

Review Article

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Role of Effective Microorganisms (EM) in Sustainable Agriculture

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ABSTRACT

Agricultural production is mainly depends on the health of soil, which is a measure of a complex set of biological, chemical and physical interactions driven by microorganisms. Effective microorganism increases the beneficial microbial population in the soil for sustainable crop production. Effective Microorganisms are mixed cultures of beneficial naturally-occurring organisms that can be applied as inoculants to increase the microbial diversity of soil ecosystem. They consist mainly of the photosynthesizing bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi. EM will improve the structure of the soil, increase its fertility and radically improve biological diversity, suppress soil-borne pathogens, fixes the nitrogen in soil and enhances nutrient uptake, accelerates the decomposition of organic waste, residues and composting, increases beneficial minerals in organic compound, enhances the activities of indigenous microorganism and boosts the strength of plants and yield of crops. EM works by being dominant over other soil microbes. As a result, this encourages the bulk of the other microbes in the soil to follow them and in doing so suppress the activity of the smaller group of negative or opportunistic microbes. Effective microorganisms can help to improve and maintain the soil chemical and physical properties.

Keywords

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Introduction

The human population is increasing day by day and it requires intensifying the existing agricultural production systems. The agricultural production is high due to the immense use of synthetic agrochemicals but environmental deterioration and unsustainable systems are the consequences of these ways of management (Armstrong and Taylor, 2014). The environmentally friendly effective microorganisms (EM) have a large number of

benefits when they are applied as manure or spray to the field crops (Alluri *et al.*, 2007).

Cho and Koyama (1997) reported that microorganisms are tiny units of life that are too small; exist everywhere in nature and plays important role in maintaining the ecological balance. Effective Microorganisms are mixed cultures of beneficial naturally-occurring organisms that can be applied as inoculants to increase the microbial diversity of the soil ecosystem. There is evidence that

EM inoculation to the soil can improve the quality of soil, plant growth and yield (Han *et al.*, 2006). Healthy soil ecology has the capability of protecting plants against soil born diseases caused by pathogenic microorganisms and parasites. The soil system offers this protection through a balanced relationship between pathogenic and billions of beneficial microorganisms working together in synergy. Chan *et al.*, (2003) observed that presence or absence of these beneficial microorganisms in any soil system precisely distinguishes “living soil” from a “dead soil”. They decompose and ferment organic fraction of the soil system converting it into humus containing nutrients while releasing hormones that facilitate plant growth. They are responsible for providing hormones, nutrients and minerals to the plants through the root system. In addition, they bring together soil particles in the soil structure enabling it to retain nutrients and moisture (Kengo and Hui-lian, 2000).

Prof. Dr Teruo Higa worked on the excessive use of chemicals, and then he realized the harmful effects of these chemicals on human beings and environment. Thus, he developed a mixture of beneficial microorganism and he also reported that approximately 80 different types of microorganism are able to decompose organic matter. The concept of EM is based on the inoculation of mixed cultures of beneficial microorganisms into the soil where they shift the microbiological equilibrium and create an environment that is favourable to the growth and health of plants (Goessler and Kuehenelt 2002).

A series of inoculations are made to ensure that the introduced microorganisms continue their dominance over the indigenous populations. The principal organisms are usually five *viz.* photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi. These include the

suppression of plant pathogens and diseases, conservation of energy in plants, solubilisation of soil minerals, soil microbial-ecological balance, photosynthetic efficiency, and biological nitrogen fixation (Van *et al.*, 1997).

Beneficial effects of effective microorganisms

Urmi and Sariah (2006) studied that there are numerous benefits to using effective microorganisms in agriculture. Effective microorganisms contribute to soil enrichment, by harmonizing and diversifying native microorganisms. A diversified base of microorganisms will be fed on by earthworms and the number of micro-pores will increase. This makes the soil healthy and results in good growth of plants, pest pressure is reduced and high-quality crops can be grown. This group of bacteria is completely safe for human, plants, animal and soil as it is derived from natural and organic matters (Brown *et al.*, 2000). The usage in agriculture spreads vast and wide in various activities including planting, fertilizing, composting and sanitation as well. The different species of organisms in effective microorganisms complement each other and are in a mutually beneficial relationship with the roots of plants in the soil ecosystem. Plants would, therefore, grow exceptionally well in soils inhabited and dominated by these effective microorganisms (Sun *et al.*, 2014). Effective microorganisms enhance soil fertility and promote growth, flowering, fruit development and ripening in crops. It can increase crop yields and improve crop quality as well as accelerating the breakdown of organic matter from crop residues (Cortez *et al.*, 2000). The population of beneficial microorganisms in the soil is also increased helping to control of soil diseases through competitive exclusion (Postma-Blaauw *et al.*, 2006). Some advantages of using effective microorganisms in agriculture and gardening are explained below.

