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# Effective microorganisms and their influence on vegetable production – a review

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SUMMARY
This review aims to describe the nature of effective microorganisms (EM) and how EM influence the growth, yield, quality, and protection of vegetable plants. EM comprise a mixture of live natural cultures of microorganisms isolated from fertile soils that are used to improve crop production. EM technology was developed over 40 years ago by Dr. Tero Higa in Japan. How EM act and interact in the soil-plant environment to suppress plant pathogens and disease, to conserve energy, to solubilise soil minerals, to aid the balance and ecology of soil microbes, and to improve photosynthetic efficiency and biological nitrogen fixation are described. In 70% of published studies, it was concluded that EM had a positive effect on the growth of vegetables, while, in the other 30%, they had no significant influence. In this investigation, among 22 reports on the effects of EM on the yields of vegetables, 84% were positive, 4% were negative, and 12% showed no significant influence. It is concluded that EM can improve the quality and yield of vegetables by reducing the incidence of pests and diseases, and by protecting against weeds, thereby contributing to sustainable agriculture.

Effective microorganisms (EM) consist of a mixture of live cultures of microorganisms, isolated from naturally fertile soils, that are useful during crop production (Mohan, 2008). The principal activity of EM appears to be to increase the bio-diversity of soil microflora, thereby increasing crop yields. Photosynthetic bacteria, the major components of EM, are reported to work synergistically with other microorganisms to support the nutritional requirements of plants and to reduce the incidence of pathogenic microorganisms (Condor *et al*., 2007). Subadiyasa (1997) described EM technology as a technique that supported “natural farming”. The rationale behind EM is based on the concept of inoculating mixed cultures of beneficial microorganisms into the soil to create an environment that is more favourable for the growth and health of plants. EM may interact with the soil-plant ecosystem to suppress plant pathogens and other agents of disease, to solubilise minerals, to conserve energy, to maintain the microbial and ecological balance of the soil, to increase photosynthetic efficiency, and to fix biological nitrogen (Subadiyasa, 1997).

This review aims to illustrate the nature of EM and to describe how EM can influence the growth, yield, quality, and protection of major temperate vegetable crops.

## GENERAL OVERVIEW

### *The history of EM*

EM technology was first developed in the 1970’s (Higa, 2012). Initially, microbes from various ecosystems were isolated, then remixed. However, due to a repeated lack of success, some microbes were eliminated and simpler mixtures were tested on plants. Finally, a mixture containing primarily lactic acid bacteria, photosynthetic bacteria and yeasts maintained at pH 3.5, was developed in the late 1970’s. The concept was first reported in 1986 at an IFOAM conference (Higa, 2012). Considerable interest then led the developers of EM to promote the technology more widely. A beneficial commercial co-operation between Kyusei Nature Farming and EM Technology soon resulted in positive effects in Japanese ecosystems (Higa, 2012). The First Conference on Kyusei Nature Farming was held in Khon Kaen, Thailand in 1989, with further meetings held at 2-year intervals in Brazil, the USA, France, Thailand, and South Africa, encompassing all five continents, then in Oceania and the Pacific countries. To date, EM have been adopted in over 100 countries, not only for experimentation, but also for commercial production and environmental management (Higa, 2012).

EM consist of mixed cultures of beneficial, naturally-occurring micro-organisms such as photosynthetic bacteria (e.g., *Rhodopseudomonas palustris*, *Rhodobacter sphaeroides*), lactobacilli (e.g., *Lactobacillus plantarum*, *L. casei*, and *Streptococcus lactis*), yeasts (e.g., *Saccharomyces* spp.), and Actinomycetes (*Streptomyces* spp.; Javaid, 2010). Condor *et al*. (2007) described these microorganisms as follows: photosynthetic bacteria (phototrophic bacteria) are independent self-supporting microorganisms. They synthesise amino acids, nucleic acids, bio-active substances and sugars, using substances from root secretions, organic matter (carbon), sunlight, and geothermal heat from the soil as sources of energy. Unlike plants, they use energy from the infrared band of solar radiation (700 – 1,200 nm) to produce organic matter, thereby increasing the efficiency of plant growth.

