Review Article

# Potential Role of Arbuscular Mycorrizhal Fungi (AMF) and Vermicompost (VC) on the Maturation of Agriculture Crops - A Review

**P.V. Sivakumar[1], K. Palanisamy[2], M. Lenin[3*]**

*[1]Department of Botany, Thiru kollanjiappar Govt. Arts College, Virudhachalam-1, Tamilnadu, India; [2]PG & Research Department of Botany Arignar Anna Govt. Arts College, Namakkal-2. Tamilnadu, India; [3]PG & Research Department of Botany, Government Arts College, Dharmapuri-5. Tamilnadu, India.*

**Abstract** | Agriculture is the method of plant interaction with microorganisms. There is a growing need for an eco-friendly, eco-responsive system in agriculture that can provide adequate nutrients to the growing human population by improving the quality and quantity of agricultural manufacture. Plant Growth-Promoting Microorganisms (PGPMs) have the potential to inhibit the rhizosphere and are at the center of microbial inoculations to regulate risk of rooting. The decomposition of organic matter by earthworms by vermicompost (VC) is known as cheap and environmentally friendly process. It is a substantial provenance of essential nutrients, which bounce back the overall soil condition and stimulate the yield and development of plants that enhance the physical and chemical properties of the soil. . For this vindication the blear of this review is on the momentary of soil symbiotic fungi like Arbuscular Mycorrhizal Fungi (AMF) and Vermicompost (VC), and their precious repercussions on plant maturation. An extensive outline of profuse details of the conservation process is of extraordinary consequence for crops maturation in cultivations.

**Keywords:** PGPMs, AMF, VC, Plant maturation.

**Received** | December 29, 2019 **Accepted** | May 23, 2020; **Published** | August 05, 2020
***Correspondence** | M Lenin, PG & Research Department of Botany, Government Arts College, Dharmapuri-5. Tamilnadu, India; **Email:** leninreegan@gmail.com
**Citation** | Sivakumar PV, Palanisamy K, Lenin M (2020). Potential role of arbuscular mycorrizhal fungi (amf) and vermicompost (vc) on the maturation of agriculture crops - a review. S. Asian J. Life Sci. 8(2): 24-37.
**DOI** | http://dx.doi.org/10.17582/journal.sajls/2020/8.2.24.37
**ISSN** | 2311–0589



## INTRODUCTION

The Green Revolution (GR) resulted in an increase in the mass-production. Growth of mechanized agriculture, that relied on the use of plant grains and produce, chemical high yielding varieties respond to high levels of chemical fertilizers, which are slow yield stagnation, soil degradation, environmental erosion and pollution, low soil organic carbon, low fertility, excess nutrient mining and disease, pest and weed risk. Agriculture is the most salient future contributing to India's economic development with 114 million hectares cultivated in India's geographical area of 329 million hectares (Raghuwanshi, 2012). In order to collect good harvest farmers inoculate the soil with fertilizers their chemicals are biofertilizers and in the last 150 years, heavy inputs of chemical fertilizers have rise the pollution of the soil, causing less productivity and severe health and environmental hazards. Soil an active living medium is a crucial part of the global ecosystem.

It is a beneficial resource not only for agricultural fabrication and food differentiation but also for maintaining most of the life process. Enlarge the competition and parasitism with the rhizosphere to provide some soil fertility factor for sustainable agriculture by controlling soil borne disease, including increment soil microbial activity (Dar et al., 2018). Progress has been made in exploring the use of microorganisms to refine soil fertility. Much emphasis is placed on the enhanced exploitation of indigenous soil microorganisms, which contribute to plant maturation and plant protection to intensification soil fertility. The soil organisms may contain more than 90% of the soil's biological activity and nutrient cycling,

soil fertility and the co-operative process in the rhizosphere. So far the fungal diversity and function of the soil is not fully understood (Navnita et al., 2015). Plant growth promoting microorganisms has a positive effect on the growing and yield of plants through biological nitrogen determination, vitamins building, growth product manufacture, supply of plants with available phosphorus, spiraling the amount of nutrients in the rhizosphere as bio-control agents (Berg, 2009; Tagore et al., 2013; Warwate et al., 2017; Zaferanchi et al., 2019).

Organic farming is a method of creation that avoids or often excludes the use of synthetic fertilizers. Where possible, the organic farming systems rely on bio-composting, while reduction is a major issue in the organic creation systems (Song et al., 2015; Mishra et al., 2018). Organic resources are promising due to local availability as a supply of many nutrients and have the potential to enhance maturation properties (Sivakumar et al., 2013). Plant nutrients in organic fertilizers, such as enzymes and hormones, are essential for promoting soil sprouting and productivity (Jat et al., 2010; Mishra, 2014).

The organic assets such as biogas slurry, hen manure, green fertilizer and Farmyard Manure (FYM) can replacement for inorganic fertilizers to sustain making and environmental eminence (Mhamdi et al., 2015; Kaur et al., 2017). Organic fertilizers are directly affected by plant growth and their positive effects on soil physicochemical and biological properties. Here are the main effects on getting nutrition. Many of the benefits have been documented due to organic fertilizers by (Prasanna et al., 2016; Igiehon et al., 2017; Mitra et al., 2019). Magnification the population of beneficial microorganisms and their functions in the decomposition of organic matter was testimony by (Bakry et al., 2013; Kowsar et al., 2014). Organic fertilizers have made an entry into the economy of Nitrogen content and long-term availability in the field (Pandian and Perumal, 2002; Zhong et al., 2010). Srivastava et al. (2007) said that the use of organic fertilizer not only acts as a source of $N_2$ and other source of nutrients but also addition of the efficiency of nitrogen used.

Nahum et al. (2007) details on the organic fertilizers naturally contain ($N_2$) and they are commonly added to other wastes to inflation nitrogen content and enter fertilizer with active biomass. Yang et al. (2004) investigated that the integration of excess of organic compost notably meliorated the uptake of N, P and K by rice plants and make possible the share and transfer of nutrient elements to the rice ears and grains.

## AMF in Plant Development

More than 80% of plant species are linked with AMF, along with vascular and non-vascular plants and some main crops such as carrots, maize, leek, coffee, cocoa, soybeans, apples, citrus fruits, tomatoes and pepper to point out a few (Posta et al., 2013; Robl et al., 2013; Bona et al., 2017). Because AMF is normally distributed in various parts of the world, especially in the tropic, little operational information is known about them until the mid1950s (Smith and Read, 1997; Cozzolino et al., 2013; Li et al., 2014). They are found in a variety of landscapes, such as limestone, meadows, dry/semi-arid grasslands with many temperate forests, tropical rainforests and shrub lands in various parts of the globe (Sedlacek et al., 2013; Navnita et al., 2015). These studies have focused on AMF diversity in different regions and soil types or on the AMF status of the original crop plant species (Hawley and Dames, 2004; Boumari et al., 2006; Mohammadi et al. 2011; Piliarova et al., 2019). When AMF species are isolated each time among the *Glomus* sp. and other species are *Acaulospora, Gigaspora* and *Scutellospora* found in some members, where other species are not present (Bonfante and Perotto, 2000; Uhlmann et al.,2006). Sailo and Bagyaraj (2005) observed that the level of development of varies with the AMF used by the biomass, *Glomus bagyarajj* was originated to be the most excellent AMF symbiont for inoculating *Coleus forskohlii,* after that behavior of *Scutellospora* and *Calospora*.

Inoculation of AMF has been recognized to enhance the germination of many plant species. This is credited with the boosting seedling growth (Karasawa et al., 2012). Multiplication of growth parameters due to AMF inoculation has been previously accounted in certain medicinal plants (Lima dos Santos et al., 2017). Perner et al. (2007) notes that in the case of three different commercial AMF inoculation, 28.2-36.4% of total root length was colonized, resulting in non- inoculated plants free root colonization. The role of AMF in the stimulation of sprouting and nutrient uptake of many host plants is well documented (Jeffries et al., 2003; Minaxi et al., 2013; Kim et al., 2017; Bianciotto et al., 2018; Khan et al., 2019). Fracchia *et al.* (2000) found that duel inoculation of *Glomus mosseae* or *G. deserticola* and *E. oxysporum* led to better maturation of plants. Likewise, combined inoculation of *Trichoderma aureoviride* and *G. mosseae* had a synergistic outcome on the growth of marigold plants (Calvet et al., 1993).

Haggag and Abd-El Latif (2001) establish that incorporate inoculation of *G. mosseae* and *T. harzianum* or *P. oxalium* better progress of sprout plants. Garcia-Garrido et al. (1998) noted that dual inoculation with *G. mosseae* and some strains of *Fusarium* sp. led to extent of growth in soybean plants. Ravansko et al. (2006) found that *Clonostachys rosea* and *G. intraradices* were reciprocally inhibitory, but encourage the plant growth with several changes in soil microbial communities. Mathur and Vyas (2000) mention that AMF provision of legume crops establish to multiply it's vegetative of blooming and seed yield in count to get better

nodulation on its root structure. Vaingankar and Rodrigues (2015) recounted that the inoculation with the *G. fasciculatum* enhanced *Crossandra infundibuliformis* development and enlarged its dry matter more than 2-fold compared with the non-inoculated and control treatments. Rabie and Al-Humiany (2004) and El-Azouni et al. (2008) designated that dual inoculation with *G. clarum* and *A. brasile* utilize be able to enhance the plant height, dry weight and shoot, root fraction in cowpea plants.

The special effects of AMF cooperative association on the maturation of plants are well known (Rajasekaran and Nagarajan, 2004). Arumugam et al. (2010) announced that inoculation either with AMF or *Rhizobium* extensively addition (29.7-38%) of the shoot and root length, dry weights of shoot and root, total number of nodules when compared to un-inoculated seedlings. Lenin et al. (2010) observed that AMF soaring plant uptake of nutrients and consequently enhancing (17.2-28.5%) of root, shoot biomass and developed the experimental plants. Khade and Rodrigues (2010) reported that *G. intraradices* and *G. mosseae* make headway the growth in leaf petiole in *Carica papaya*. Halder and Ray (2006), communicate that development of growth in AMF inoculated plants. Tahat et al. (2008) examined that reaction of tomato (*Lycopersicum esculentum* Mill.) to *G. mosseae,* they found that *G. mosseae* was (5.8%) of build up shoot dry weight and make a larger in root length.

Augmentation of soil with different positive microorganisms including AMF species assist plant maturation (Xavier and Germida, 2002; Khakpour and Khara. 2012). AMF may stimulate in advance flowering and stretch flower numbers (Gaur and Adholeya, 2005; Usha et al., 2005). These AMF are capable to assist for plentiful plant dry weights (Lee and George, 2005; Sivakumar, 2013; Mitra et al., 2019). AMF inoculation is stimulated widely the production of shoot biomass to a higher level than the addition of the amendment alone to soil or the mutual treatments (Xiuxiu et al., 2019).

