In: Organic Fertilizers
Editor: Rajeev Pratap Singh
ISBN: 978-1-62081-422-2
© 2012 Nova Science Publishers, Inc.

No part of this digital document may be reproduced, stored in a retrieval system or transmitted commercially in any form or by any means. The publisher has taken reasonable care in the preparation of this digital document, but makes no expressed or implied warranty of any kind and assumes no responsibility for any errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of information contained herein. This digital document is sold with the clear understanding that the publisher is not engaged in rendering legal, medical or any other professional services.

Chapter 8

A PROSPECTUS FOR BIO-ORGANIC FERTILIZER BASED ON MICROORGANISMS: RECENT AND FUTURE RESEARCH IN AGRICULTURAL ECOSYSTEM

Yonghong Wu [*] ***and Linzhang Yang***
State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Sciences, Chinese Academy of Sciences, Nanjing, China

ABSTRACT

The long-term use of large quantities of inorganic fertilizer is usually associated with environmental problems such as the degradation of soil quality, resulting in the decline of agricultural products. Hence, an environmentally benign and relatively inexpensive organic fertilizer has been developed.

This review focuses on response of bio-organic fertilizer based on microorganisms (BFM) to environmental variation. A specific objective of this review is to identify the BFM - insightful concepts and environmental relationships in agricultural ecosystem. Contributors to microbial fertilizer (MF) have led the field in testing and expanding concepts in agricultural ecosystem. However, many detailed topics about organic fertilizer remain unexplored and underexplored, e.g., BFM in agricultural ecology for benefiting ecosystem. These topics include the specific define and composition of BFM, resource reuse, benefit responses to flora and fauna, allelopathy, competitive inhibition and exclusion. Under the heavy situation of nonpoint source pollution across the world, the application of BFM was introduced in this field in preventing the output of excessive nutrients in agricultural ecosystem. In this review, the BFM type, development and application in the field of controlling nonpoint source pollution in China will be summarized briefly.

Based on the theory of hierarchical eco-restoration, both the decrease of unnecessary nutrient inputs and the reuse of natural resource are the primary aims. The development BFM is of practical significance in meeting these primary aims, thereby providing a beneficial transitional habitat for the restoration of agricultural ecosystem. Overall, the

[*] Corresponding author email: yhwu@issas.ac.cn.

introduction of the BFM will provide a robust insight to expand the current understanding of organic fertilizer.

Keywords: Bio-organic fertilizer; microorganisms; nonpoint source pollution

1. THE HISTORY FROM MF TO BFM

The prototype of microbial fertilizer is that soil microorganisms were used for enhancing agricultural yield due to the benefit of bacteria in the soil. In ancient times, the farmers in Rome had found out that the product of rice increased as long as legume plants had been planted at the rice-cropland, which resulted from the enrichment of bacteria (Zhuang, 2003). In the early 1900s, in order to enhance agricultural products, some U.S. and German farmers input the soils that had been planted with legume or alfala plants into some newly reclaimed croplands (Crews and Peoples, 2004). In 1838, J. B. Boussingault, a France agricultural chemist, found that nitrogen could be fixed by legume plants. He then built the first agricultural field experimental station at 1843 and analyzed relevant parameters (Manlay et al., 2007). Under the conditions of sand culturing legume plants between 1886 and 1888, H. Hellriegal, a German agriculturist, demonstrated that the nitrogen in the air could be fixed as long as *Rhizobium* formed (Fogarty, 1992). A Holland researcher, Mr. M.W. Beijerinck successfully isolated *Rhizobium* in 1888, representing a breakthrough in terms of microbial fertilizer (Rodelas et al., 1999).

From then on, many microbial fertilizer products were widely applied in agriculture across the world. The first product of microbial fertilizer based on a kind of soil bacteria was sold by a U. S. company in 1898 (Arvanitoyannis, 2008). In the early 1900s, some organic fertilizers based on legume root *Rhizobium* were produced (Amarger, 2001). In 1930s, many studies concerning self-fixed-nitrogen bacteria had been conducted by scientists in many countries such as U.S. and Soviet Union researchers (Bowen and Rovira, 1999). Then a combined fixed-nitrogen-system in corn roots was discovered by China and Brazil researchers (Oelofse et al., 2010). Thereafter, the combined fixed-nitrogen-systems in the rhizospheres of rice, cane and some tropic pasturage crops were also found (Ying et al., 1992). The nitrogen-fixed activities in these combined fixed-nitrogen-systems existed widely were proved strong. In the middle of 1980s, the organic fertilizer based on nitrogen-fixed bacteria started to be applied in plot and field experiments in U.S. and Israel (Ladha et al., 2005). With the development of the fertilizer based on nitrogen-fixed bacteria, the fertilizers based on phosphorus/potassium-fixed bacteria have been also arisen in 1960s (Epstein, 2003; Bao et al., 2007).