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The metabolites thus produced can be absorbed by plants directly, or act as substrates for other bacteria, thereby increasing the bio-diversity of the soil microflora.

Adding photosynthetic bacteria to the soil enhances other EM. For example, levels of vesicular-arbuscular mycorrhiza (VAM) in the rhizosphere were increased due to the availability of nitrogenous compounds (amino acids) for use as substrates after secretion by photosynthetic bacteria (Condor *et al*., 2007). VAM increase the solubility of phosphates in soils, thereby supplying bio-available phosphorus to plants. VAM can co-exist with *Azotobacter*, a nitrogen-fixing bacterium, and enhance the nitrogen-fixing ability of legumes (Condor *et al*., 2007).

Lactic acid bacteria produce lactic acid from sugars. Lactic acid acts to sterilise soils and suppress harmful microorganisms, as well as increasing the decomposition of organic matter (Condor *et al*., 2007). Lactic acid bacteria enhance the breakdown of organic matter such as lignin and cellulose, and ferment these materials more rapidly. Lactic acid bacteria have the ability to suppress the growth of *Fusarium* ssp., harmful microorganisms that cause diseases during continuous cropping. Under suitable conditions, *Fusarium* spp. cause an increase in harmful nematodes. Nematodes gradually disappeared as lactic acid bacteria suppressed the growth of *Fusarium* (Condor *et al*., 2007).

Yeasts synthesise anti-microbial substances that also promote plant growth from amino acids and sugars secreted by photosynthetic bacteria, organic matter, and plant roots. Bio-active substances such as photohormones and enzymes, produced by yeasts, can promote active cell and root division. These secretions also provide useful substrates for EM such as lactic acid bacteria and actinomycetes (Condor *et al*., 2007).

Actinomycetes, with a structure intermediate between bacteria and fungi, produce anti-microbial substances from the amino acids secreted by photosynthetic bacteria and from soil organic matter. These substances can suppress harmful fungi and bacteria. Actinomycetes can co-exist with photosynthetic bacteria. Thus, both can act synergistically to enhance the quality of the soil environment by increasing the anti-microbial activity of the soil (Condor *et al*., 2007).

The following beneficial influences of EM have been described (Anon, 1995):

- EM promote germination, flowering, fruiting, and ripening in plants.
- EM improve the physical, chemical, and biological environments of the soil and suppress soil-borne pathogens and pests.
- EM enhance the photosynthetic capacity of crops.
- EM ensure better germination and plant establishment.
- EM increase the efficacy of organic matter as a fertiliser.

Due to the beneficial effects of EM, crop yields and quality can be enhanced. EM are not classified as a pesticide, and do not contain chemicals that could be construed as such. EM are microbial inoculants that function as biological control agents to suppress and/or control pests through the introduction of beneficial microorganisms into the plant-soil environment. Pests and pathogens are suppressed or controlled by the competitive and/or antagonistic activities of those microorganisms present in the EM inoculant (Anon, 1995).

*The concept of EM*

The mechanisms by which EM are claimed to act and interact in the soil-plant environment are shown in Table I.

Soil microorganisms can be broadly classified into decomposing or biosynthetic microorganisms. Decomposing microorganisms are further sub-divided into taxa that perform oxidative and fermentative decomposition. The fermentative group is further divided into those causing useful fermentation (simply called fermentation) or harmful fermentation (putrefaction). The biosynthetic microorganisms can be sub-divided into taxa that have the physiological abilities to fix atmospheric nitrogen into amino acids, and/or carbon dioxide into simple organic molecules through photosynthesis. Figure 1 shows a simplified flow chart of the transformations of organic matter catalysed by soil microorganisms that can lead to the development of disease-inducing, disease-suppressing, zymogenic, or synthetic soils (Higa and Parr, 1994).