Fix the nitrogen in the soil and enhance nutrient uptake

Effective microorganisms will increase nutrient availability in the soil for plants which will reduce the need for constant fertilization and cost of cultivation (Daniel *et al.*, 1992). Foliar application of effective microorganisms results in a large number of beneficial microorganisms at the phyllosphere.

It is believed that certain microorganisms in effective microorganism's culture including photosynthetic bacteria and N-fixing bacteria can enhance the plant's photosynthetic rate and efficiency and N-fixing capacity as well (Pati and Chandra 1981). Vaid *et al.*, (2017) concluded that when bacterial isolates are used in combination they perform better in comparison to their individual use and these isolates significantly increase the mean Fe concentration in grain and straw by 34 per cent and 52.4 per cent over none inoculated control and also increase the total Fe uptake in comparison to none inoculated controls. The bacterial inoculation also shows a positive impact on the bioavailability of Fe in the soil. Effective microorganisms enhance nitrogen, phosphorus and potassium nutrition of plant when farmyard manures applied both at flowering and maturity stage. In FYM amended soil effective microorganisms application markedly enhance plant nutrition at later growth stages of mung bean crop (Javaid and Bajwa, 2011). It is said that our vegetables contain much less nutritional value compared with those grown in olden days. EM vegetables have high nutritional value and increased sugar content which improves their taste and allows them to be preserved longer (EMRO, Japan).

Suppressing existing pathogen in soil

The use of effective microorganisms in agricultural soil not only suppresses soil-borne

pathogens but also increases the decomposition of organic materials and consequently the availability of mineral nutrients and important organic compounds to plants (Singh *et al.*, 2003). Introduction of a population of beneficial bacteria in the soil has a supporting effect in reducing soil associated microbiological diseases. The inoculation of effective microorganisms stimulates "Rotation effect", an occurrence that comes as a result of regeneration of beneficial organisms and elimination of pathogenic bacteria. Disease suppression is brought by the completion of available resources between the disease-causing microbes in the soil and beneficial microbes introduced in effective microorganisms which result in an enhanced population of effective microorganisms through inoculation will deplete the available resources in the soil leading to a reduction of pathogenic microorganisms due to starvation (Johan and Jesper, 2005). Lactic acid has sterilizing effects and its presence in the soil checks the proliferation of nematode population and offers protection against nematode associated plant diseases. Lactic acid bacteria in effective microorganisms also participate in the breakdown of cellulolytic and lignified organic materials in the soil (Ouwehand, 1998).

Accelerate the decomposition of organic waste, residues and composting

Effective microorganisms consist of common and food-grade aerobic and anaerobic microorganisms. When we pour activated effective microorganisms into environments dominated by putrefactive bacteria, the microbiomes will be improved and foul odors will be suppressed. Altering the microbial environment in the way that effective microorganism will lead to accelerating fermentation of organic matter and a shortening of the period required to manufacture high-quality compost. With the

application of effective microorganism products, we can efficiently solve problems such as foul odors at waste treatment sites of all kinds like incineration and sewage treatment facility (EMRO, Japan). Hussain *et al.*, (1999) found an increase in wheat and rice grain yield when effective microorganism's application was carried out in combination with farmyard manure and mineral NPK. The higher grain yield in the present and earlier studies, when effective microorganisms were applied in combination with organic matters, can be attributed largely to the activity of the introduced beneficial microorganisms, which enhanced the decomposition of organic materials and the release of nutrients for plant uptake. Jusoh *et al.*, (2013) reported that compost applied with effective microorganism has more N, P and K content compared to compost without effective microorganism. This study suggests that the application of effective microorganism is suitable to increase the mineralization in the composting process. The final resultant compost indicated that it was in the range of the matured level and can be used without any restriction.

Biocomposting by indigenous microorganisms

The disposal of agro-industrial wastes have become a major problem and due to this most of farmers dispose them through burning. Open burning cause emission of a large amount of harmful air pollutants (particles and inorganic and organic gases), which have severe impact on environment and human health (Korenaga *et al.*, 2001) and the danger of soil erosion and degradation due to repeated burning (Kahlon and Dass, 1987). In addition, disposal in water bodies (for example, river or lake) may contribute to a decrease in water quality and increase the problem of water bloom and eutrophication. Because of these concerns, there is a need to find efficient alternatives for agro-industrial waste

management. Composting being one of the most attractive on account of its low environmental impact and cost effective also (Bustamante *et al.*, 2008; Canet *et al.*, 2008 and Lu *et al.*, 2009) as well as its capacity for generating a valuable product used for increasing soil fertility (Weber *et al.*, 2007 and Perez-Murcia *et al.*, 2005). When complex organic materials such as; plants, animal excrements, and organic fertilizers enter into the soil, IMO break down these complex compound into simpler form or elements that can undergo ionic interactions (Anastasia *et al.*, 2004). Compost residues have more benefits than fertilization of crops. A study was conducted by Hanim *et al.*, (2012) to manage Paddy husk and Corn Stalk residues through composting and to determine the physico-chemical properties of different composts and humic acid extracted from the final product. For this study, the results showed that IMO compost from Corn stalk had better quality (chemical characteristics) compared to that of paddy husk. The methods for safe residue management are relatively time consuming but biocomposting is reliable method for most of farmers to recycle residue easily.