A kind of fertilizer based on cyanobacteria (blue-green algae) have been developed and applied extensively in rice cropland in Asia since 1940s, which was defined as bio-fertilizer (Irisarri et al., 2001). This bio-fertilizer still plays an important role in improving rice high yield and maintaining soil quality in long-term. Investigations have been under progress at the Central Rice Research Institute, Cuttack, since 1961 on the role of blue-green algae in augmenting the fertility of rice soils and for increasing rice production.

Some of the results have already been reported (Relwani, 1963, 1965; Relwani and Subrahmanyan, 1963; Rewani and Manna, 1964; Subrahmanyan et al., 1964a, b, 1965). The

nitrogen-fixing capacity, the extra-cellular nitrogen liberated and organic matter produced have also been investigated (Subrahmanyan and Sahay, 1964, 1965).

In recent years, much attention has paid to the complex organic fertilizer based on different microorganisms. Heterocystous nitrogen-fixing blue-green algae consist of filaments containing two types of cells: the heterocysts, responsible for ammonia synthesis, and vegetative cells, which exhibit normal photosynthesis and reproductive growth. This unique biological system could be used for the conversion of solar energy into organic fertilizer, through cultivation of these algae in open ponds (Benemann, 1979). Complex organic fertilizer comprising of daily organic manure plus chemical fertilization of three earthen provided an average of 3 g carbon and 0.3 g nitrogen and approximately 0.3 g phosphorus/m^2 per day. Twenty-four-hour net primary production added an average of 4.0 algal carbon/m^2 (Schroeder et al., 1990).

2. THE DEFINITION OF BFM

BFM is defined as a kind of new organic fertilizer comprising of specific living microorganisms (Zhang et al., 2005). The microorganisms may be heterotrophic or phototrophic microorganisms or their complex mixture, including algae, bacteria, protozoa, metazoan, epiphytes and detritus (Azim, 2005).

In this definition mentioned above, it is specifically indicated that the BFM is a kind of new organic fertilizers and the component of BFM must include some living microorganisms. When BFM is applied in the soils in cropland or in pond for fish cultivation, the living microorganisms in the BFM will activate (or adjust or regular) the environmental conditions such as increasing the soil porosity and affecting the nutrient (e.g. phosphorus) circle, and then in potential in improving the qualities of agricultural product and eco-environment.

Compared with the conversional inorganic and organic fertilizers, a series of benefits might occur after the BFM is applied in the soils in cropland, promoting the agricultural ecosystem in a more stable and harmonious state.

The application of BFM not only increases the nutrient level but provides all kinds of necessary element for crop growth. Moreover, the advantage of the BFM can enhance the activity of beneficial soil organisms, depleting the excessive nutrient in some context, avoiding many malpractice caused by inappropriate use of fertilizers.

The BFM can accelerate the transformation of soil organic matter into humus matter, increase the granular structure of soils, enhance the capacity of maintaining fertility and water, activate the nutrients fixed by soils and then improve the efficiency of fertilizers.

In addition, the microorganisms BFM might produce some beneficial secondary materials such as growth-stimulating hormone, Indole acetic acid (IAA), Gibberellic acid (GA) and many kinds of enzymes. These favorable materials might help to transform nutrients, decrease the occurrence of soil-borne disease, and restore the polluted soils.

Thus, it is an excellent option that the BFM is a kind of ideal fertilizer for the development of green- and organic- agriculture. In a word, the development of the BFM is of great potential and practice in the sustained agricultural progress, thereby leading to a large increase of agricultural efficiency.

3. THE BENEFITS TO AGRICULTURAL ECOSYSTEM

Many kinds of living microorganisms such as algae, bacteria, protozoa, metazoan, epiphytes and detritus live at the BFM, this is because the BFM is the substrates (or/and habitats) for these microorganisms. As a result, the application of the BFM has great potential to benefit the agricultural ecosystem, which is summarized as follows.