Research has shown that EM must be applied together with organic matter. They can be applied as a liquid, or mixed with nutrient-rich organic matter as a fermented compost (called 'Bokashi' in Japanese). The benefit of applying EM plus organic matter lies in the ability of the EM to ferment organic matter, thereby releasing nutrients and nutrient-rich organic acids which can be used by plants. Derivatives of EM in which leaf material, especially leaves from spice or medicinal plants, are fermented by the microbial solution are claimed to offer additional prophylactic benefits to plants (Higa, 2012). EM can also be applied directly onto crop plants. Research has shown that this can enhance physiological parameters such as photosynthesis, which results in higher crop yields, a key factor in organic farming (Higa, 2012).

TABLE I

*Functions of beneficial and harmful soil microorganisms that affect soil quality, crop production, and plant health (Higa and Parr, 1994)*

| Beneficial effects | Harmful effects |
|---|---|
| Decomposition of organic wastes and residues | Induction of plant diseases |
| Recycling and increased availability of plant nutrients | Stimulation of soil-borne pathogens |
| Production of antibiotics and other bioactive compounds | Immobilisation of plant nutrients |
| Complexing heavy metals to limit plant uptake | Inhibition of seed germination |
| Production of polysaccharides to improve soil aggregation | Inhibition of plant growth and development |
| Fixing of atmospheric nitrogen | Production of phytotoxic substances |
| Suppression of soil-borne pathogens | |
| Degradation of toxic compounds including pesticides | |
| Production of simple organic molecules for plant uptake | |
| Solubilisation of insoluble sources of mineral nutrients | |

