003)Fishemulsion as a food base for rhizobacteria promoting growth of radish(*Raphanus sativus* L. var. *sativus*) in a sandy soil. *Plant and Soil* **252**,397–411.doi:10.1023/A:1024729620154

21. Engelking B, Flessa H, Joergensen RG (2007) Shifts in amino sugar andergosterol contents after addition of sucrose and cellulose to soil. *SoilBiology&Biochemistry***39**,2111–2118.doi:10.1016/j.soilbio.2007.03.020

22. Fließbach A, Winkler M, Lutz M, Oberholzer H-R, Mäder P (2009) Soilamendment with *Pseudomonas fluorescens* CHA0: lasting effects onsoilbiologicalpropertiesinsoilslowinmicrobialbiomassandactivity.*MicrobialEcology***57**,611–623.doi:10.1007/s00248-009-9489-9

23. Fussell GE, Goodman C (1941) Crop husbandry in eighteenth centuryEngland:Part1.*AgriculturalHistory***15**,202–216.

24. GhoshN(2004)Reducingdependenceonchemicalfertilizersanditsfinancial implications for farmers in India. *Ecological Economics* **49**,149–162.doi:10.1016/j.ecolecon.2004.03.016

25. Ghosh S, Hulugalle N, Lockwood P, King K, Kristiansen P, Daniel H (2008)Organicamendmentsinfluencenutrientavailabilityandcottonproductivity in irrigated Vertosols. *Indian Journal of AgriculturalResearch***59**,1068–1074.doi:10.1071/AR08141

26. GianinazziS,TrouvelotA,LovatoP,vanTuinenD,FrankenP,Gianinazzi-Pearson V (1995) Arbuscular mycorrhizal fungi in plant production oftemperateagroecosystems.*CriticalReviewsinBiotechnology***15**,305–311.doi:10.3109/07388559509147416

27. GopinathK,SahaS,MinaB,PandeH,KunduS,GuptaH(2008)Influenceof organic amendments on growth, yield and quality of wheat and on soilproperties during transition to organic production. *Nutrient Cycling inAgroecosystems***82**,51–60.doi:10.1007/s10705-008-9168-0

28. Gutierrez-Miceli FA, Santiago-Borraz J, Montes Molina JA, Nafate CC,Abud-Archila M, Oliva Llaven MA, Rincon-Rosales R, Dendooven L(2007) Vermicompost as a soil supplement to improve growth, yieldand fruit quality of tomato (*Lycopersicumesculentum*). *BioresourceTechnology***98**,2781–2786.doi:10.1016/j.biortech.2006.02.032

29. Hargreaves JC, Adl MS, Warman PR (2008*b*) A review of the use ofcomposted municipal solid waste in agriculture. *Agriculture, Ecosystems&Environment***123**,1–14.doi:10.1016/j.agee.2007.07.004

30. HargreavesJC,AdlMS,WarmanPR(2009*a*)Arecompostteasaneffectivenutrient amendment in the cultivation of strawberries? Soil and planttissue effects. *Journal of the Science of Food and Agriculture* **89**,390–397.doi:10.1002/jsfa.3456

31. HargreavesJC,AdlMS,WarmanPR(2009*b*)Theeffectofmunicipalsolidwastecompostandcompostteaonmineralelementuptakeandfruit quality of strawberries. *Compost Science & Utilization* **17**, 85–94.

32. HayesMHB,ClappCE(2001)Humicsubstances:considerationsofcompositions, aspects of structure, and environmental influences. *SoilScience***166**,723–737.doi:10.1097/00010694-200111000-00002

33. HodsonME,Valsami-JonesE,Cotter-HowellsJD,DubbinWE,KempAJ,Thornton I, Warren A (2001) Effect of bone meal (calcium phosphate)amendments on metal release from contaminated soils – a leachingcolumn study. *Environmental Pollution* **112**, 233–243. doi:10.1016/S0269-7491(00)00116-0

34. Jala S, Goyal D (2006) Fly ash as a soil ameliorant for improving cropproduction–areview.*BioresourceTechnology***97**,1136–1147.doi:10.1016/j.biortech.2004.09.004

35. Jeng A, Haraldsen T, Grønlund A, Pedersen P (2006) Meat and bone meal asnitrogen and phosphorus fertilizer to cereals and rye grass. *NutrientCyclinginAgroecosystems***76**,183–191.doi:10.1007/s10705-005-5170-y

36. KhushGS(1999)Greenrevolution:preparingforthe21stcentury.*Genome* **42**,646–655.doi: 10. 1139/gen-42-4-646

37. Larney FJ, Blackshaw RE (2003) Weed seed viability in composted beefcattle feedlot manure. *Journal of Environmental Quality* **32**, 1105–1113.doi:10.2134/jeq2003.1105