Firstly, due to different microorganisms resided at BFM, the use of the BFM will affect the prosperity of the soils, change the nutrient circle and optimize the structure (including composition and temporal-spatial characteristics) of soil ecosystem, thereby affecting soil health. Organic fertilizers, which mainly come from crop residues like rice bran, various oilseed cakes and animal byproducts like meat bone meal, blood meal, fish meal and crab meal, are sometimes distinguished from animal manure or compost based on animal waste (Lee, 2010). They contain specifically high levels of nutrients, e.g. N in oilseed cakes and blood meal and P in rice bran and meat bone meal, and are also high in organic matter content and a variety of micronutrients in general (Blatt, 1991; Cayuela et al., 2008), so that they have been widely used as alternative fertilizers for organically grown fields. Fertilization such as the application of BFM is one of the soil and crop management practices which exert a considerable influence on soil quality such as soil microbial properties, carbon contents, enzyme activities etc (Li et al., 2008). Various organic materials have been recognized as soil amendments and disease controllers, including the control of brown spot disease and augmentation of bacterial numbers by rice bran (Osunlaja, 1989) and the increase in plant growth and reduction of nematodes population by oil cakes (Khan and Saxena, 1997).

However, there have been problems like the accumulation of nitrate in vegetables and increased soil electronic conductivity in organic farming caused by excessive application of animal manure and organic fertilizer (Lee et al., 2004; Sohn et al., 1996). Such advantages and disadvantages mentioned above then might change the composition and temporal-spatial structures of soil ecosystem.

Secondly, it is likely that the application of BFM can prevent and/or carry some soil-borne disease due to the reaction among the microorganisms and the virus causing soil-borne disease. In other world, the BFM is actually a kind of bio-control agents (Zhao Q., et al., 2011). It is well known that biological control was an alternative strategy to control fusarium wilt disease (De Cal, 1995; Larkin and Fravel, 1998). Many antagonistic strains life in BFM have been proved to be effective bio-control agents in controlled laboratory or greenhouse conditions. *Rhizoctonia* (Muslim et al., 2003), *Bacillus* spp. (Gong et al., 2006), *Penicillium* spp. (Sabuquillo et al., 2006; Larena et al., 2003), *Aspergillus* spp. (Suárez-Estrella et al., 2007), *Trichoderma* spp. (Rojo et al., 2007) are a few among the long lists. There has been no bio-control agent that is universally effective everywhere, because of genetic diversity of responsible pathogens (Mishra et al., 2010).

In addition, antagonistic strains must be combined with a suitable substrate to improve their bio-control efficacy because they can survive for a long time after been applied to soil (El-Hassan and Gowen, 2006). BFM not only plays an important role in providing a suitable substrate, but also serves as a growth-promoting medium (Raviv et al., 1998). The microorganisms in compost may produce antibiotics (Whipps, 1997), compete for nutrients and ecological niches (Hoitink and Boehm, 1999), and/or induce resistance in plants (Weller et al., 2002). Therefore, the development of a new bio-organic fertilizer with improved field

consistency such as BFM is continuous process and mandatory for several and individual ecological niches.

Thirdly, the application of BFM is environmentally benign. Chemical fertilizers also tend to release many chemicals into the soil that contain nutrients helpful to soil but may also contain elements that are not easily biodegradable. These may go on to contaminate our lands and water. On the other hand, by definition, organic fertilizers such as the BFM almost always have only biodegradable contents. When lawns and gardens are sprayed with chemical fertilizers, one has to be careful that the family members, especially kids and pets who often play on lawns, do not ingest the harmful chemicals. However, there is no way of preventing local wildlife from being affected. Organic fertilizers raise no such concerns and can be used safely (http://edu.udym.com/five-advantages-of-organic-fertilizers/). In addition, the application of some organic fertilizer such as complex microbial fertilizer can be used against soil-borne plant pathogenic fungi (Yan et al., 2004).

Last but not the least, the application of the BFM is inexpensive and cost-effective. BFM can be produced at home or on farms by using a mix of chicken, pig, cow, sheep and horse manure along with wastes like leaves and dead plants. This is a great way of getting rid of wastes and certainly a cheaper alternative to purchasing chemical fertilizers (http://edu.udym.com/five-advantages-of-organic-fertilizers/).