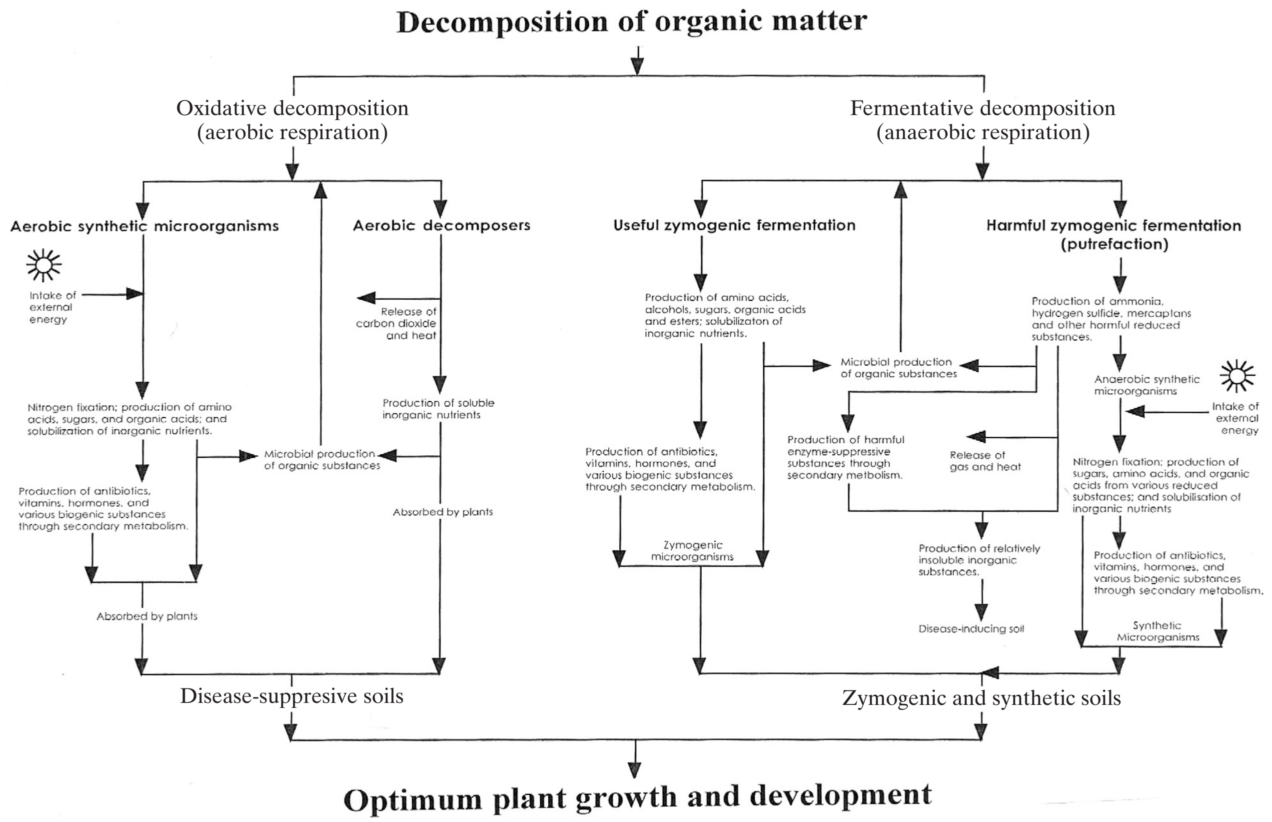


FIG. 1
Transformations of soil organic matter by soil microorganisms leading to the development of disease-inducing, disease-suppressive, zymogenic (fermenting), or synthetic soils (from Higa and Parr, 1994).

*EM in crop production*:

The original uses of EM were in agriculture (Sangakkara, 2012a). EM were first applied to enhance the productivity of organic or natural farming systems. EM were applied directly into the organic matter being added to fields, or into composts, which reduced the time required for the preparation of this bio-fertiliser. EM were also added in the form of 'Bokashi' (a compost made with waste material such as rice husks and sawdust as a carrier) or mixed with nitrogen-rich materials such as rice, corn, wheat bran, fish meal, or oil cakes. The benefits of EM have been attributed to many factors. These include a greater release of nutrients from organic matter when composted with EM, and/or enhanced photosynthesis and protein synthetic activity. Studies have also identified greater soil and plant resistance to water stress, higher rates of mineralisation of carbon, improved soil properties, and better penetration of plants roots following the application of EM (Sangakkara, 2012a). The impact of EM in promoting plant growth by controlling or suppressing pests and diseases has also been reported in many countries (Sangakkara, 2012a).

For many years, soil microbiologists and microbial ecologists have differentiated between beneficial or harmful soil microorganisms according to their function, and how they affect soil quality, plant growth and yield, and plant health. As shown in Table I (Higa and Parr, 1994), beneficial micro-organisms are those that can fix atmospheric nitrogen, decompose organic wastes and residues, detoxify pesticides, suppress plant diseases and soil-borne pathogens, enhance nutrient cycling, and produce bio-active compounds such as vitamins, hormones, and enzymes that stimulate plant growth.

Research has also shown that inoculation of soil/plant ecosystems with cultures of EM can improve soil quality and soil health. Improved soil quality is usually characterised by increased infiltration, aeration, aggregation, and organic matter content and by decreased bulk density, compaction, erosion, and crusting (Higa and Parr, 1994).

There are no reports on reliable tests for monitoring the establishment of mixed cultures of beneficial microorganisms after the application of EM to soils. The desired effects appear only after the EM become established, become dominant, and remain stable and active in the soil. In some soils, a single inoculation of EM may be sufficient to produce the desired results, while in other soils, even repeated applications of EM appear to be ineffective. Repeated applications, especially during the first cropping season, can facilitate earlier establishment of the introduced EM (Higa and Parr, 1994).