Rajasekaran and Nagarajan (2004) reveal that AMF inoculation in mixture with phosphorus, inflating fresh and dry weights (8.2-13.7%) of shoot (2.2-4.7cm) and leaf area and leaf number of *Vigna unguiculata* (L). Germain et al. (2016) published that outstanding shoot dry weights (10.4-26.8%) hiking when *Theobroma cacao* was inoculated with AMF. The positive effects of these AMF and additional of organic manures have been reported by (Lesueur et al., 2001).

Sailo and Bagyaraj (2005) and (Xiuxiu et al., 2019) investigated that maximum (22.6 to 37.5) percentage of root length, shoot length, fresh weight, dry weight was observed in *Coleus* and cucumber seedlings inoculated with AMF. Gill et al. (2002) give that biomass of the plant expand by AMF infectivity. Hazarika et al. (2000) proclaim that on the dual inoculation of AMF and *Rhizobium* it stimulated the assembly of more than (40-50%) root nodules when inspected to control plants. Ortas (2012) informed that the AMF due to indirect effects of the host plants affected a similar inspection in the lower parts of the roots. Many biochemical and physical factors affect soil quality. it has been demonstrated that rhizosphere contributes to nutrient cycling among microbial communities and directly affects soil fertility through transport to the process needed to upgrade structure development of soil health (Wu et al., 2005; Miransari et al., 2007; St-Arnaud and Vujanovic 2007; Wu et al., 2014; Khan et al., 2019).

Symbiosis has been shown to greatly aid the growth of many field crops due to the development of a broad hyphal network that aims to make communities more of value and encompass hormonal manufacture of nutrient availability and root diseases. Regulate the growth of nutrients in the soil nutrient availability and enhanced plant development (Manoharan et al., 2010; Tabassum et al., 2012; Martin-Robles et al., 2018). Soil usually contains the natives of AMF, which grows plant roots in colonies. Phosphorus uptake and sprouting of plants colonized by AMF is well-known process (Bonfante and Genre 2010; Farzaneh et al., 2011; Wang et al., 2019; Song et al., 2020).

On the additional, mainly strengthen in yield of maize subsequent inoculation with AMF (Sabia et al., 2015; Mitra et al., 2019) particularly in low-P soils (Wang et al., 2018). Covacevich et al. (2007) communicated that the lesser use of agrochemical research is towards crop yield stability. Smith et al. (2011) described those mycorrhizae infection is known to build on plant growth by escalating nutrients. Linderman and Davis (2004) heard that the AMF inoculations enhance the 18.2% of plant height, 15.7% of number of leaves, and 19.1% of fresh and dry weights of crop plants. Charitha Devi and Reddy (2001) outlined that the unify inoculation of AMF and *Rhizobium* gave the maximum (23.7-28.6) percentage of shoot and root length, fresh and dry weight of groundnut plantlet.

Growth and productivity of the legumes were always dependent on the combination of selected AMF and rhizobia, revealing that positive interactions between compatible symbionts could indispensable get larger development and yields. Enlargement and productivity of pulses, which are always dependent on a combination of selective AMF and rhizobia, reveals that positive correlation between compatible indices can appreciably proliferated (26.5-31.8) percentage of growth and yield (Attarzadeh et al., 2019). Pot tests with soybean with 9-16.8% of knots dry nodule, dry weight demonstrated that nitrogen fixation in mycorrhizal plants was generally higher than in non-mycorrizal plants under controlled environmental conditions (Goss and de Varennes, 2002; Wang and Qiu 2006; Shuab et al.,2014).

However, it seems that nitrogen fixation is not always assist under field condition. Even if the tripartite symbiosis formed by native *rhizobium* and soybean is established (Antunes et al., 2006; Baum et al., 2015).

The hyphopodia of AMF enter the root cortex to obtain carbon from the host plant and in return assist the plant with more uptakes of nutrients, especially P, which is necessary for the synthesis of nucleic acids, enhancing vegetative growth this might be the reason for the higher weight (fresh/dry root/shoot weight) of the plants (Bona et al., 2017; Solange et al., 2019). Biro et al. (2000) also noted a favorable effects on soybean of co-inoculation with *A. brasilense, Rhizobium meliloti* and *G. jasciculatum,* while *Azospirillum* and growth-promoting rhizobacteria has an indirect effect on AMF with a positive effect on root length that can be understood as an end result in pot and field experiments (Russo et al. 2005;Vacheron et al., 2013; Volpe et al., 2015).

## Vermicompost (VC) in Plant Improvement

Vermitechnology is the latest feature of biotechnology where the use of earthworms to compost the problem of waste disposal to reduce pollution effects (Subha and Pushpa, 2007; Allardice et al., 2015). Composting is biological process through which microorganisms convert organic matter into compact rich soil. It is the same natural process that creates a layer of dark humus on the wild ground. It is the same natural process that created a layer of dark humus in the wild. vermicompost building differs only in the creations of international conditions, resulting in rapid decomposition of organic matter, and then what usually happens in nature. While creating valuable soil fix for composting gardens and lawns, earthworm compost is a simple way to recycle home yards and food scraps (Blouin et al., 2013).

Atiyeh et al. (2002) account that the incorporation of little amount (10%) of pig manure VC, into commercial bedding plant potting media was sufficient to produce a major enhance in the 70 percentage of total biomass of tomato seedlings. Norman et al. (2007) explained that the number of seedling sprouted in the earthworm compost mixture of interest ranged from 0 to 100 per cent on petunias on greenhouse tests. VC contains a hormone like fertilizer function, and it triggers greater root opening, recuperate root biomaterials, and alters plant maturation and change of the morphology of plants (Mathivanan et al., 2013; Verma et al. 2018; Rahil et al., 2019).

Atiyeh et al. (2000) have established that VC generally has strikingly favorable effects on plan growing. Growth lifted in of *Sesamum indicum* seedlings at the ordinary level of VC treatments (Vasanth Pandiyan, 2020). There is good evidence that VC boost the plant growth (Joshi et al., 2013). Ansari (2008) statement that the sprouting enhancement of potato, spinach and turnip was recorded to 6 t $ha^{-1}$ VC applications. Chanda et al. (2011) disclose that tomato seedlings excellence in a growth medium substituted with 20%, 30% of VC. Gholami et al. (2018) initiate that VC stimulating the root length accruing the large number of Iranian chicory roots. Appliance of VC to field soils have also been reported to raising crop yields (Arancon et al., 2006; Bellit et al., 2017; Suresh et al., 2018; Mishra et al., 2018; Manimegala and Gunasekaran, 2020).
VC has been found to have a positive pressure on all yield parameters of crops such as wheat, paddy, pea and sugarcane (Ismail, 2005; Ansari, 2008; Pezeshkpour et al., 2014). Ahmed et al. (2010) mentioned that (17.8-21.7%) of plant height; total dry weight and leaf area extensively hike up on the application of biofertilizers. Mahmood et al. (2006) found that plant height difference in (5.3-9.8cm) of wheat swell by inoculation with *Azospirillum* sp.

Many studies have reported mature compost positive effect on the promotion and development of plants by using parameters such as rooting (21.6-30.8%), time of flowering, leaf area (18.3-23.5%), development and lengthening of internodes (Arancon et al., 2004; Jim et al., 2007; Shishehbor et al., 2013; Jandaghi et al., 2020). The shoot dry weights of marigold plants gain strength eloquently and highest maturation of *Dolichous lab lab* was taking place in $T_4$ compost hold mixture (Esakkiammal et al., 2015).

In the past few workers have reported the escalated germination of agriculture crops grown in media amended with humic acid that were extracted from VC (Jindo et al., 2016; Frasetya et al., 2019). Singh et al. (2008) information the maximizing in dry weight of strawberry (*Fragaria×anunassa* Duch.) leaves in 7.5 t $ha^{-1}$ VC application. Vermicompost which are stabilized organic materials created by interactions between earthworms and microorganisms in a non-thermophilic procedure have been reported to enhance in plant growth and yields in green house crops (Edwards and Arancon, 2004). Applications of VC have also reported to shoot up the improvement and yield in Cabbage (Nurhidayati et al., 2016).

Miceli et al. (2007); Ansari and Sukhraj (2010) statement that the application of VC to tomatoes and okra cultivated in the field also gets larger the yield. The greenhouse testing has demonstrated that VC can get larger the germination, growth and yields of different vegetables and ornamental plants were widely and consistently (Warman and Lopez, 2010; Manh and Wang, 2014; Goswami et al., 2017; Mahaly et al., 2018).

The small number of field trial explanation in the literature have revealed that 50% VC amending soils can magnifying the growth and yield of *Capsicum annum* (Rekha et al., 2017). Quite a few researchers have reported that

VC enhancing seed germination, seedling growth and yield (Mishra et al., 2012; Joshi et al., 2013; Gholami et al., 2018). Ravindran et al. (2007) observed the halophytic compost and phosphobacteria pick up the plant height, number of leaves, leaf area, root nodules, fresh weight and dry weight in *Arachis hypogaea* L. Fresh and dry weights of cucumber seedlings were affected harmfully by high amount of vermicompost (30%) indicating salt stress that resulted in growth retardation as nominated by Parthasarathi and Ranganathan (2002). Enormous data on the yield and shoot length heighten in several ornamentals, vegetable crop plants and trees treated with VC. Few attempts have been made to establish the role and expansion productivity of legume plants (Sinha et al., 2010; Yadav and Garg 2015; Hosseinzadeh et al., 2016; Kiran 2019).

Joshi and Vig (2010) also published the make bigger in plant development factors such as plant height, number of leaves, and plant dry biomass with application of 45% VC (cattle dung) amended treatment in *Lycopersicum esculentum*. And also, Gupta et al. (2014) inspected that addition of cow dung and household-based VC in appropriate quantities to the potting media resulted in increased rapid growth and flowering of marigold seedlings including plant biomass, plant height, number of buds and flowers. Plant height of maize also better knowingly as compared to the control when grown in soil amended with VC (Gutierrez- Miceli et al., 2008; Scaglia et al., 2016). Azarmi et al. (2008) present enhance in leaf area and shoot dry weight by 43.4% and 27.3%, correspondingly, in tomato with 15 t/ha sheep manure vermicompost applications. The microbes present in the VC may generate various plant growth regulators like auxin, cytokinins, gibberellins etc. and many metabolites which can be consume by the plants (Yang et al., 2015; Gholami et al., 2018).

## AMF WITH VC ON BIOCHEMICAL CONTENT

The effects of VC amendments on plant improvement and physiology vary depending on biological and environmental factors such as species and location. Few studies have reported on the developmental effects of VC and AMF use on some key role of agro-crops (Khorshidi et al., 2013; Khan et al., 2014; Oliveira et al., 2015; Hussain et al., 2016; Shamshiri et al., 2016; Nikkah Naeeni et al., 2017).