4. THE CONTROL OF AGRICULTURAL NONPOINT SOURCE POLLUTION

About 30-40% amount of fertilizer such as nitrogen fertilizer applied into cropland just be absorbed in China's agricultural system, which is very low compared to the average fertilizer use efficiency (68%) in developed countries' agricultural system (Keeney, 1982; CAAS, 1994). This leads to the losses of more than half amount of fertilizer from cropland into downstream waters carried by runoff or leakage. The process of fertilizer loss is the main form of the occurrence of agricultural nonpoint source pollution. Thus, it is practically significant in preventing the movement of the excessive fertilizer via using environmentally benign bio-organic fertilizer.

The application of manures to agricultural fields also has the potential to contaminate surface waters through several different routes, including (1) runoff directly to drainage ditches and streams, and (2) percolation into groundwater that may later ''daylight'' as springs or contribute directly to surface waters through channels connecting groundwater and creeks, streams and sloughs (Dowd et al., 2008). After decades of working to reduce emissions from point sources, pollution from nonpoint sources now constitutes the number one source of pollution in waterways, with agriculture being the single largest contributor (EPA, 2000). How to best manage agricultural nonpoint source (NPS) pollution is still an issue of increasing importance to policymakers in China. Therefore, the development of new fertilizer with low pollution loads is practical to control agricultural nonpoint source pollution.

In China, many kinds of BFMs have been developed to substitute inorganic fertilizer and then decline the losses of nutrients. As a result, the intensity and frequency of agricultural

nonpoint source pollution discharge decreases. The populated example in China is that the bio-materials such as cyanobacteria were used for producing organic fertilizers.

Cyanobacteria are a phylum of bacteria that obtain their energy through photosynthesis (Stewart and Falconer, 2008). Cyanobacteria account for 20-30% of earth's photosynthetic productivity and convert solar energy into biomass-stored chemical energy at the rate of ~450 TW (Oren, 2004). Cyanobacteria utilize the energy of sunlight to drive photosynthesis, a process where the energy of light is used to split water molecules into oxygen, protons, and electrons. Due to their ability to fix nitrogen in aerobic conditions, cyanobacteria are often found as symbionts with a number of other groups of organisms such as fungi (lichens), corals, pteridophytes (*Azolla*), angiosperms (*Gunnera*) etc, even forming a kind of biofilm (Spolaore, et al., 2006). Therefore, cyanobacteria are used for the materials produced organic fertilizers.

The results showed that cyanobacteria in Dianchi Lake, West China is a kind of good raw materials for utilization (Table 1 and 2), such as fertilizer and feed.

Moreover, the concentration of heavy metals in cyanobacteria showed that the cyanobacteria could be used as fertilizer safely according to the national pollutants control standard in agriculture (Table 3).

Table 1. The nutrient content of cyanobacteria (%)

Protein	17.8-26.4	Fat	1.49-4.67	Fiber	12.6-19.3
Ash	13.8-20.0	N	1.56-8.14	P_2O_5	0.71-1.95
Fe	0.05-0.1	Mn	0.05-0.1	Ca	0.58-2.5
Mg	0.18-0.46	K2O	3.11-5.90	Na	0.12-0.93

Table 2. The nutrient content in cyanobacteria and other feeds (dry weight)

	Protein (%)	LYS (%)	MET (%)	Vitamin E (mg kg^{-1})
Cyanobacteria	24.2	1.16	0.31	> 50
Barley	10.8	0.37	0.13	38
Rice	8.5	0.29	0.14	13
Broomcorn	8.70	0.22	0.08	12
Chaff	12.1	0.86	0.25	
Bran	14.4	0.47	0.15	

Table 3. The content of heavy metals in cyanobacteria from Dianchi Lake, West China (mg kg^{-1} dry weight)

Elements	Stem	Leaf	Roots	Total plant
Zn	18.09	15.68	39.53	25.22
Cu	10.28	3.08	20.83	12.22
Pb	0.93	0.14	2.07	0.91
Cd	0.25	0.59	0.91	0.72
Cr	1.57	0.69	2.99	1.76
As	0.9	0.3	2.3	1.68
Hg	0.02	0.02	0.03	0.02

Table 4. Prescription of complex organic and inorganic fertilizers for various crops (Shen et al., 2005)