*Application of EM*:

According to Ncube (2008), EM are effective during crop production and are environmentally safe, with different commercial brands or formulations of EM using local microbial isolates being produced in approx. 40 countries, worldwide. EM are used in different areas, ranging from agricultural and horticultural cropping, environmental management, animal production, and aquaculture (Ncube, 2008). Different formulations of EM have been applied in these areas in different ways, as discussed in the following sub-sections.

1. *Inoculation of EM into the soil*: Different preparations of EM can be applied either as a soil drench or spread directly onto plants during crop production. When inoculating into the soil, a 1:500 dilution of EM multiplied in water, or EM in FKG (fermented kitchen garbage) is used. When using EM in FFW (fermented fish waste), or EM in FCM (fermented chicken manure), a 1:300 dilution is advisable. Up to 2.5 metric tonnes (MT) $ha^{-1}$ of 'Bokashi' is usually applied to soils. Dosages > 2.5 MT $ha^{-1}$ are detrimental to plants due to high levels of organic acids which can damage their roots. 'Bokashi' is usually applied to the soil 10 – 14 d before planting and is placed 10 – 15 cm away from the roots (Ncube, 2008)
2. *Spraying EM on leaves*: Spraying EM on the leaves of plants can serve as a prophylactic treatment for disease and insect control. Spraying often starts early in the growing season and is continued until harvest. Dilutions of 1:1000 of EM multiplied in water, or EM-5 (Agri Partners OÜ, Tartu, Estonia), or a mixture of different EM formulations are advised, although 1:500 or 1:2,000 dilutions can also be used (Ncube, 2008).
3. *Soaking seeds in EM*: Before planting, seeds can be soaked in a 0.1% (w/v) suspension of EM in water. Small seeds are soaked for approx. 30 min, and larger seeds for 4 – 6 h. After soaking, the seeds are dried in the shade to reduce the chance of them sticking together (Ncube, 2008), then sown in the field.
4. *EM irrigation (fertigation)*: EM or various EM formulations multiplied in water are frequently applied to the soil via the irrigation water. Dilutions of EM multiplied in water from 1:1,000 to 1:5,000 or EM in fermented plant extract (FPE) are used (Ncube, 2008).
5. *Insect control*: EM can also be used as a bio-control agent to suppress and control insect pests through the introduction of beneficial microorganisms into the planting environment. The odours emitted by EM may repel harmful insects and/or serve as a prophylactic spray. EM in FPE or EM-5 have been used as insect repellents, and are not toxic to ladybirds, spiders, dragonflies, or frogs (Ncube, 2008). EM attracts fruit flies and affects mostly the females which later become sterile (Ncube, 2008). Pests and pathogens are suppressed or controlled through natural processes by increasing the competitive and antagonistic activities of the microorganisms present in EM inoculants (Ncube, 2008).

*The amounts of EM to be applied to vegetable crops*

Depending on the amount of waste to be converted into humus, the dose of EM-Naturally Active (Agri Partners) required ranges from 20 – 40 l $ha^{-1}$ or 1 – 3 l $ha^{-1}$ of EM-5, depending on the severity of any fungal diseases. EM preparations are mixed into the soil by ploughing. The minimum Spring spray dose of EM-Naturally Active is 20 l $ha^{-1}$, or 1 l $ha^{-1}$ of EM-5. If an Autumn treatment had not been performed, these doses should be at 40 l $ha^{-1}$ or 3 l $ha^{-1}$ of EM-5. The purposes of these doses are to antagonise soil pathogens and to inoculate the soil with EM. If the soil contains high levels of non-decomposed organic matter, the dose of EM-Naturally Active (Agri Partners) may be increased by a further 20 l ha-1. It is best to conduct such treatments when the soil temperature exceeds 6ºC (usually in late-March or early-April), and to mix the EM preparation into the soil by harrowing (Table II).