Increase beneficial minerals in the organic compound

Bossuyta and Hendrix (2005) demonstrated that photosynthetic bacteria are independent self-sustaining microorganisms. They harvest energy from the sun and soil heat and use it to convert exudates from root systems, soil organic fraction and gases such as ammonia into building materials of cells such as amino acids, nucleic acids and sugars. These can all be absorbed directly into plants to promote plant growth and also in the soil system promote and maintain the growth and establishment of other beneficial microorganisms. For example, Vesicular-arbuscular mycorrhiza fungi known to

enhance the plant's absorption capability of soil phosphates increases in the root zone in the presence of amino acids secreted by the beneficial bacteria. In addition, in the soil ecosystem, The VAM fungi live in association with *Azotobactor* and *Rhizobium* which increase the capacity of plants to fix nitrogen.

Enhance the activities of indigenous microorganism

Effective microorganism enhances the activities of beneficial indigenous microorganisms, for example, mycorrhizae (ecto as well as endomycorrhizae) which fix atmospheric nitrogen and accelerate phosphorus and zinc uptake from soil thereby supplementing the use of chemical fertiliser and pesticides. Improvement in soil fertility has a significant positive effect on plant growth, flowering, fruit development and ripening in crops (Levai *et al.*, 2006).

Boost the strength of plants and yield of crops

Muthaura *et al.*, (2010) demonstrated that growth and yield of pigweeds improved by inoculating the plants with effective microorganisms, and as a result reduce the use of fertilizers in the production of this vegetable hence promoting sustainable agriculture. EM significantly increased grain yield by 24 per cent and 46 per cent in farmyard manure and NPK fertilizers amendments, respectively in mung bean (Javaid and Bajwa, 2011). Cheng and Yingchun (2013) concluded that long-term application of effective microorganisms' compost could affect soil nematode community structure, wheat biomass and grain yield. Some soil microbes performed as bioinoculants for supplying nutrients and stimulating plant growth and rhizospheric microbes are known for the synthesis of plant growth promoters, siderophores and

antibiotics as well as aiding phosphorous uptake. We have seen quick steps made in our appreciation of the diversity of environmental microbes and their possible advantage to sustainable agriculture and for production system. Soil is the major medium where plant exists and takes up nutrients from it and it act as nutrient bin. The "intrinsic bioremediation" and this is one of the best remedial actions for soil contamination (Vaxevanidou *et al.*, 2015).

Benefits of EM in livestock farming

EM will reduce offensive odors resulting from the build-up of ammonia and trimethylamine which are alkaline. Feeding animals with ration which incorporates effective microorganism Bokashi will improve their internal microbiota and thereby reduce the offensiveness of the odors from manure (Higa, 1991). Spraying effective microorganisms inside the barns as well as adding effective microorganisms to feed and drinking water for animals will improve the microbial environment of the whole barn, including the intestinal bacteria flora of the livestock and maintain the health of the entire operation. As a result, the quality of fat will improve, there is no distinctive meat smell, products will stay fresh for longer periods and the taste and quality of animal products will improve. Also, it is possible to reduce usage of vaccines and antibiotics, thus supporting safer production of animal products from the standpoint of both producers and consumers (EMRO, Japan).

Reduce environmental pollution

Valls and Lorenzo (2002) revealed that repeated application of effective microorganisms will reduce the need of chemical fertilizers and pesticides in succeeding crops which results in a reduction of environmental pollution. Similarly, they also purify polluted water. Pouring effective

microorganisms into rivers increases the number of microbes, which form the bottom of the ecological pyramid. When the bottom grows larger, the pyramid itself also becomes larger, resulting in richer diversity in the ecosystem. This will improve the self-purification ability of rivers, helping them to become clean and beautiful again (Nikolopoulou and Kalogerakis 2010). Mudball is effective microorganisms to activate local and native microorganisms that live in ground and water and maximizes their natural power. These mud balls purportedly contain properties that will purify water, better

water quality and solve sanitation problems. In polluted rivers, accumulated sludge is in a state of oxygen deficiency, since there is a little oxygen dissolved in the water. Inside the sludge, harmful fermentation bacteria produce harmful gasses such as methane, ammonia and hydrogen sulphide by decomposing organic matter without oxygen. When mud balls are added to the water with that condition, they become embedded in the surface of the sludge and effective fermentation bacteria contained in mud balls start to decompose the sludge (EMRO, Japan) (Fig. 1–3).