Douds et al. (2012) showed that different isolates of AMF can result in different effects on plant maturation. Expected growing retardation and diminish in chlorophyll content at 30% VC. Erashin et al. (2009) communicated that the 30% VC shoot up the chlorophyll content in cucumber seedlings. Reports from (Rathod et al., 2011) proved a raise of photosynthetic activity in leaves of *Glycine max,* injected with *G. fasciculatum.* There was a progress in chlorophyll content (chlorophyll 'a' and 'b' and total chlorophyll) noted in the leaves of *P. juliflora* inoculated with *G. fasciculatum* (Zhu et al., 2012).

Arumugam et al. (2010) disclosed that the booster of AMF, either alone or arrangement with *Rhizobium,* approved about great changes in chlorophyll 'a', 'b' and total chlorophyll content in concurrence with result reported elsewhere (Rajasekaran and Nagarajan 2004; Rajasekaran et al., 2006). Shrestha et al. (1995) have shown that the photosynthesis and transpiration rates of mycorrhizal *Satsuma mandarian* trees are higher than non-mycorrhizal trees. Zhang et al. (2018) also statement that the higher specific leaf area and strengthen rate of photosynthesis were present in AMF inoculated plants when compared with non AMF plants (*Ricinus communis*). The chlorophyll content, fresh weight and leaf area are higher in mycorrhizal plants than in non-mycorrhizal plants, but variations are notably under drought stress environment (Morte et al., 2000; Zhu et al., 2012).

Get over something nutrition and water performance of AMF immunization leads to raise the physiology and quality of the product (Yang et al., 2014; Gao et al., 2020). In the documentation (Bolandnazar et al. 2007) confirmed 30% add to in chlorophyll content of *A. cepa* leaves under AMF application, with no major differences between the *Glomus species* tested. Borde et al. (2010) investigated that the AMF inoculated plants increased thes photosynthetic action of *A. sativum* under salinity situation. Thus AMF symbiosis could make better the photosynthetic capacity of garlic leaves, as to the results of (Giri and Mukerji 2004; Sannazzaro et al. 2006; Sheng et al., 2008; Boldt et al., 2011).

Yang et al. (2014) observed high stomatal conductance, high transpiration rates and high photosynthetic rates with reduced internal $CO_2$ concentration in fungal colonized plants than the non-colonized plants. Such higher photosynthetic rate as a consequence of fungal association has also been reported by Zhu et al. (2012). They observed high photosynthetic and transpiration rates in AM fungi colonized plants of maize than in non-colonized plants both under control and drought stress conditions.

Nemec and Meredith (1981) found that *G. etunicatum* inoculated *Citrus limon* leaves had higher total amino acids than control. Selvaraj (1998) also heard that accrue level of total amino acids in *P. juliflora,* immunization with *G. fasciculatum*. However, AMF seedlings have greater concentrations of soluble sugars in roots than non-mycorrhizal seedlings. Protein content also accumulates in AMF plants. It was exposed that *G. fasciculatum* with, tannery effluent treated *P. juliflora* showed a widen of protein content in both leaves and roots than the control. Whereas plant treated with tannery effluent alone showed least protein content due to the absence of AMF influence (Selvaraj et al., 2004). The higher protein content in mycorrhizal roots then in non-my-

corrhizal root also observed by (Arines et al., 1993) in red clover. El-Azouni et al. (2008) published the magnify protein content was witness in AMF and *bradyrhizobium* injected groundnut plants. Manoharan et al. (2008) accounted that the escalate protein content was recorded in AMF application when compared to control plants (trees plant seedlings). Selvaraj and Chellappan (2006) inspected that the early enhance in the level of sugars and amino acids in the seedling inoculated with AMF. Incorporated of AMF and vermicompost rising (30.2-38.6%) of photosynthetic pigments such as chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid contents. Induction of fungus mycelium of AMF in plant roots supplied access to better volumes of soil that lead to additional water and nutrient absorption (Smith et al., 2003; Gao et al., 2020). In fact, AMF colonization greatly influences the stomatal activities in the leaves of host plants, formative the water vapor efflux, $CO_2$ gas exchange, and thus photosynthetic activity (Auge et al., 2015).

AMF have hyphae and mycelia with inside and external root zone (Zarei et al., 2006).Using AMF in corn enhanced the synthesis of chlorophyll and multiply photosynthesis in plants (Smith and Read, 2010). AMF symbiosis with spearmint was also found to raise water and nutrients absorption through roots which leads to revive the photosynthesis and this turn outcome in more production, bump up the biological performance, and build up biochemical activity (Canellas et al., 2015; Shi-chua et al., 2019). AMF also supplement the absorption of $N_2$ that play a key role in chlorophyll structure and protein synthesis (Balestrini 2016; Cheng et al., 2016; Lin et al., 2017; Khafagi et al., 2018).

Concerning the outcome of applying these microorganisms on inflate the enzyme activation obtained in this assessment. Some investigators recorded increments in peroxides activity as a result of immunization plants with *Pseudomonas strains* (Balamuralikrishnan et al., 2005; Sardi et al., 2006) on tobacco, sorghum bicolor, *Triticum aestivum* and *Phaseolus vulgaris* L. respectively. Shaukat et al. (2006) used as *Azotobacter* inoculated the seeds of *Triticum aestivum* was recorded noticeable increments in peroxidase activity. Increments in catalase enzyme activity were also detected by Stainer et al. (1997) when inoculated wheat plants with *Azotobacter* and AMF-mediated wax in leaf sugar metabolism by changing sugar metabolized enzymes particularly donate to the osmotic regulation of colonized plants. However, contrast clarifications have been shown in olive trees (Ouledali et al., 2018). Legumes have developed a symbiosis with bacteria from the *Rhizobiaceae* family in such a way that the bacteria are able to satisfy plant nitrogen requirements through the activity of the nitrogenase enzyme (Gage, 2003).

Nitrogenase, responsible for $N_2$ fixation in legume nodules, can be denatured by $O_2$ and functions under micro-aerobic conditions. However, $O_2$ is required for ATP construction associated with nitrogenase activity. Inducement of nitrogenase activity occurred early in plant development and plant growth response about two weeks (Asimi et al., 1980). The inoculations of *Rhizobium* species make larger root nodulation of rice (Hassan and Bano, 2016) and lentil (Tena, 2016). It showed a better nodulation with higher nitrogenase activity. The normally grown plants of *Vicia faba* and *Phaseolus* sp. showed the maximum nitrogenase activity of flowering stage and declined after pod filling (Vidal et al., 1992; Jamro et al., 1994). Nitrogenase activity was positively correlated with nodule number in the case of *Vicia faba* and *Phaseolus* plants. Mishra and Dash (2014) accounted that difference in nitrogenase activity under water logged condition in legumes inoculated with *Rhizobium*. Htwe et al. (2019) reported that young nodules in Mung Bean, Cowpea, and Soybean had quite high nitrogenase activity even though only low levels of leghaemoglobin were distinguished. AMF inoculation also conspicuously bump up the concentrations of anthocyanins and carotenoids and ascorbic acid in plants in revelation to water restriction (Mo et al., 2016; Rahimzadeh and Pirzad, 2017; Bakr et al., 2017).

## CONCLUSION

In the finale AMF and VC are recommended for all over the agricultural, horticultural crops to improve productivity and argument the soil nutrient status. The majority of this nutrient exchange is believed to occur within root cortical cells containing highly branched hyphal structures termed arbuscules. The beneficial effects of AMF symbiotic association on the growth of plants are well known. AMF help in water regulation of plants by extending their hyphae towards the available moisture zone for continuous water absorption and translocation them to plants. It has been established that AMF plants grow better in infertile soils because of improved mineral nutrition through hyphae, which helps in exploring greater volume of soil, beyond root hairs. In this review, the AMF and VC are focused on maintaining the health of the soil and staying rich. A balanced approach to the use of fertilizers is good for adopting sustainable agriculture crop growth. We have described several instances of AMF and VC plants that increase yield when used as a micronutrient to contribute to project growth and raise certain parameters linked to food quality. On the other hand, how the use of plant AMF obtains the quality of agricultural crops has been reported, among other benefits, by boosting of plant enlargement, biochemical, and enzyme activities. The farmers followed the inappropriate methods in cultivation by applying the excess amount of chemical fertilizers, which is not suitable

for crop growth and soil health. To find and use bio-fertilizers and native soil microorganisms suitable for integrated management system for sustainable agriculture.