TABLE II
*Applications of EM*

| Soil conditions | Amount of Naturally Active EM‡ to be applied to the soil (l $ha^{-1}$) |
|---|---|
| Humus content > 5%; pH 7.0; annual application | 40 |
| Humus content approx. 3%; pH approx. 6.0 | |
| First year | 80 |
| Second year | 60 |
| Third year | 40 |
| Humus content < 1%; pH < 5.0 | 100¶ |

‡Naturally Active-EM is provided by Agri Partners OÜ, Tartu, Estonia.
¶Use simultaneous organic fertilisation and/or green fertilisation. Maintain the dose until improvement is observed, then gradually decrease.

Among the preparations EM tested, a mixture of activated EM and EM-5 was shown to be most effective at accelerating the decomposition of organic matter and mineralisation in the soil (Zydlik and Zydlik, 2008).

## GROWTH FACTORS

Data from a randomised experiment showed statistically significant differences to indicate that EM-Naturally Active (Agri Partners) increased seed germination and vigour in carrot, cucumber, pea, beet, and tomato (Siqueira *et al*., 2012). Seed germination and the growth of cowpea plants were promoted by this EM formulation at a dilution of 1:500, compared to plants fertilised with a slurry of cattle manure (Sangakkara and Weerasekera, 2012).

The application of EM appeared to promote early fruiting and root growth in tomato (Ncube *et al*., 2011), but not leaf or shoot development in Chinese cabbage (In-Ho and Ji-Hwan, 2012). A combined application of inorganic phosphate fertiliser ($P_2O_5$) at 0, 75, or 150 kg $ha^{-1}$ and EM-Naturally Active at 50 l $ha^{-1}$ enhanced vegetative and reproductive growth in cabbage (Zahoor *et al*., 2003). Chantal *et al*. (2010) showed increased leaf areas and improved photosynthesis in cabbage treated with a 1:1,000 dilution of EM.

Sangakkara (2012) stated that EM had no significant effect on the growth of bush bean in chemically-fertilised plots. In contrast, the growth of bush bean was enhanced by EM when grown in the presence of organic amendments, especially those with low C:N ratios. Although there was no significant difference in plant height, treatment with 'Bokashi' resulted in stems with the highest diameter, followed by use of a chemical fertiliser (Nakano, 2007).

On the other hand, Puranapong and Siphuang (2001) studied the use of mixtures of EM with chicken, quail, pig, or cow manure on the growth of yard-long bean and snake eggplant, but found no significant difference in any plant growth parameter.

A search of ten published papers revealed that the application of EM had a positive effect on the growth of vegetables in 70% of cases, while in 30% of cases it did not make any significant difference.

## VEGETABLE AND CROP YIELDS

Applying EM plus molasses increased onion yields by 29% (on average), and the proportion of the highest grade of onions by 76%. EM also increased pea yields by 31% (Daly and Stewart, 1999). Javaid (2006) showed that foliar applications of EM, combined with proper soil amendments, improved nodulation and yields in pea. The application of EM plus an NPK amendment enhanced grain yields significantly (by 48%) without *B. japonicum* inoculation (Javaid, 2009). Javaid (2006) also showed that foliar applications of EM enhanced nodulation in pea, using an NPK amendment, causing a 217% increase in nodule numbers and a 167% increase in nodule biomass. Similarly, Javaid (2006) reported an increase in pea grain yield of 126% following an NPK amendment, and of 145% following a green manure amendment after foliar application of EM. Sangakkara (2012) stated that bush bean yields and nodulation were enhanced by EM in the presence of organic amendments, especially those with low C:N ratios.