Fig.1 Fixation of atmospheric nitrogen and its beneficial effects on plants and soil

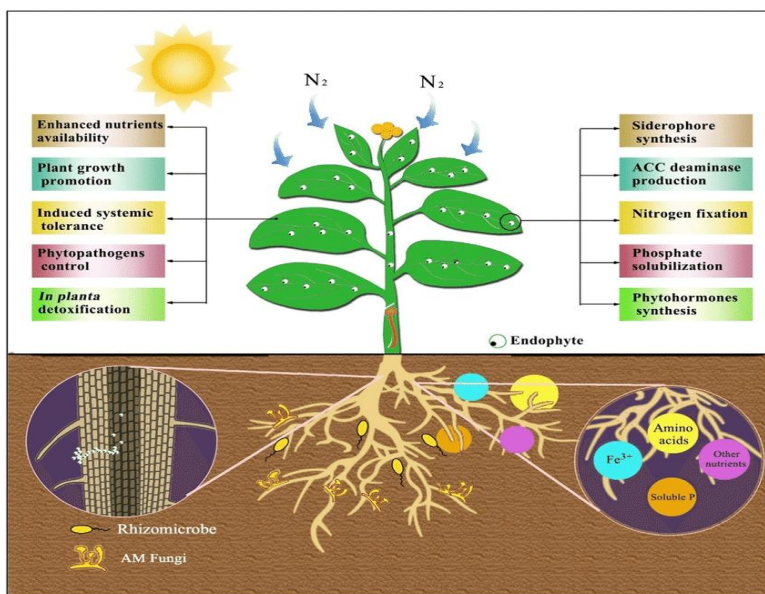


Fig.2 Bioaugmentation of vermicompost biobeds enhanced pesticide degradation

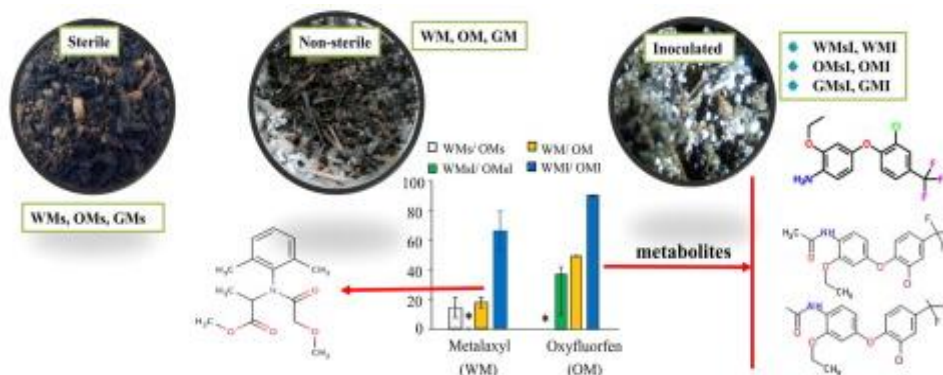


Fig.3 Reuse and recycle of waste residue by effective microorganisms



Bioremediation

The inherent abilities of microorganisms are suitable for the removal of undesirable and heavy metals from solutions (Beveridge and Murray, 1976; Langley and Beveridge, 1999; Nies, 1999). These abilities have been identified as play a passive or active for accumulation and biosorption, respectively, (Brandl and Faramarzi, 2006). Indigenous strains are more suitable to overcome the challenges such as high concentration of these metals, acidic conditions as they had well adapted to conditions in situ. Bacillus strains have been widely used in the removal of such kind of metals (Pb, Cd, Cu, Ni, Co, Mn, Cr, Zn) from wastewaters (Philip and Venkobachar, 2001; Srinath *et al.*, 2003 and Kim *et al.*, 2007) and also from soil solution if applied there to improve inherent quality and fertility of soil.

In conclusion, effective microorganisms are composed of naturally-derived microorganisms, which are safe and eco-

friendly. It is not necessary to put on goggles, masks and protective clothing when spraying effective microorganisms. Similarly, effective microorganisms never pollute water systems. The effective microorganism is manufactured from naturally-derived material. It is easy to be decomposed after use and effective microorganism never pollutes groundwater. Instead, it purifies soil, groundwater, lakes and rivers, thereby reducing environmental burdens. The effective microorganism is compatible with various methods of farming, regardless of their scale. It is effective because it diversifies the population of beneficial microorganisms in water. Effective microorganism products help plants grow well which leads to yield increases, longer cultivation periods, and high-quality crops. Together these improvements lead to richer harvests.

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