Sorts	Tobacco	Celery	Chinese Chives	Carnation
Urea	15	25	15	15
Uperphosphate	9	9	9	16
Ammonium phosphate	6	6	6	9
Potassium sulfate	20	10	10	10
Cyanobacterial biomass	50	50	60	50
Total	100	100	100	100
Organic matter (%)	35	35	35	35
Total maintain ($N+P_2O_5+K_2O$)	26.27	25.77	23.78	24.27

To remove the microcystins from cyanobacteria, the cyanobacteria were fermented under aerobic and anaerobic conditions sequentially. The residuals of the fermentation of cyanobacteria were used as the raw materials for producing organic fertilizers. To balance the nutrients for crop growth, some inorganic fertilizers were added into the organic fertilizer based on cyanobacterial biomass (Table 4). Then, it was called complex organic and inorganic fertilizer.

To test the effect of the complex organic and inorganic fertilizer based on cyanobacterial biomass, a series of field experiments had been conducted. The results showed that compared with efficiency of general compound fertilizes on the market, that of the organic and inorganic fertilizes from several cyanobacteria (*Microcystis*) were higher to the output of tobacco, celery leek and carnation. Dose of 900 kg/ hm^2 is best in tobacco experiments, and tobacco's yield, production value and fine tobacco ratio increased 7.28%, 5.04% and 19.81% , respectively; Treated with three doses of 600 kg/ hm^2, 900 kg/ hm^2 and 1200 kg/ hm^2, Chinese chives' output is higher than the control's, increased 9.5%, 17.1% and 16.3%, respectively; leek's high, leaf broad and yield increased 12.21% and 13.32% respectively, with treatment of 900 kg/hm^2, 1200 kg/hm^2 of cyanobacterial fertilizer; Output of Carnation arrived to 4865 bunch/100m^2, increased 11.6% compared with the control. No cyanobacterial toxin was determined in leek and soil, suggesting that the safety of cyanobacterial fertilizer (Shen et al., 2005).

During the organic fertilizer based on cyanobacterial biomass was applied in leek cropland, the losses of nitrogen and phosphorus was studied. The results showed that the application of organic fertilizer based on cyanobacterial biomass could decrease nitrification, leading to the decline of nitrate movement from soil into groundwater. Compared with the control, the nitrate concentration in leakage in the treatments with organic fertilizer based on cyanobacterial biomass was low by 32.9-60.2%. In addition, ammonia concentration in the runoff was reduced by 8.8-43.7% after the application of organic fertilizer based on cyanobacterial biomass. The losses of total dissolved phosphorus in the runoff declined from 12.3-53.6% after the leek cropland was applied the organic fertilizer based on cyanobacterial biomass.

Overall, the application of BFM such as the organic fertilizer based on cyanobacterial biomass not only solves the difficult problem of reducing the input of chemical fertilizer into cropland and then decline the output of agricultural nonpoint source pollution into downstream waters, but also improves environment, and increases benefits of society and economy.

CONCLUSION

Although the use of bio-organic fertilizer based on microorganisms in improving the productivity of crops and protecting soil quality is commonplace, so far, there is no new investigation to emerge from decades of research to intentionally use specific microorganisms or microbial aggregates (biofilms) for decrease nonpoint source pollution. Several proposals, including development of bio-organic fertilizer bases on microorganism biomass (or substrates), including microalgae and combinations of several microorganisms, have the best potential for future commercial use. So far, in terms of production of bio-organic fertilizer based on microorganisms, it is difficult to differentiate between the role of microalgae and other microorganisms, mostly bacteria.

Currently, there are major advantages to 'greener' technologies. The public, even in more developing countries in agriculture, is constantly demanding green technologies for most aspects of daily life. The common decontamination technologies, wastewater included, that produce more, or a different kind, of secondary pollution (like precipitation of phosphorus in nonpoint source wastewater by metal salts that are disposed of as a toxic waste in landfill) have a negative public perception. With public opinion on its side, it appears that the development and application of BFM is a prime candidate as a green technology.