Mohan (2008) evaluated the traditional Ayurvedic growth-promoters, Panchagavya and Amrit Pani, by comparing them with 'Bokashi' made using EM technology. The results indicated higher yields and lower glycoalkaloid contents in 'Bokashi'-treated tomatoes, followed by Panchagavya. EM inoculation in chicken manure increased photosynthesis and fruit yields in tomato plants (Xu *et al.*, 2001). In tomato, data from early field trials showed that 'Bokashi' or EM-Naturally Active, used singly or in combination, or in combination with inorganic fertiliser, significantly increased mean fruit weights over the untreated controls and increased total marketable yields harvested over the cropping season (Escano, 1996). EM applied with a green manure (e.g., *Gliricidia* leaves) also significantly increased tomato yields throughout this study. In year-3, tomato yields due to EM were comparable to those obtained with a chemical fertiliser (Marambe and Sangakkara, 1996). Zaenudin (1993) concluded that EM were needed in Indonesia because EM increased tomato production. The lower numbers of tomato fruit per plant following application of EM in a greenhouse resulted in a higher average fruit weight possibly due to more assimilates being partitioned to fewer fruit (Ncube and Calistus, 2012).

Foliar applications of EM in FPE, or EM-5 had a positive effect on the yields of organically grown cucumber (Condor *et al.*, 2007; Table III).

Chantal *et al.* (2010) found that EM increased cabbage yields by improving photosynthesis. Yadav (2012) concluded that, when EM was applied as a foliar spray at an appropriate concentration and frequency, crop yields were increased significantly. Radish yields of 70.5% over untreated controls were recorded in test plots sprayed with EM (a 1:500 dilution) at 15-d intervals. Foliar spray applications of EM (at 1:500) at 15-d intervals resulted in 91.6% higher cabbage yields over non-treated controls. Cabbage yields in plots sprayed with a 1:1,000 dilution of EM at 45-d intervals were the lowest, among the EM sprayed plots, but were still 9.5% higher than in the controls. This indicates that EM have a positive impact on the growth and yields of vegetables (radish and cabbage). Results from cabbage studies showed that plots treated with EM ('Bokashi') gave significantly higher yields than NPK plus chicken manure (Escano, 1996). Seed pod, plant biomass, and microbial density showed maximum responses to 'Bokashi' (Nakano, 2007). Maximum cabbage seed yields were recorded following the application of 150 kg $P_2O_5$ ha$^{-1}$ combined with EM (Zahoor *et al.*, 2003).

Kim *et al.* (2012) showed that treatments with EM and EM-fermented compost in a greenhouse increased the yields of spinach and costmary by 10.4 – 24.8% and by 19.4 – 32.9%, respectively. Similarly, Autumn yields of Chinese cabbage and radish were increased by 23.5 – 57.9% and 38.8 – 47.2%, respectively, in the field.

In contrast, applications of "microbial tea" (a form of EM; Knewtson *et al.*, 2009) did not affect collard or spinach yields, and did not support the hypothesis that EM improves the uptake of plant nutrients. Moreover, soil microbe respiration and biomass were unaffected after two or three of these applications of "microbial tea" (Knewtson *et al.*, 2009). In tomato, applications of EM alone, or in combination with other amendments, depressed yields, possibly because of an outbreak of early and late blights, which affected the EM-treated pots first (Ncube *et al.*, 2011). In lettuce, treatment with 'Bokashi' or EM-Naturally Active did not show significant differences in terms of the numbers or weights of heads (Escano, 1996).

In summary, our findings indicate that in 22 reports, the application of EM affected vegetable yields 84% positively and 4% negatively, while 12% had no significant influence.

TABLE III
*Effect of applications of EM on organic cucumber yield and pickle worm infection*[‡]

| Treatment[¶] | Yield (g m$^{-2}$) | Fresh weight (g) | Infected fruit yield (%) | Non-infected fruit yield (g m$^{-2}$) |
|---|---|---|---|---|
| Water only (Control) | 3.29 a | 222.3 a | 80.0 a | 629.0 a |
| EM in FPE | 4.41 b | 235.6 b | 36.0 b | 2,800.0 b |
| EM in FPE+EM-5 | 4.81 b | 232.8 b | 9.0 c | 4,415.0 c |

[¶]Three foliar treatments (with four replications) were applied in the same volume every 4 d. Treatments were control (no application), EM in fermented plant extract (FPE) (dilution 1:500); or EM in FPE (dilution 1:500) with EM-5 (dilution 1:500).
[‡]Data are from Condor *et al.* (2007). Mean values in each column followed by a different lower-case letter were statistically different.