38. LazarovitsG,TenutaM,ConnKL(2001)Organicamendmentsasadiseasecontrol strategy for soilborne diseases of high-value agricultural crops.*AustralasianPlantPathology***30**,111–117.doi:10.1071/AP01009

39. Lehmann J (2007) Bio-energy in the black. *Frontiers in Ecology and theEnvironment* **5**, 381–387. doi:10.1890/1540-9295(2007)5[381:BITB]2.0.CO;2

40. LehmannJ,GauntJ,RondonM(2006)Bio-charsequestrationinterrestrialecosystems–areview.*MitigationandAdaptationStrategiesforGlobalChange***11**,395–419.doi:10.1007/s11027-005-9006-5

41. LiuM,HuF,ChenX,HuangQ,JiaoJ,ZhangB,LiH(2009)Organic amendments with reduced chemical fertilizer promote soilmicrobial development and nutrient availability in a subtropical paddyfield: the influence of quantity, type and application time of organicamendments. *Applied Soil Ecology* **42**, 166–175. doi:10.1016/j.apsoil.2009.03.006

42. McGregorAC,ShepherdJF(2000)FertilizationpracticesinPacificNorthwestwheat-producingareas.*AgriculturalHistory***74**,433–450

43. Moore AD, Alva AK, Collins HP, Boydston RA (2010) Mineralization ofnitrogen frombiofuelby-productsandanimalmanuresamended toa sandy soil. *Communications in Soil Science and Plant Analysis* **41**,1315–1326.doi:10.1080/00103621003759320

44. Monaco S, Hatch DJ, Sacco D, Bertora C, Grignani C (2008) Changes inchemical and biochemical soil properties induced by 11-year repeatedadditions of different organic materials in maize-based forage systems.*Soil Biology & Biochemistry* **40**, 608–615. doi:10.1016/j.soilbio.2007.09.015

45. MondiniC,CayuelaML,SiniccoT,Sanchez-MonederoMA,BertoloneE,Bardi L (2008) Soil application of meat and bone meal. Short-termeffectsonmineralizationdynamicsandsoilbiochemicalandmicrobiological properties. *Soil Biology & Biochemistry* **40**, 462–474.doi:10.1016/j.soilbio.2007.09.010

46. Moritsuka N, Matsuoka K, Matsumoto S, Masunaga T, Matsui K, WakatsukiT (2006) Effects of the application of heated sewage sludge on soilnutrientsupplytoplants.*SoilScienceandPlantNutrition***52**,528–539.doi:10.1111/j.1747-0765.2006.00062.x

47. Murakami K, Cruz AF, Ramos MDF, Yamanishi OK, S date. (2021) Effect of Organic Fertilizer on Tomato Growth and Production under Soil-less System. Asian J. Agric. Hortic. Res. 8(3):37-50.

48. Nastri A, Ramieri NA, Abdayem R, Piccaglia R, Marzadori C, Ciavatta C(2006) Olive pulp and its effluents suitability for soil amendment.*Journal of Hazardous Materials* **138**, 211–217. doi:10.1016/j.jhazmat.2006.05.108

49. OkonY,ItzigsohnR(1995)ThedevelopmentofAzospirillumasacommercialinoculantforimprovingcropyields.*BiotechnologyAdvances***13**,415–424.doi:10.1016/0734-9750(95)02004-M

50. Padmavathiamma PK, Li LY, Kumari UR (2008) An experimental studyofvermi-biowastecompostingforagriculturalsoilimprovement.*BioresourceTechnology***99**,1672–1681.doi:10.1016/j.biortech.2007.04.028

51. ParniskeM(2008)Arbuscularmycorrhiza:themotherofplantrootendosymbioses. *Nature Reviews Microbiology* **6**, 763–775. doi:10.1038/nrmicro1987

52. PedraF,PoloA,RibeiroA,DominguesH(2007)Effectsofmunicipalsolidwaste compost and sewage sludge on mineralization of soil organicmatter.*SoilBiology&Biochemistry***39**,1375–1382.doi:10.1016/j.soilbio.2006.12.014

53. PimentelD,HepperlyP,HansonJ,DoudsD,SeidelR(2005)Environmental, energetic and economic comparisons of organic andconventional farming systems. *Bioscience* **55**, 573–582. doi:10.1641/0006-3568(2005)055[0573:EEAECO]2.0.CO;2

54. Rondon M, Lehmann J, Ramírez J, Hurtado M (2007) Biological nitrogenfixation by common beans (*Phaseolus vulgaris* L.) increases with bio-charadditions.*BiologyandFertilityofSoils***43**,699–708.doi:10.1007/s00374-006-0152-z

55. RotenbergD,CooperbandL,StoneA(2005)Dynamicrelationshipsbetweensoilpropertiesandfoliardiseaseasaffectedbyannualadditions of organic amendment to a sandy-soil vegetable productionsystem.*SoilBiology&Biochemistry***37**,1343–1357.doi:10.1016/j.soilbio.2004.12.006

56. Semple EC (1928) Ancient Mediterranean agriculture: Part II. Manuring andseedselection.*AgriculturalHistory***2**,129–156.