From a scientific standpoint, the BFM development has many advantages:

(1) Its main advantage is that it controls and protects the dominant and always useful microorganism within the agricultural ecosystem itself. The microorganisms in the organism fertilizers, with usually superb ability to adopt the agricultural environments because of the organism fertilizers acting as their substrates, can be dominated within the agricultural ecosystem despite competition with other microorganisms present in the agricultural ecosystem.
(2) It is possible to maintain a sustained agricultural ecosystem using different microorganisms in the BFM to simultaneously treat several contaminants in the soils and then improve the soil quality. This will be useful, especially for recalcitrant compounds that require specialized microalgae for degrading the pollutant.
(3) The microorganisms in BFM (BFM as the substrates for Microorganisms) have better plasmid stability within the agricultural ecosystem, allowing successful use of genetically modified special microorganisms designed for specific cleaning purposes of polluted soils and avoiding the common failure of such genetically modified microorganisms in environmental systems. From a practical view, the microorganisms in BFM systems use solar energy and need relatively small amounts of other inputs for operation. They are relatively easy to handle on a large scale because they have been used by compound producing industries for a very long time.

BFM application in agricultural ecosystem without health hazards, are environmental friendly (promoting the image of the public/company/government that uses them), produce no secondary pollution, and the BFM application in large scale can decrease the output of nonpoint source pollution loads in intensive agricultural areas. In addition, the cost of BFM application is not expensive, about 1/3 cost of that of the chemical fertilizer.

It is assumed that the application of BFM will find its greatest usefulness when (1) several different contaminants in soils need to be treated simultaneously and the degraded soil quality needs to be improve in large scale; (2) the discharge of some pollutants such as output of nitrogen and phosphorus is very high, and the discharge modern of these pollutants is not fixed forms (including discharge intensity, frequency and time). That is, the heavy nonpoint source pollution in this agricultural ecosystem needs to be treated in source by applying BFM; or (3) when complex degrading processes are needed that require specialized microorganisms.

There are still a number of technical aspects of the application of BFM that could be developed, such as improvement of the component of the BFM to create ‘‘real substrate conditions” for the living microorganisms in BFM, development of more complex constitution of heterotrophic and heterotrophic microorganisms to maintain a steady ecological status in the BMF, optimizing selection of the proper microorganisms for specific applications such as removing or fixing some specific pollutants in soils, and decreasing the volume of BFM to transport and operate easily. Solving these shortcomings will enhance the future potential of the application of BFM in commercial agriculture.

ACKNOWLEDGMENT

This work was supported by the Innovative Project of Chinese Academy of Sciences (KZCX2-EW-QN401), the National Natural Science Foundation of China (41171363 and 41030640), and the Key Project of Basic Research, Yunnan Province, China 41030640), and the Key Project of Basic Research, Yunnan Province, China (2009CC006). The authors sincerely appreciate Dr Mercy Ijenyo, from University of Ibadan, Nigeria for her helpful editing of language.

REFERENCES

Amarger, N., 2001. Rhizobia in the field. *Advances in Agronomy*, 73, 109-168.

Arvanitoyannis, I. S., Waste Management in Food Packaging Industries, in Book: *Waste Management for the Food Industries*, 2008, p 941-1045.

Azim, M.E., Verdegem, M.C.J., van Dam, A.A., Beveridge, M.C.M., Edit, 2005. Periphyton: Ecology, Exploitation and Management. CABI Publishing.

Bao, L. L., Li, D., Li, X. K., Huang, R. X., Zhang, J., LV, Y., Xia, G. Q., 2007. Phosphorus accumulation by bacteria isolated from a continuous-flow two-sludge system. *Journal of Environmental Sciences*, 19, 391-395.

Benemann, J. R., 1979. Production of nitrogen fertilizer with nitrogen-fixing blue-green algae. *Enzyme and Microbial Technology*, 1, 83-90.

Blatt, C.R., 1991. Comparison of several organic amendments with a chemical fertilizer for vegetable production. *Scientia Horticulture*, 47, 177-191.

Bowen, G.D. and Rovira, A.D. 1999. The Rhizosphere and its management to improve plant growth. *Advances in Agronomy*, 66, 1-102.

CAAS (Chinese Academy of Agricultural Science), edt. Chinese Fertilizer, Shanghai: Shanghai Sci-Tech Press, 1994, p3-5.

Cayuela, M.L., Sinicco, T., Mondini, C., 2008. Mineralization dynamics and biochemical properties during initial decomposition of plant and animal residues in soil. *Applied Soil Ecology*, 41, 118-127.

Cebolla, V., Pera, J., 1983. Suppressive effects of certain soils and substrates against *Fusarium* wilt of carnation. *Acta Horticulture*, 150, 113-119.