## CROP QUALITY

Inoculation with EM increased ascorbic acid (vitamin C) concentrations in tomato fruit in 'Bokashi' and in chicken manure treatments (Xu *et al.*, 2001).

Untreated (control) chard plants had higher water contents than plants treated with EM or 'Bokashi' plus EM, or "Greengold" (Daiss *et al.*, 2008). In contrast, chard plants treated with 'Bokashi' had lower ascorbic acid contents than control plants (Daiss *et al.*, 2008). Chard plants treated with 'Bokashi' plus EM had higher phosphorus and magnesium contents than control plants (Daiss *et al.* 2008). The application of EM to plants resulted in higher levels of calcium compared to non-treated plants (Daiss *et al.*, 2008).

EM significantly enhanced the NPK nutrition of mung bean plants following farmyard manure amendment, both at the flowering stage and at maturity. However, in NPK-amended soil, the application of EM enhanced NPK nutrition markedly only at a later growth stage (Javaid and Bajwa, 2011).

## PLANT PROTECTION

Escano (1996) reported that 'Bokashi' alone, or in combination with EM, reduced the incidence of soft rot disease in lettuce compared with usual commercial practice (i.e., applying 240-60-60 NPK plus chicken manure).

Studies on applying EM to achieve more sustainable agriculture showed that these microorganisms act in a holistic manner, changing the chemical and physical properties of the soil, mainly the aggregation of particles that causes rapid drying of the surface layer. Drying the superficial soil layer delayed fungal sporulation, increased the abortion of apothecia, and suppressed *Sclerotinia* in lettuce by increasing the competition for nutrients, enhancing antibiosis, and reducing the sclerotia bank in the soil (Tokeshi *et al*., 2010).

Controlling pathogens such as *Sclerotium rolfsii*, *Fusarium* spp., *Pythium* spp., *Phytophthora* spp. and *Rhizoctonia solani* that cause stem and root rot in lettuce in disease-suppressive soils may be due to changes in soil properties and the soil environment that enhance aeration and drying. This, in turn, probably increases the activity of competitive saprophytic microorganisms which are better adapted to a drier superficial soil layer, despite wide variations in soil water content. However, this hypothesis requires further study to confirm its validity (Tokeshi *et al*., 2010).

Similarly, the incidence of soft rot disease on cabbage was lower on plants treated with EM and 'Bokashi' (Escano, 1996).

Xu *et al*. (2012) suggested that the improved nitrogen metabolism in 'Bokashi'-fertilised tomato plants accounted for their higher resistance to *Phytophthora*. Zaenudin (1993) concluded that EM were needed for pest management in tomato cultivation in Indonesia. Marambe and Sangakkara (1996) found that organic amendments alone suppressed weed growth during tomato production, and variations between years were not significant. However EM applied with organic amendments enhanced weed growth in year-1, which then declined significantly in later years.

Foliar applications of EM in FPE, or EM-5 reduced pickle-worm infection in organically grown cucumber (Condor *et al*., 2007; Table III). EM in FPE also proved best to control insects (Condor *et al*., 2007). In contrast, Thaveechai *et al*. (1996) found that EM or SUTOJU (a non-specified pesticidal formulation) were not effective against bacterial, fungal, or viral diseases in tomato.

A farm preparation of the herb, *Zanthoxylum,* fermented with an EM inoculant, effectively controlled aphids on *Brassica*, while ginkgo and neem extracts effectively controlled whitefly on tomato (Xu *et al*., 2008).

Thus, vegetables can be protected by the use of EM to reduce the incidence of disease and pests, and to protect against weeds.

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