57. ShawG(2005)'Soilhealthissuesfor Indiancottonproduction.Growers'perspective.'CottonResearchandDevelopmentCorporation,andCottonCatchmentCommunitiesCooperativeResearchCentre.(CottonResearchandDevelopmentCorporation:Narrabri)

58. ShermanRB(1979)DanielWebster,gentlemanfarmer.*AgriculturalHistory***53**,475–487.

59. Sierra J, Marti E, Garau MA, Cruanas R (2007) Effects of the agronomic useof olive oil mill wastewater: field experiment. *The Science of the TotalEnvironment***378**,90–94.doi:10.1016/j.scitotenv.2007.01.009

60. SinhaRK,HeratS,BharambeG,BrahambhattA(2010)Vermistabilizationof sewage sludge (biosolids) by earthworms: converting a potentialbiohazard destined for landfill disposal into a pathogen-free, nutritiveand safe biofertilizer for farms. *Waste Management & Research* **28**,872–881.

61. Sivasankari S, Venkatesalu V, Anantharaj M, Chandrasekaran M (2006)Effect of seaweed extracts on the growth and biochemical constituentsof *Vigna sinensis. Bioresource Technology* **97**, 1745–1751. doi:10.1016/j.biortech.2005.06.016

62. Smidt E, Meissl K, Schmutzer M, Hinterstoisser B (2008) Co-composting oflignintobuilduphumicsubstances–strategiesinwastemanagementtoimprove compost quality. *Industrial Crops and Products* **27**, 196–201.doi:10.1016/j.indcrop.2007.07.007

63. SpadaroD,GullinoML(2005)Improvingtheefficacyofbiocontrolagentsagainst soilborne pathogens. *Crop Protection* **24**, 601–613. doi:10.1016/j.cropro.2004.11.003

64. SteinerC,TeixeiraW,LehmannJ,NehlsT,deMacêdoJ,BlumW,ZechW(2007) Long term effects of manure, charcoal and mineral fertilization oncropproductionandfertilityona highlyweatheredCentralAmazonianupland soil. *Plant and Soil* **291**, 275–290. doi:10.1007/s11104-007-9193-9

65. Stirk W, van Staden J (1996) Comparison of cytokinin- and auxin-likeactivity in some commercially used seaweed extracts. *Journal of AppliedPhycology***8**,503–508.doi:10.1007/BF02186328

66. Sudhanshu Verma, Abhishek Singh, Swati Swayamprabha Pradhan, R.K.Singh and Singh J.P (2007) Bio efficacy of organic formulations on crop Production- A Review. Int. J.Curr.Microbiol.App.Sci. 6(5). Doi: https://doi.org/10.20546/ijcmas.2017.605.075

67. TenutaM,LazarovitsG(2004)Soilpropertiesassociatedwiththevariableeffectiveness of meat and bone meal to kill microsclerotia of *Verticilliumdahliae*. *Applied Soil Ecology* **25**, 219–236. doi:10.1016/j.apsoil.2003.09.007

68. TognettiC,MazzarinoMJ,LaosF(2007)Improvingthequalityofmunicipalorganicwastecompost.*BioresourceTechnology***98**,1067–1076.doi:10.1016/j.biortech.2006.04.025

69. van Zanden JL (1991) The first green revolution: the growth of productionand productivity in European agriculture, 1870–1914. *The EconomicHistoryReview***44**,215–239.doi:10.2307/2598294

70. Van Zwieten L, Kimber S, Morris S, Chan K, Downie A, Rust J, Joseph S,Cowie A (2010) Effects of biochar from slow pyrolysis of papermillwaste on agronomic performance and soil fertility. *Plant and Soil* **327**,235–246.doi:10.1007/s11104-009-0050-x

71. Varadachari C, Mondal AH, Ghosh K (1991) Some aspects of clay-humuscomplexation: effect of exchangeable cations and lattice charge. *SoilScience***151**,220–227.doi:10.1097/00010694-199103000-00004

72. Walsh UF, Morrissey JP, O'Gara F (2001) Pseudomonas for biocontrol ofphytopathogens:fromfunctionalgenomicstocommercialexploitation.*Current Opinion in Biotechnology* **12**, 289–295. doi:10.1016/S0958-1669(00)00212-3