## REFERENCES


- Ahmed AG, Orabi S, Gomaa AM (2010). Bio-organic farming of grain sorghum and its effect on growth, physiological and yield parameters and antioxidant enzyme activity. Res. J. Agric. Biol. Sci. 6: 270-277.
- Allardice RP, Kapp C, Botha A, Valentine A (2015). Optimizing vermicompost concentrations for the N cutrition and production of the legume *Lupinus angustifolius*. Compost Sci. Util. 23:217-236. https://doi.org/10.1080/1065657X.2015.1038399.
- Ansari AA (2008). Effect of vermicompost on the productivity of potato (*Solanum tuberosum*), spinach (*Spinacia oleracea*) and turnip (*Brassica campestris*). World J. Agri. Sci. 4: 333-336.
- Ansari AA, Sukhraj K (2010). Effect of vermiwash and vermicompost on soil parameters and productivity of okra (*Abelomoschus esculentus*) in Guyana. Afr. J. Agric. Res. 5:1794-1798. http://www. acade micjo urnal s.org/AJAR. https://doi.org/10.5897/ajar0 9.107.
- Antunes PM, de Varennes A, Zang T, Goss MJ (2006). The tripartite symbiosis formed by indigenous AMF. *Bradyrhizobium japonicum* and soybean under field conditions. J. Agr. Crop Sci. 192: 373-378.
- Arancon NQ, Edwards CA, Bierman P (2006). Influences of vermicomposts on field strawberries: Part 2. Effects on soil microbiological and chemical properties. Biores Technol. 97(6): 831- 840. https://doi.org/10.1016/j.biortech.2005.04.016
- Arancon NQ, Edwards CA, Bierman P, Welch C, Metzger JD (2004). The influence of vermicompost applications to strawberries part 1. Effects on growth and yield. Bioresour. Technol. 93: 145-153.
- Arines J, Palma JM, Vilarino A (1993). Comparison of protein patterns in non-mycorrhizal and vesicular-arbuscular mycorrhizal roots of red clover. New Phytol. 123: 763-768.
- Arumugam R Rajasekaran S, Nagarajan SM (2010). Response of arbuscular mycorrhizal fungi and *Rhizobium* inoculation on growth and chlorophyll content of *Vigna unguiculata* (L.) Walp. var. Pusa 151. J. Appl. Sci. Environ. 14: 113-115.
- Asimi S, Gianinazzi-Pearson V, Gianinazzi S (1980). Influence of increasing soil phosphorous levels on interactions between vasicular arbuscular mycorrhizae and *Rhizobium* in soybeans. Can. J. Bot. 48: 2200-2205.
- Atiyeh RM, Arancon NQ, Edwards CA, Metzger JA (2000). Influence of earthworm processed pig manure on the growth and yield of green house tomatoes. Bioresour. Technol. 75: 175-180.
- Atiyeh RM, Arancon NQ, Edwards CA, Metzger JD (2002). The influence of earthworm-processed pig manure on the growth and productivity of marigolds. Bioresour. Technol. 81:1-6. https://doi.org/ 10.1016/S0960-8524(01)00122-5.
- Attarzadeh M, Balouchi H, Rajaie M, Dehnavi MM, Salehi A (2019). Growth and nutrient content of Echinacea purpurea as affected by the combination of phosphorus with AMF and Pseudomonas florescent bacterium under different irrigation regimes. J. of Environ. Manag. 231:182-188. https://doi.org/10.1016/j.jenvman.2018.10.040.
- Auge RM, Toler HD, Saxton AM (2015). Arbuscular mycorrhizal symbiosis alters stomatal conductance of host plants more under drought than under amply watered conditions: A meta-analysis. Mycor. 25(1):13-24. http://dx.doi.org/10.1007/s00572-014-0585-4.
- Azarmi R, Ziveh PS, Satari MR (2008). Effect of vermicompost on growth and nutrient status of tomato (*Lycopersicum esculentum*) Pak. J Biol. Sci. 11(14):1797-802.
- Bakr J, Daood HG, Pek Z, Helyes L, Posta K (2017).Yield and quality of mycorrhized processing tomato under water scarcity. Appl. Ecol. Environ. Res. 15 (1): 401- 413. http://dx.doi.org/10.15666/aeer/1501_401413.
- Bakry AB, Sadak MS, Moamen HT, Lateef EMB. El (2013). Influence of humic acid and organic fertilizer on growth, chemical constituents, yield and quality of two flax seed cultivars grown under newly reclaimed sandy soils. Inter J. Acad. Res. 5:125-134.
- Balamuralikrishnan M, Sabitha Doraisamy T, Ganapathy N, Viswanathan R (2005). Effects of biotic and abiotic agents on sugarcane mosaic virus titre, oxidative enzyme and phenols in Sorghum biocolor, acta-phytopathologica et.al., Entomologica Hungarica. 40: 9-22.
- Balestrini R (2016). Biological potential of Arbuscular mycorrhizal Fungi. In: Bioformulations: for Sustainable Agriculture. Springer. p. 127-135.
- Baum C, El-Tohamy W, Gruda N (2015). Increasing the productivity and product quality of vegetable crops using arbuscular mycorrhizal fungi: A review. Sci. Hortic., 187, 131-141.
- Bellit OK, Adiloglu S, Salmaz Y, Zahmaologlu A, Adiloglu A (2017). Effect of increasing doses of vermicompost application on P and K contents of pepper (*Capsicum annum* L.) and egg plant (*Solanum melongena* L.). J. Adv. Agri. Tech. 4(4), 372-375. https://doi.org10.18178/joaat.4.4.372-375.
- Berg G (2009). Plant-microbe interactions promoting plant growth and health: perspectives for controlled use of microorganisms in agriculture. Appl. Microbiol. and Biotechnol. 84: 11-48.
- Berg G, Mahnert A, Moissl-Eichinger C (2014). Beneficial effects of plant-associated microbes on indoor microbiomes and human health? Front. Microbiol. 5:15. https://doi.org/10.3389/fmicb.2014.00015.
- Bianciotto V, Victorino I, Scariot V, Berruti A (2018). Arbuscular mycorrhizal fungi as natural biofertilizers: Current role and potential for the horticulture industry. Acta Hortic. 207-216. https://doi.org/10.17660/ActaHortic.2018.1191.29.
- Biro B, Koves-Pechy K, Voros I, Takacs T, Eggenberg P, Strasser RJ (2000). Inter-relations between Azospirillum and *Rhizobium* nitrogen fixers and arbuscular mycorrhizal fungi in the rhizosphere of alfalfa as sterile AMF-free or normal soil conditions. Appl. Soil Ecol. 15: 159-168.
- Blouin M, Hodson ME, Delgado EA (2013). A review of earthworm impact on soil function and ecosystem services. Eur. J. Soil Sci. 64: 161-182. https://doi.org/10.1111/ejss.12025.
- Bolandnazar SA, Neyshabouri MR, Aliasgharzad N, Chaparzadeh N (2007). Effects of Mycorrhizal Colonization on Growth Parameters of Onion under Different Irrigation and Soil Conditions. Pak. J. of Biol. Sci. 10: 1491-1495.
- Boldt K, Pors Y, Haupt B, Bitterlich M, Kuhn C, Grimm B, Franken P (2011). Photochemical processes, carbon assimilation and RNA accumulation of sucrose transporter

genes in tomato Arbuscular Mycorrhiza. J. Plant Physiol. 168, 1256-1263.
- Bona E, Cantamessa S, Massa N, Manassero P, Marsano F, Copetta A, Lingua G, D'Agostino G, Gamalero E, Berta G (2017). Arbuscular mycorrhizal fungi and plant growth-promoting pseudomonads improve yield, quality and nutritional value of tomato: A field study. Mycorrhiza. 27: 1-11.
- Bonfante P and Genre A (2010). Mechanisms underlying beneficial plant+fungus interactions in mycorrhizal symbiosis. Nat Commun. 1:1-11. https://doi.org/10.1038/ncomms1011.
- Bonfante P and Perotto S (2000). Outside and inside the roots: cell to cell interactions among arbuscular mycorrhizal fungi, bacteria and host plant. In: G.K. Podila and D.D. Douds (Eds.), Curr. Adv. in Myco. Research. The American Phytopathological Society, Minnesota. pp. 141-155.
- Borde M, Dudhane M, Jite PK (2010). AMF influences the photosynthetic activity, growth and antioxidant enzymes in Allium sativum L. under salinity condition. Notsic. Biol. 2: 64-71. https://doi.org/10.15835/nsb245434.
- Boumari R, Dalpe Y, Serrhini MN, Bennani A (2006). Arbuscular mycorrhizal fungi species associated with rhizosphere of *Phoenix dactylifera* L. Morocco. Afr. J. Biotech. 5: 510-516.
- Calvet C, Pera J, Barea JM (1993). Growth response of marigold (*Tagetes erecta* L.) to inoculation with Glomus mosseae, Trichoderma aueroviride and Phythium ultimum in a peat-perlite mixture. Plant Soil. 148: 1-6.
- Canellas LP, Olivares FL, Aguiar NO, Jones DL, Nebbioso A, Mazzei P, Piccolo A (2015). Humic and fulvic acids as biostimulants in horticulture. Sci. Horticul. 196:15- 27. https://doi.org/10.1016/j.scienta.2015.09.013.
- Chanda GK, Bhunia G, Chakraborty SK (2011). The effect of vermicompost and other fertilizers on cultivation of tomato plants. J. Horti. Fore. 3(2):42-45. http://www.acade micjournal s.org/jhf.
- Charitha Devi M and Reddy MN (2001). Growth response of groundnut to VAM fungus and *Rhizobium* inoculation. Plant Pathol. Bull. 10: 71-78.
- Cheng DD, Zhang ZS, Sun XB, Zhao M, Sun GY (2016). Photoinhibition and photoinhibition-like damage to the photosynthetic apparatus in tobacco leaves induced by pseudomonas syringeepv. tabaciunder light and dark conditions. BMC Plant Biol. 16(1):1-11. https://doi.org/10.1186/s12870-016-0723-6.
- Covacevich F, Echeverria HE, Aguirrezabal LAN (2007). Soil available phosphorus status determines indigenous mycorrhizal colonization of field and glasshouse-grown spring wheat from Argentina. Appl. Soil Ecol. 35: 1-9.
- Cozzolino V, Di Meo V, Piccolo A (2013). Impact of arbuscular mycorrhizal fungi applications on maize pro¬duction and soil phosphorus availability. J Geochemi. Expl. 129: 40-44.
- Dar ZM, Masood A, Asif M, Malik AM (2018). Review on Arbuscular Mycorrhizal Fungi: An Approach to Overcome Drought Adversities in Plants. Int. J. Curr. Microbiol. App. Sci. 7(3): 1040-1049. https://doi.org/10.20546/ijcmas.2018.703.124.
- Douds DDJ, Lee J, Rogers L, Lohman ME, Pinzon N, Ganser S (2012). Utilization of inoculum of AMF produced on-farm for the production of Capsicum annuum: a summary of seven years of field trials on a conventional vegetable farm. Biol. Agric. Hortic. 28, 129-14.
- Edwards CA and Arancon NQ (2004). The use of earthworms in the breakdown of organic wastes to produce vermicomposts and animal feed protein. In: Edwards, C.A. (ed.), Earthworm ecology, CRC Press, Boca Raton, FL, pp. 345-438.
- El-Azouni IM, Hussein Y, Shaaban LD (2008).The associative effect of VA mycorrhizae with Brady *Rhizobium* as biofertilizers on growth and nutrient uptake of *Arachis hypogaea*. Res. J. Agric. Biol. Sci. 4: 187-197.
- Esakkiammal B, Lakshmibai L, Sornalatha S (2015). Studies on the combined effect of vermicompost and vermiwash prepared from organic wastes by earthworms on the growth and yield parameters of Dolichous lab lab. Asian J. of Pharma. Sci. 5(4), 246-252.
- Erashin Y, Haktanir K, Yanar Y (2009). Vermicompost suppresses Rhizoctonia solani Kuhn. in cucumber seedlings. J. Plant Diseases Protect. 116: 182-188.
- Farzaneh M, Vierheilig H, Loss A, Kaul HP (2011). Arbuscular mycorrhiza enhances nutrient uptake in chickpea. Plant Soil and Environ. 57(10): 465-470. https://doi.org/10.17221/133/2011-PSE.
- Fracchia S, Garcia-Romera I, Godeas A, Ocampo JA (2000). Effect of the saprophytic fungus Fusarium oxysporum on Arbuscular mycorrhizal colonization and growth of plants in green house and field trials. Plant Soil, 223: 175-184.
- Frasetya B, Harisman K, Maulid S, Ginandjar S. (2019). The effect of vermicompost application on the growth of lettuce plant (*Lactuca sativa* L.) 4th Annu. Appl. Sci. and Engin. Conf. 1402 033050. https://doi.org/10.1088/1742-6596/1402/3/033050.
- Gage J (2003). Infection and invasion roots by symbiotic nitrogen fixing rhizobia during nodulation in temperature legumes. J. Biochem. 3: 270-282.
- Gao X, Guo H, Zhang Q, Guo H, Zhang L, Zhang C, Gou Z, Liu Y, Wei1 J, Chen A, Chu Z, Zeng F (2020). Arbuscular mycorrhizal fungi (AMF) enhanced the growth, yield, fiber quality and phosphorus regulation in upland cotton (*Gossypium hirsutum* L.) Sci. Rep. 10:2084 1-12. https://doi.org/10.1038/s41598-020-59180-3.
- Garcia-Garrido I, Garcia-Garrido JM, Martin J, Fracchia S, Mujica MT, Godeas A Ocampo JA, (1998). Interaction between saprophytic Fusarium strains and arbuscular mycorrhiza of soybean plants. Symbio. 24: 235-246.
- Gaur A and Adholeya A (2005). Diverse response of five ornamental plant species to mixed indigenous and single isolate arbuscular mycorrhizal inocula in marginal soil amended with organic matter. J. Plant Nutr. 28: 707-723.
- Germain D, Abou-Bakari K, Zaka Ghislaine Claude K, Adolphe ZEZE, Assanvon Simon-Pierre N, Ian R. (2016). Effect of two AMF on growth of cocoa seedlings (*Theobroma cacao* L.) in greenhouses. Global J. Adv. Res. 3(3) 157-164.
- Gholami H, Fard FR, Saharkhiz MJ, Ghani A (2018). Yield and physicochemical properties of inulin obtained from Iranian chicory roots under vermicompost and humic acid treatments. Indust. Crops Prod. 123: 610-616.
- Gill TS, Singh RS, Kaur J (2002). Comparison of four arbuscular mycorrhizal fungi for root colonization, spore population and plant growth responses in chickpea. Ind. Phytopath. 55: 210-212.
- Giri B and Mukerji KG (2004). Mycorrhizal inoculant alleviates slat stress in Sesbania aegyptiaca and Sesbania grandiflora under field conditions, evidence for reduced sodium and improved magnesium uptake. Mycorr. 14: 307-

312.
- Goss MJ and de Varennes A (2002). Soil disturbance reduces the efficacy of mycorrhizal associations for early soybean growth and N2 fixation. Soil Biol. Biochem. 34: 1167-1173.
- Goswami L, Nath A, Sutradhar S, Bhattacharya SS, Kalamdhad A, Vellingiri K (2017). Application of drum compost and vermicompost to improve soil health, growth, and yield parameters for tomato and cabbage plants. J Environ Manage 200 243-52.
- Gupta R, Yadav A, Garg VK (2014). Influence of vermicompost application in potting media on growth and flowering of marigold crop. Inter. J. Recycl. Orga. Waste in Agri. 3(47): 1-7. https://doi.org/10.1007/S40093-014-0047-1.
- Gutierrez-Miceli FA, Moguel-Zamudio B, Abud-Archila M, Gutier- rez-Oliva VF, Dendooven L (2008). Sheep manure vermicom- post supplemented with a native diazotrophic bacteria and mycorrhizas for maize cultivation. Bioresour. Technol. 99:7020-7026.
- Haggag WM, Abd-El Latif F (2001). Interaction between veiscular arbuscular mycorrhizae and antagonistic biocontrol microorganisms on controlling root rot disease incidence of greengram plants. J. Biol. Sci. 1: 1147-1153.
- Halder S, Ray MB (2006). Effect of VAM soil containing Glomus fasciculatum on growth of Withania somnifera Dun. Asian J. Exp. Sci. 20: 261-268.
- Hassan TU, Bano A (2016). Biofertilizer; a novel formulation for improving wheat growth, physiology and yield. Pak J. Bot. 48:2233-2241
- Hawley GL, Dames JF (2004). Mycorrhizal status of indigenous tree species in forest biome of the Eastern Cape, South Africa. South African J. Sci. 100: 633-637.
- Hazarika DK, Das KK, Dubey LN, Phookan AK (2000). Effect of vesicular arbuscular mycorrhizal fungi *Rhizobium* on growth and yield of greengram (*Vigna radiata* L.). J. Mycology Plant Pathol. 30: 424-426.
- Hosseinzadeh SR, Amiri H, Ismaili A (2016). Effect of vermicompost fertilizer on photosynthetic characteristics of chickpea (*Cicer arietinum* L.) under drought stress. Photosynthetica. 54:87-92. https://doi.org/10.1007/s11099-015-0162-x.
- Htwe AZ, Moh SM, Soe KM, Moe K, Yamakawa T (2019). Effects of Biofertilizer Produced from Brady*Rhizobium* and Streptomyces griseoflavus on plant growth, nodulation, nitrogen fixation, nutrient uptake, and seed yield of mung bean, cowpea, and soybean, Agronomy 9 (77), 1-12.
- Hussain S, Sharif M, Khan S, Wahid F, Nihar H, Ahmad W, Khan I, Haider N, Yaseen T (2016). Vermicompost and mycorrhiza effect on yield and phosphorus uptake of wheat crop. Sarh. J. of Agrr. 32(4):372-381. http://dx.doi.org/10.17582/journal.sja/2016.32.4.372.381.
- Igiehon NO, Babalola OO (2017). Biofertilizers and sustainable agriculture: exploring arbuscular mycorrhizal fungi. Appl. Microbiol. Biotechnol. 101, 4871-4881. https://doi.org/10.1007/s00253-017-8344-z.
- Ismail SA (2005). The earthworm book ecology: the biology of earthworms, Orient Longman Press, Hyderabad, p. 92.
- Jamro GH, Posyanov GS, Posypanov VN, Kobzova TP, Koshken YE, Buriro UA (1994). Effect of soil moisture on biological nitrogen fixation in pot grown *Phaseolus vulgaris* (L.). Sarhad J. Agric.10: 209-216.
- Jandaghi M, Hasandokht MR, Abdossi V, Moradi P (2020). The effect of chicken manure tea and vermicompost on some quantitative and qualitative parameters of seedling and mature greenhouse cucumber. J. of Appl. Biolo & Biotechnol. 8(1);33-37. DOI: 10.7324/JABB.2020.80106.
- Jat RA, Ahlawat IPS (2010). Effect of organic manure and sulphur fertilization in pigeonpea (*Cajanus cajan*) and groundnut (*Arachis hypogaea*) intercropping system. Ind. J. of Agro. 55(4), 276-281.
- Jeffries P, Gianinazzi S, Perotto S, Tumau K, Barea JM (2003). The contribution of arbuscular mycorrhizal fungi in sustainable maintenance of plant health and soil fertility. Biol. Fertil. Soils. 37: 1-16.
- Jim F, Howell G, Hobson AM (2007). Effect of pre-composting and vermicomposting on compost characteristics. European J. Soil Biol.43: 320-326.
- Jindo K, Chocano C, De Aguilar JM, Gonzalez D, Hernandez T, Garcia C (2016). Impact of compost application during 5 years on crop production, soil microbial activity, carbon fraction, and humification process. Commun. Soil Sci. Plant Anal. 47, 1907-1919. https://doi.org/10.1080/00103624.2016.1206922.
- Joshi R and Vig AP (2010). Effect of vermicompost on growth, yield and quality of tomato (*Lycopersicum esculentum* L). Afr. J. Basic Appl. Sci. 2(3-4):117-123.
- Joshi R, Vig AP, Singh J (2013). Vermicompost as soil supplement to enhance growth, yield and quality of *Triticum aestivum* L. A field study. Inter. J. of Recyc. of org. waste in Agric.2(1), p.16. https://doi.org/10.1186/2251-7715-2-16
- Karasawa T, Hodge A, Fitter AH (2012). Growth, respiration and nutrient acquisition by the arbuscular my¬corrhizal fungus Glomus mosseae and its host plant Plan¬tago lanceolata in cooled soil. In Plant Cell & Environ¬ment, vol. 35, no. 4, pp. 819-828. https://doi.org/10.1111/j.1365-3040.2011.02455.x.
- Kaur HS, Gosal K Walia SS (2017). Synergistic Effect of Organic, Inorganic and Biofertilizers on Soil Microbial Activities in Rhizospheric Soil of Green Pea. Annu Res & Rev in Biol. 12(4); 1-11. https://doi.org/10.9734/ARRB/2017/32509.
- Khade SW and Rodrigues BF (2010). Studies on effects of arbuscular mycorrhizal (AM). Nat. Bot. Hort. Agrobot. 37: 183-186.
- Khafagi EY, Eid El-Abeid S, Soliman MS, El-Sayed Mohamed El-Nahas S, Ahmed Y (2018). Role of Arbuscular Mycorrhizae Fungi and Humic Acid in Controlling Root and Crown Rot of Strawberry. Plant Pathol. J. 17; 64-74 https://doi.org/10.3923/ppj.2018.65.74.
- Khakpour O and Khara J (2012). Spore Density and Root Colonization by Arbuscular Mycorrhizal Fungi in Some Species in the Northwest of Iran. Inter. Res. J. of Appl. and Basic Sci. 3, 977-982.
- Khan MH, Meghvansi MK, Gupta R, Veer V, Singh L (2014). Foliar Spray with Vermiwash Modifies the Arbuscular Mycorrhizal Dependency and Nutrient Stoichiometry of Bhut Jolokia (*Capsicum assamicum*). Plos One.. 9(3): e92318. https://doi.org/10.1371/journal.pone.0092318.
- Khan SW, Yaseen T, Naz F, Abidullah S, Kamil M (2019). Influence of Arbuscular Mycorrhizal Fungi (AMF) Inoculation on Growth and Mycorrhizal Dependency of (*Lens culinaris* L.) Varieties. Inter J of Bioorga Chem. 4(1);47-52. https://doi.org/10.11648/j.ijbc.20190401.17.
- Khorshidi M, Bahadori F, Behnamnia M (2013). The effects of arbuscular mycorrhizal fungi (*Glomus intraradices*) and vermicompost application on yield and nutrient uptake in garden thyme (*Thymus vulgaris* L.) under field conditions.

Int. J. Agric. Crop Sci. 5: 1191-1194.
- Kim SJ, Eo JK, Lee, EH, Park H, Eom AH (2017). Effects of Arbuscular Mycorrhizal Fungi and soil conditions on crop plant growth Mycobiol. 45(1): 20-24 https://doi.org/10.5941/MYCO.2017.45.1.20.
- Kiran S (2019). Effects of vermicompost on some morphological, physiological and biochemical parameters of lettuce (*lactuca sativa* var. crispa) under drought stress. Not Bot Horti Agrobo., 47. https://doi.org/10.15835/nbha47111260.
- Kowsar J, Abid RM, Rather M, Boswal V, Ganie GH (2014). Effect of biofertilzers and organic fertilzer on morpho-physiological parameters associated with grain yield with emphasis for further improvement in wheat yield production (Bread wheat *Triticum aestivum* L.). Inter J of Agri. and Crop Sci. 7 (4): 178-184.
- Lee YJ. and George E (2005). Contribution of mycorrhizal hyphae to the uptake of metal cations by cucumber plants at two levels of phosphorus supply. Plant Soil, 278: 361-370.
- Lenin M, Selvakumar G, Thamizhiniyan P, Rajendiran R (2010). Growth and biochemical changes of vegetable seedlings induced by arbuscular mycorrhizal fungus. J. Exp. Sci. 1: 27-31.
- Lesueur D, Inglebiy K, Odee D, Chamberlain J, Wilson J, Manga TT, Sarraih JM, Pottinger A (2001). Improvement of forage production in *Calliandra calothyrsus*: methodology for the identification of an effective inoculum containing *Rhizobium* strains and arbuscular mycorrhizal isolates. J. Biotechnol. 91: 269-282.
- Li C, Yue X, Wu C, Xu X, Yu J (2014). An ABA-responsive DRE-binding protein gene from *Setaria italica*, SiARDP, the target gene of SiAREB, plays a critical role under drought stress. J. of Experi. Bot. 65: 5415-5427. https://doi.org/10.1093/jxb/eru302.
- Lima dos Santos E, Alves da Silva F, Fabio, Barbosa da Silva S (2017). Arbuscular Mycorrhizal Fungi Increase the Phenolic Compounds Concentration in the Bark of the Stem of *Libidibia Ferrea* in Field Conditions. The Open Micro. Jour. 11, 283-291. https://doi.org/10.2174/1874285801711010283.
- Lin J, Wang Y, Sun S, Mu C, Yan X (2017). Effects of arbuscular mycorrhizal fungi on the growth, photosynthesis and photosynthetic pigments of Leymus chinensis seedlings under salt-alkali stress and nitrogen deposition. Sci. Total Environ. 576:234-241. https://doi.org/10.1016/j.scitotenv.2016.10.091.
- Linderman RG, Davis EA (2004). Vesicular arbuscular mycorrhizal and plant growth response to soil amendment with composed grape promac or its water extract. Phyton. Anals. Botanicase, 11: 446-450.
- Mahaly M, Senthilkumar AK, Arumugam S, Kaliyaperumal C, Karupannan N (2018). Vermicomposting of distillery sludge waste with tea leaf residues. Sust Environ. Res. 28(5); 223-227. https://doi.org/10.1016/j.serj.2018.02.002.
- Mahmood MR, Abd El-Warth M, Mansour SF (2006). Effect of biotechnologies on improving some properties of salt affected soils and its wheat production. Egypt J. Appl. Sci. 21: 332.
- Manh VH, and Wang CH (2014). Vermicompost as an important component in substrate: effects on seedling quality and growth of muskmelon (*Cucumis melo* L.). Apcbee Proc. 8, 32-40. https://doi.org/10.1016/j.apcbee.2014.01.076.
- Manimegala G, Gunasekaran G (2020). Effect of vermicompost and NPK fertilizer on growth and yield components of egg plant (*Solanum Melongena* L.) Inter. J of Sci. & Technol. Res. 9 (01): 1388-1391.
- Manoharan PT, Pandi M, Shanmugaiah V, Gomathinaygam S, Balasubramanian N (2008). Effect of vesicular arbuscular mycorhizal fungus on the physiological and biochemical changes on five different tree seedlings grown under nursery conditions. Afr. J. Biotechnol. 7: 3431-3436.
- Manoharan PT, Shanmugaiah V, Balasubramanian N, Gomathinayagam S, Sharma MP, Muthuchelian K (2010). Influence of AM fungi on the growth and physiological status of *Erythrina variegata* Linn. Grown under different water stress conditions. Eur. J. of Soil Biol. 46(2); 151-156. https://doi.org/10.1016/j.ejsobi.2010.01.001.
- Martin-Robles N, Lehmann A, Seco E, Aroca R, Rillig MC, Milla R (2018). Impacts of domestication on the arbuscular mycorrhizal symbiosis of 27 crop species. New Phytolo. 218:322-334. https://doi.org/10.1111/nph.14962.
- Mathivanan S, Kalaikandhan R, Chidambaram AL. A, Sundramoorthy P (2013). Effect of vermicompost on the growth and nutrient status in groundnut (*Arachis hypogaea*. L). Asian J. Plant Sci. Res. 3(2): 15-22.
- Mathur N and Vyas A (2000). Influence of arbuscular mycorrhizae on biomass production, nutrient uptake and physiological changes in *Ziziphus mauritiana* Lam. under water stress. J. Arid. Environ. 45: 191-195.
- Mhamdi R, Nouairi I, Hammouda T, Mhamdi R, Mhadhbi H (2015). Growth capacity and biochemical mechanisms involved in rhizobia tolerance to salinity and water deficit. Journal of Basic Microbiology, 55, 451-461. https://doi.org/10.1002/jobm.20140 0451.
- Miceli FAG, Borraz JS, Molina JA, Nafate CC, Archila MA, Angela M, Llaven O, Rosales RR, Dendooven L (2007). Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). Bioresource Technol. 98: 2781-2786.
- Minaxi J, Saxena S, Chandra K, Nain L (2013). Synergistic effect of phosphate solubilizing rhizobacteria and arbuscular mycorrhiza on growth and yield of wheat plants. J. Soil Sci. Plant Nut. 13(2): 511-525. http://dx.doi.org/10.4067/S0718-95162013005000040.
- Miransari M, Bahrami HA, Rejali F, Malakouti MJ, Torabi H (2007). Using arbuscular mycorrhiza to reduce the stressful effect of soil compaction on corn (*Zea mays* L.) growth. Soil Biol. Biochem. 39: 2014-2026.
- Mishra DJ, Rajvir S, K.Mishra U, Kumar SS (2012). Role of Bio-Fertilizer in Organic Agriculture: A Review. Res. J. Recent. Sci. 2: 39-41.
- Mishra P (2014). Rejuvenation of Biofertilizer for Sustainable Agriculture and Economic Development The J. Sustain. Develop. 11: 41-61. http://www.jstor.com/stable/26188729?seq=1&cid=pdf.
- Mishra P, Dash D (2014). Rejuvenation of biofertilizer for sustainable agriculture and economic development. The J. Sust. Develop. 11 (1); 41-61 https://www.jstor.org/stable/26188729.
- Mishra VK, Kumar S, Pandey VK (2018). Effect of organic manure and biofertilizers on growth, yield and quality of brinjal (*Solanum Melongena* L.). Int. J. Pure Appl. Biosci. 6(1),704-707. DOI: http://dx.doi.org/10.18782/2320-7051.6105.
- Mitra D, Navendra U, Panneerselvam U, Ansuman S, Ganeshamurthy AN, Divya J (2019). Role of mycorrhiza

and its associated bacteria on plant growth promotion and nutrient management in sustainable agriculture. Int. J. Life Sci. Appl. Sci. 1, 1–10.
- Mo Y, Wang Y, Yang R, Zheng J, Liu C, Li H (2016). Regulation of plant growth, photosynthesis, antioxidation and osmosis by an arbuscular mycorrhizal fungus in watermelon seedlings under well-watered and drought conditions. Front in Plant Sci., 7:644. DOI:10.3389/fpls.2016.00644.
- Mohammadi K, Khalesro S, Sohrabi Y, Heidari G (2011). A review: Beneficial effects of the mycorrhizal fungi for plant growth. Inter. J. of Appli. Environ. and Biol. Sci. 1 (9); 310-319.
- Morte A, Lovisolo C, Schubert A (2000). Effect of drought stress on growth and water relations of the mycorrhizal association *Helianthemum almeriense-Tertezia Cla-veryi* Mycorrhiza, 10: 115-119.
- Nahum ZS, Hadar Y, Chen Y (2007). Physico-chemical properties of commercial composts varying in their source materials and country of origin. Soil Biol. Biochem. 39: 1263-1276.
- Navnita S, Kuldeep Y, Jagbeer C, Neetu B, Ashok A (2015). Arbuscular Mycorrhizal Symbiosis and Water Stress: A Critical Review. Pert. J. of Trop. Agri. Sci. 38 (4): 427-453.
- Nemec S and Meredith FI (1981). Amino acid content of leaves in mycorrhizal and non-mycorrhizal citrus root stocks. Ann. Bot. 47: 351-358.
- Nikkah Naeeni F, Moghadam ARL, Moradi P, Rezaei M, Abdoosi V (2017). Effect of vermicompost and mycorrhiza fungi on yield and growth of milk thistle and antioxidant system activity. Iran J of Plant Physiol, 7:3 2063-2074. https://doi.org/10.22034/IJPP.2017.533560
- Norman Q, Arancon CA, Edwards A, Babenko J, Cannon P, Galvis R, Metzger J.D (2007).Influence of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. Appl. Soil Ecol. 1131: 1-9. https://doi.org/10.1016/j.apsoil.2007.11.010.
- Nurhidayati N, Ali U, Murwani I (2016). Yield and quality of cabbage (*Brassica oleracea* L. var. Capitata) under organic growing media using vermicompost and earthworm pontoscolex corethrurus inoculation. Agric. Sci. Procedia. 11 5-13.
- Oliveira MS, Campos MA, Silva FS (2015). Arbuscular mycorrhizal fungi and vermicompost to maximize the production of foliar biomolecules in Passiflora alata Curtis seedlings. J. Sci. Food. Agric. 95(3):522-8. https://doi.org/10.1002/jsfa.6767.
- Ortas I (2012). The effect of mycorrhizal fungal inoculation on plant yield, nutrient uptake and inoculation effectiveness under long-term field conditions. Field Crops Res. 125, 35-48. https://doi.org/10.1016/j.fcr.2011.08.005.
- Ouledali S, Ennajeh M, Zrig A, Gianinazzi S, Khemira H (2018). Estimating the contribution of arbuscular mycorrhizal fungi to drought tolerance of potted olive trees (*Olea europaea*). Acta Physiol Planta.40:81. https://doi.org/10.1007/s11738-018-2656-1.
- Pandian S and Perumal R (2002). Fertilizer nitrogen prescription with organics and biofertilizer for the desired yield target-rice. Madras Agric. J. 89: 334-337.
- Parthasarathi K and Ranganathan LS (2002). Supplementation of pressmud vermicast with NPK enhances growth and yield in leguminous crops (*Vigna mungo* and *Arachis hypogaea*). J. Curr. Sci., 2: 35-41.
- Perner H, Schwarz D, Bruns C, Mader P, George E (2007). Effect of arbuscular mycorrhizal colonization and two levels of compost supply on nutrient uptake and flowering of Pelargonium plants. Mycorrhiza, 17: 469-474.
- Pezeshkpour P, Ardakani MR, Paknejad F, Vazan S (2014). Effects of Vermicompost, mycor-rhizal symbiosis and biophosphate soulbilizing bacteria on seed yield and quality of chickpea as autumn plantation in rain fed conditions. Bull. Environ. Pharma. Life Sci. 3 (2): 53- 58.
- Piliarova M, Ondreickova K, Hudcovicova M, Mihalik D, Kraic J (2019). Arbuscular mycorrhizal fungi their life and function in ecosystem. Agri. Polnohospo., 65; (1) 3-15. https://doi.org/10.2478/agri-2019-0001.
- Posta K (2013). Effect of production technological measures on arbuscular mycorrhizal fungus communities in arable and horticultural crops. DSc Thesis, Godollo.
- Prasanna R, Kanchan A, Ramakrishnan B, Ranjan K, Venkatachalam S, Hossain F, (2016). Cyanobacteria-based bioinoculants influence growth and yields by modulating the microbial communities favourably in the rhizospheres of maize hybrids. Eur. J. Soil Biol. 75, 15-23. https://doi.org/10.1016/j.ejsobi.2016.04.001.
- Rabie GH and Al-Humiany A (2004). Role of VA-mycorrhiza on the growth of cowpea plant and their associative effect with N¬2-fixing and P-solubilizing bacteria as biofertilizers in calcareous soil. Food Agric. Environ. 2: 185-191.
- Raghuwanshi R (2012). Opportunities and challenges to sustainable agriculture in India, NEBIO, 3(2): 78-86.
- Rahil K, Amin S, Mohsen Movahhedi D, Hooshang F, Mohammad Amin K (2019). Physiological and yield responses of Aloe vera plant to biofertilizers under different irrigation regimes. Agri. Water Manag. 225: 105768. https://doi.org/10.1016/j.agwat.2019.105768
- Rahimzadeh S and Pirzad A (2017). Arbuscular mycorrhizal fungi and Pseudomonas in reduce drought stress damage in flax (*Linum usitatissimum* L.): A field study. Mycorrhiza. 27:537-552. https://doi.org/10.1007/s00572-017-0775-y.
- Rajasekaran S and Nagarajan SM (2004). Occurrence and histochemical studies on VAM fungi in some medicinal plants. Asian J. Microbiol. Biotechnol. Environ. Sci. 6: 553-556.
- Rajasekaran S, Nagarajan SM, Arumugam K, Sravanamuthu R, Balamurugan S (2006). Effect of dual inoculation (AM fungi and *Rhizobium*) on Chlorophyll content of *Arachis hypogaea* L. CV. TMV-2. Plant Arch. 6(2): 671-672.
- Rathod DP, Brestic M, Shao HB (2011). Chlorophyll a fluorescence determines the drought resistance capabilities in two varieties of mycorrhized and non-mycorrhized Glycine max Linn. Afr. J. Microbiol. Res. 5, 4197-4206.
- Ravansko S, Jensen B, Knudsen MB, Bodker L, Jensen DF, Karlinski L, Larson J (2006). Soil inoculation with the biocontrol agent *Clonostachys rosea* and the mycorrhizal fungus *Glomus intraradices* results in mutual inhibition plant growth promotion and alteration of soil microbial communities. Soil Biol. Biochem. 38: 3453-3462.
- Ravindran KC, Venkatesan K, Balasubramanian T, Balakrishnan V (2007). Effect of halophytic compost along with farmyard manure and phosphobacteria on growth characteristics of *Arachis hypogaea* L. The Sci. Total Environ. 384: 333-341. https://doi.org/10.1016/j.scitotenv.2007.05.026.

- Rekha GS, Kaleena PK, Elumalai D, Srikumaran P, Maheswari VN (2017). Effects of vermicompost and plant growth enhancers on the exo-morphological features of *Capsicum annum* (Linn.) Hepper, Inter. J. Recyc. of Org. Waste in Agri. https://doi.org/10.1007/s40093-017-0191-5.
- Robl D, da Silva, Delabona P, Montanari Mergel C, Rojas JD, dos Santos Costa P, Chapaval Pimentel I (2013). The capability of endophytic fungi for production of hemicellulases and related enzymes. BMC Biotechnol. 13, 94. https://doi.org/10.1186/1472-6750-13-94.
- Russo A, Felici C, Toffanin A, Gotz M, Collados C, Barea JM, Locoz YM, Smalla K, Vanderleyden J, Nuti N (2005). Effect of Azospirillum inoculants on arbuscular mycorrhiza establishment in wheat and maize plants. Biol. Fert. Soils, 41: 301-309.
- Sabia E, Claps S, Morone G, Bruno A, Sepe L, Aleandri R (2015). Field inoculation of arbuscular mycorrhiza on maize (*Zea mays* L.) under low inputs: preliminary study on quantitative and qualitative aspects. Italian J. Agron. 10, 30-33. https://doi.org/10.4081/ija.2015.607.
- Sailo L and Bagyaraj J (2005). Influence of different AM fungi on the growth, nutrition and forskolin content of Coleus forskohlii. Mycol. Res. 109: 795-798.
- Sannazzaro A, Oscar IR, Edgardo A, Ana M (2006). Alleviation of salt stress in lotus glaber by *Glomus intraradices* Plant Soil, 285: 279-287.
- Sardi E, Stefanovits H, Banyai E (2006). Relationship between peroxidase activity and the amount of fully N-methylated compounds in bean plants infected by Pseudomonas savastanoi, pv. Phaseblicola. Acta Physiol. Planta.28: 95-100.
- Scaglia B, Nunes RR, Rezende MOO, Tambone F, Adani F (2016). Investigating organic molecules responsible of auxin-like activity of humic acid fraction extracted from vermicompost. Sci Total Environ. 562, 289-295. https://doi.org/10.1016/j.scitotenv.2016.03.212.
- Sedlacek M, Pavlousek P, Losak T, Zatloukalova A, Filipcik R, Hlusek J, Vitezova M. (2013). The effect of arbuscular mycor¬rhizal fungi on the content of macro and micro elements in grapevine (*Vitis vinifera*, L.) leaves. Acta Uni. Agri¬. Silvicul. Mend. Brune. 61: 187-191.
- Selvaraj T (1998). Studies on mycorrhizal and rhizobial symbiosis on tolerance of tannery effluent treated Prosopis juliflora. Ph.D. Thesis, University of Madras, Chennai, India, p. 209.
- Selvaraj T and Chellappan P (2006). Arbuscular mycorrhizae A diverse personality. J. Central Eur. Agric.2: 349-358.
- Selvaraj T, Chellappan P, Jeong YJ, Kim H (2004). Occurrence of vesicular-arbuscular mycorrhizal (VAM) fungi and their effect on plant growth in endangered vegetations, J. Microbiol. Biotechnol. 14: 885- 890.
- Shamshiri M and Fattahi ME (2016). Effects of arbuscular mycorrhizal fungi on photosystem II activity of three pistachio rootstocks under salt stress as probed by the OJIP-test. Russ. J. Plant Physiol. 63, 101-110. https://doi.org/10.1134/S1021443716010155.
- Shaukat K, Affrasayab S, Hasnain S (2006). Growth responses of *Triticum aestivum* to plant growth promoting rhizobacteria used as a biofertilizer. Res. J. Microbiol. 1: 330-338.
- Sheng M, Ming T, Hui C, Baowei Y, Fengfeng Z, Yanhui H (2008). Influence of arbuscular mycorrhizae on photosynthesis and water status of maize plants under salt stress. Mycorrhiza, 18: 287-296.
- Shi-chua L, Yonga J, Ma-bob L, Wen-xuc Z, Nand X, Hui-huib Z (2019). Improving plant growth and alleviating photosynthetic inhibition from salt stress using AMF in alfalfa seedlings. J. Plant Inter. 14;(1)482-491 https://doi.org/10.1080/17429145.2019.1662101.
- Shishehbor M, Madani H, Ardakani MR (2013). Effect of vermicompost and biofertilizers on yield and yield components of common millet (*Panicum miliaceum*). Ann. Biol. Res. 4 (2): 174-180.
- Shrestha YH, Ishii T, Kadoya K (1995). Effect of vesicular-arbuscular mycorrhizal fungi on the growth; photosynthesis, transpiration and the distribution of photosynthates of bearing *Satsuma mandarin* trees. J. Jpn. Soc. Hort. Sci. 64: 517-525.
- Shuab R, Lone R, Naidu J, Sharma V, Imtiyaz S, Koul KK (2014). Benefits of inoculation of arbuscular mycorrhizal fungi on growth and development of onion (*Allium cepa*) plant. Am. Eur. J. Agric. Environ. Sci.14: 527-535.
- Singh R, Sharma RR, Kumar S, Gupta RK, Patil RT (2008). Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria xananassa* Duch.). Bioresour. Technol. 99: 8507-8511.
- Sinha J, Biswas K Ghosh A, Saha A (2010). Efficacy of vermicompost against fertilizers on *Cicer* and *Pisum* and on population diversity of N2 fixing bacteria. J. Environ. Biol. 31: 287-292.
- Sivakumar N (2013). Effect of edaphic factors and seasonal ariation on spore density and root colonization of arbuscular mycorrhizal fungi in sugarcane fields. Ann Microbiol. 63:151-160. https://doi.org/10.1007/s13213-012-0455-2.
- Sivakumar T, Ravikumar M, Prakash M, Thamizhmani R (2013). Comparative effect on bacterial biofertilizers on growth and yield of greengram (*Phaseolus radita* L.) and cowpea (*Vigna siensis* Edhl.). Int. J. Curr. Res. Aca. Rev.1: 20-28.
- Smith SE and Read DJ (1997). Mycorrhizal symbiosis academic press, San Diego, pp. 605.
- Smith SE and Read DJ (2010). Mycorrhizal symbiosis: Academic press. Elsevier Ltd.
- Smith SE, Jakobsen I, Grnlund M, Smith, FA (2011). Roles of arbuscular mycorrhizas in plant phosphorus nutrition: interactions between pathways of phosphorus uptake in arbuscular mycorrhizal roots have important implications for understanding and manipulating plant phosphorus acquisition. Plant Physiol. 156, 1050-1057. https://doi.org/10.1104/pp.111.174581.
- Smith SE, Smith FA, Jakobsen I (2003). Mycorrhizal fungi can dominate phosphate supply to plants irrespective of growth responses. Plant physiol.133:16-20.
- Solange J, de Oliveira F, Xavier LP, Lins L, Helena E, Andrade A, Guilherme J Maia S, de Mello AH, Setzer WN, Ramos AR, Kelly J, da Silva R (2019). Effects of inoculation by arbuscular mycorrhizal fungi on the composition of the essential oil, plant growth,and lipoxygenase activity of Piper aduncum L. de Oliveira et al. AMB Expr. 9:29. https://doi.org/10.1186/s13568-019-0756-y.
- Song X, Liu M, Wu D, Griffiths BS, Jiao J, Li H, Hu F (2015). Interaction matters: Synergy between vermicompost and PGPR agents improves soil quality, crop quality and crop yield in the field. Appl. Soil Ecol. 89, 25-34. http://dx.doi.org/10.1016/j.apsoil.2015.01.005.
- Song Z, Bi Y, Zhang J, Gong Y, Yang H (2020). Arbuscular

mycorrhizal fungi promote the growth of plants in the mining associated clay. Sci. Rep.10:2663. https://doi.org/10.1038/s41598-020-59447-9.
- Srivastava R, Roseti D, Sharma AK (2007). The evaluation of microbial diversity in a vegetable based cropping system under organic farming practices. Appl. Soil Ecol. 36: 116-123.
- Stainer D, Keversan S, Gasic O, Saric Z (1997). Induction of antioxidant enzyme activities and pigment content in wheat as a result of nitrogen supply and inoculation with Azotobacter and Chroococcum cereal. Res. Commun. 25: 1007-1010.
- St-Arnaud M and Vujanovic V (2007). Effects of the arbuscular mycorrhizal symbiosis on plant diseases and pests. In: C. Hamel and C. Plenchette (eds.), Mycorrhizae in crop production, New York: Haworth, pp. 67-122.
- Subha L and Pushpa A (2007). Influence of flyash and vermicomposted flower waste on plant growth and soil fertility. Poll. Res. 26: 333-338.
- Suresh V, Fetricia JP, Saranya V (2018). To study the effect of fym, coirpith, vermicompost, humic acid and panchagavya on growth and yield of mint (*Mentha arvensis*.). Horticult. Int. J. 2(6):417-419. https://doi.org/10.15406/hij.2018.02.00088.
- Tabassum Y, Tanvir B, Farrukh H (2012). Effect of arbuscular mycorrhizal inoculation on nutrient uptake, growth and productivity of chickpea (*Cicer arietinum*) varieties. Inter. J. of Agron. and plant product. 3(9), 334-45.
- Tagore GS, Namdeo SL, Sharma SK, Kumar N (2013). Effect of *Rhizobium* and phosphate solubilizing bacterial inoculants on symbiotic traits, nodule leghemoglobin, and yield of chickpea genotypes. Int. J. Agron. Article ID 581627.
- Tahat MM, Kamaruzaman S, Radziah O, Kadir J, Masdek HN (2008). Responses of (*Lycopersicum esculentum* L. Mill.) to different arbuscular mycorrhizal fungi species. Asian J. Plant Sci. 7: 479-484.
- Tena W, Wolde-Meskel E, Walley F (2016). Symbiotic efficiency of native and exotic *Rhizobium* strains nodulating lentil (*Lens culinaris* Medik.) in soils of southern Ethiopia. Agronomy. 6:11.
- Uhlmann E, Gorke C, Petersen A, Oberwinkler F (2006). Arbuscular mycorrhizae from arid parts of Nambidia. J. Arid Environ. 64: 221-237.
- Ul Hassan T and Bano A (2016). Biofertilizer: A novel formulation for improving wheat growth, physiology and yield, Pak. J. Bot. 48(6): 2233-2241.
- Usha K, Mathew R, Singh B (2005). Effect of three species of arbuscular mycorrrhizal on bud sprout and ripening in grapevine (*Vitis vinifera* L.) cv. Perlethe. Bioagric. Hortic. 23: 73-83.
- Vacheron J, Desbrosses G, Bouffaud ML, Touraine B, Moenne-Loccoz Y, Muller D, Legendre L, Wisniewski-Dye F, Combaret CP (2013). Plant growth-promoting rhizobacteria and root system functioning. Front. Plant Sci. 4:356. https://doi.org/10.3389/fpls.2013.00356.
- Vaingankar JD, Rodrigues BF (2015). Effect of Arbuscular Mycorrhizal (AM) Inoculation on Growth and Flowering in *Crossandra infundibuliformis* (L.) Nees. J. Plant Nutr. 38: 1478-1488. https://doi.org/10.1080/01904167.2014.957398.
- Vasanth Pandiyan C, Balaji K, Saravanan S, Shylaja G, Srinivasan GR, Kiresee Saghana PR Manivel G (2020). Effect of vermicompost application on soil and growth of the plant Sesamum indicum L. Preprints (www.preprints.org) https://doi.org/10.20944/preprints202002.0080.v1.
- Venkataraman A (1984). Development of organic matter-based agricultural system in South Asia. In: S. Banta and C.V. Mendoza (eds.), Organic matter and rice, International Rice Research Institute, Philippines, pp. 57-70.
- Verma S, Singh A, Pradhan SS, Singh JP, Verma SK (2018). Effects of organic formulations and synthetic fertilizer on the performance of pigeonpea in eastern region of Uttar Pradesh. Bangl J. Bot. 47(3): 467- 471. https://doi.org/10.3329/bjb.v47i3.38713.
- Vidal D, Bergareche JMC Mirinda AM, Simon E (1992). Effect of methabenzthia zuronon on growth and nitrogenase activity of Vicia faba. Plant Soil, 14: 235-242.
- Volpe V, Giovannetti M, Sun GX, Fiorilli V, Bonfante P (2015). The phosphate transporters LjPT4 and MtPT4 mediate early root responses to phosphate status in nonmycorrhizal roots. Plant, Cell & Environ. 39(3):660-671. https://doi.org/10.1111/pce.12659.
- Wang B and QIU YL (2006). Phylogenetic distribution and evolution of mycorrhizas in land plants. In Mycorrhiza, 16 (5); 299-363. https://doi.org/10.1007/s00572-005-0033-6.
- Wang F, SunY, Shi Z (2019). Arbuscular mycorrhiza enhances biomass production and salt tolerance of sweet sorghum. Microorganisms. 7(9),289. https://doi.org/10.3390/microorganisms7090289.
- Wang Y, Wang M, Li Y, Wu A, Huang J (2018). Effects of arbuscular mycorrhizal fungi on growth and nitrogen uptake of *Chrysanthemum morifolium* under salt stress. PLoS One 13 (4), e0196408. https://doi.org/10.1371/journal. pone.0196408.
- Warman PR and AngLopez MJ (2010). Vermicompost derived from different feedstocks as a plant growth medium. Biores. Technol. 101:4479-4483.
- Warwate SI, Kandoliya UK, Bhadja NV, Golakiya BA (2017). The Effect of Plant Growth Promoting Rhizobacteria (PGPR) on Biochemical Parameters of Coriander (*Coriandrum sativum* L.) Seedling. Int. J. Curr. Microbiol. App. Sci. 6(3): 1935-1944. https://doi.org/10.20546/ijcmas.2017.603.220.
- Wu QS, zou YN, wang GY (2014). Arbuscular Mycorrhizal Fungi and Acclimatization of Micropropagated Citrus. Commun. in Soil Sci. and Plant Anal. 42:1825-1832.
- Wu SC, Cao ZH,. Li ZG, Cheung KC, Wong MH (2005). Effects of biofertilizer containing N-fixer P and K solubilizers and AM fungi on maize growth: a greenhouse trial. *Geoderma*, 125: 155-156.
- Xavier LJC and Germida JJ (2002). Response of lentil under controlled conditions to co-inoculation with arbuscular mycorrhizal fungi and rhizobia varying in efficacy. Soil Biol. Biochem., 34: 181-188.
- Xiuxiu S, Yansu L, Xianchang Y (2019). Effects of arbuscular Mycorrhizal fungi (AMF) inoculums on cucumber seedlings. Adv. Plants. Agric. Res. 9(1):127–130. https://doi.org/10.15406/apar.2019.09.00422.
- Xiuxiu S, Yansu L, Xianchang Y, Chaoxing H (2019). Effects of arbuscular Mycorrhizal fungi (AMF) inoculums on cucumber seedlings. Adv. Plants Agric. Res. 9(1):127-130. https://doi.org/10.15406/apar.2019.09.00422.
- Yadav A, Garg VK, (2015). Influence of vermi-fortification on chickpea (*Cicer arietinum* L.) growth and photosynthetic pigments. Inter. J. of Recycl. of Org. Waste in Agri. 4:299-

305. https://doi.org/10.1007/s40093-015-0109-z.

- Yang C, Yang L, Yang Y, Ouyang Z (2004). Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. Water Manag.70: 67-81.
- Yang LJ, Zhao FY, Chang Q Li TL, Li FS (2015). Effects of vermicomposts on tomato yield and quality and soil fertility in greenhouse under different soil water regimes. Agri Water Manage. 160: 98-105. https://doi.org/10.1016/j.agwat.2015.07.002.
- Yang Y, Tang M, Sulpice R, Chen H, Tian S, Ban Y (2014). Arbuscular mycorrhizal fungi alter fractal dimension characteristics of *Robinia pseudoacacia* L. seedlings through regulating plant growth, leaf water status, photosynthesis, and nutrient concentration under drought stress. J. Plant Growth Regul. 33: 612-625.
- Yang Y, Tang M, Sulpice R, Chen H, Tian S, Ban Y (2014). Arbuscular mycorrhizal fungi alter fractal dimension characteristics of *Robinia pseudoacacia* L. seedlings through regulating plant growth, leaf water status, photosynthesis, and nutrient concentration under drought stress. J. Plant Growth Regul. 33: 612-625. https://doi.org/10.1007/s00344-013-9410-0.
- Zaferanchi S, Salmasi SZ, Lisar SYS, Sarikhani MR (2019). Influence of Organics and Bio Fertilizers on Biochemical Properties of *Calendula officinalis* L. Inter J. of Horti. Sci. & Technol. 6 (1);125-136. https://doi.org/10.22059/IJHST.2019.266831.258.
- Zarei M, Saleh-Rastin N, Alikhani HA, Aliasgharzadeh N (2006). Responses of lentil to co-inoculation with phosphatesolubilizing rhizobial strains and arbuscular mycorrhizal fungi. J. Plant Nutri. 29:1509-1522.
- Zhang T, Hub Y, Zhang K, Tian C, Guo J (2018). Arbuscular mycorrhizal fungi improve plant growth of *Ricinus communis* by altering photosynthetic properties and increasing pigments under drought and salt stress. Indus. Crop Prod. 117:13-19. https://doi.org/10.1016/j.indcrop.2018.02.087.
- Zhong W, Gu T, Wang W, Zhang B, Lin X, Huang Q, Shen W (2010). The effects of mineral fertilizer and organic manure on soil microbial community and diversity. Plant Soil. 326(1-2):511-22.
- Zhu XC, Song FB Liu SQ, Liu TD, Zhou X (2012). Arbuscular mycorrhizae improve photosynthesis and water status of *Zea mays* L. under drought stress. Plant Soil Environ. 58(4): 186-191.