Crews, T. E. and Peoples, M. B., 2004. Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs. *Agriculture, Ecosystems and Environment*, 102, 279-297.

De Cal, A., García-Lepe, R., Melgarejo, P., 2000. Induced resistance by *Penicillium oxalicum* against of *Fusarium oxysporum f. sp. lycopersici*: histological studies of infected and induced tomato stems. *Phytopathology* 90, 260-268.

Dowd, B. M., Press, D., Huertos, M. L., 2008. Agricultural nonpoint source water pollution policy: The case of California's Central Coast. *Agriculture, Ecosystems and Environment*, 128, 151-161.

El-Hassan, S.A., Gowen, S.R., 2006. Formulation and delivery of the bacterial antagonist Bacillus subtilis for management of lentil vascular wilt caused by Fusarium oxysporum f. sp. lentis. *Phytopathology* 154, 148-155.

Environmental Protection Agency (EPA). 2000. Office of Transportation and Air Quality. National Water Quality Inventory, EPA, Washington, DC.

Epstein, W. 2003. The roles and regulation of potassium in bacteria. *Progress in Nucleic Acid Research and Molecular Biology*, 75, 293-320.

Fogarty, T. J., 1992. Organizational socialization in accounting firms: A theoretical framework and agenda for future research. *Accounting, Organizations and Society*, 17, 129-149.

Gong, M., Wang, J.D., Zhang, J., Yang, H., Lu, X.F., Pei, Y., Cheng, J.Q., 2006. Study of the antifungal ability of Bacillus subtilis strain PY-1 in vitro and identification of its antifungal substance (iturin A). *Acta Biochim. Biophys. Sin.* 38, 233-240.

Hoitink, H.A.J., Boehm, M.J., 1999. Biocontrol within the context of soil microbial communities: a substrate-dependent phenomenon. *Annual Review of Phytopathology*, 37, 427-446.

Irisarri, P., Gonnet, S., Monza, J., 2001. Cyanobacteria in Uruguayan rice fields: diversity, nitrogen fixing ability and tolerance to herbicides and combined nitrogen. *Journal of Biotechnology*, 91, 95-103.

Keeney, D. R., Nitrogen management for maximum efficiency and minimum pollution. Severnson , F. J., Nitrogen in Agricultural Soils. Am. Soc. of Agron. Maidson Wis: *Agronomy*, 1982, 605-649.

Khan, R.A., Saxena, S.K., 1997. Integrated management of root knot nematode Meloidogyne javanica infecting tomato using organic materials and Paecilomyces lilacininus. *Bioresource Technology*, 61, 247-250.

Ladha, J. K., Pathak, H., Krupnik, T. J., Six, J., van Kessel, C. 2005. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. *Advances in Agronomy*, 87, 85-156.

Larena, I., Sabuquillo, P., Melgarejo, P., De Cal, A., 2003. Biocontrol of *Fusarium* and *Verticillium* wilt of tomato by *Penicillium oxalicum* under greenhouse and field conditions. *Phytopathology*, 151, 507-512.

Larkin, R.P., Fravel, D.R., 1998. Efficacy of various fungal and bacterial biocontrol organisms for control of Fusarium wilt of tomato. *Plant Disease*, 82, 1022-1028.

Lee, J., Effect of application methods of organic fertilizer on growth, soil chemical properties and microbial densities in organic bulb onion production. *Scientia Horticulture*, 2010, 124, 299-305.

Lee, J.J., Park, R.D., Kim, Y.W., Shim, J.H., Chae, D.H., Rim, Y.S., Sohn, B.K., Kim, T.H., Kim, K.Y., 2004. Effect of food waste compost on microbial population, soil enzyme activity and lettuce growth. *Bioresource Technology*,93, 21-28.

Li, J., Zhao, B. Q., Li, X. Y., Jiang, R. B., So, H. B., 2008. Effects of long-term combined application of organic and mineral fertilizers on microbial biomass, soil enzyme activities and soil fertility. *Agricultural Sciences in China*, 7, 336-343.

Manlay, R. J., Feller, C., Swift. M. J., 2007. Historical evolution of soil organic matter concepts and their relationships with the fertility and sustainability of cropping systems. *Agriculture, Ecosystems and Environment*, 119, 217-233.

Mishra, K., Kumar, A., Pandey, K., 2010.RAPD based genetic diversity among different isolates of *Fusarium oxysporum f. sp. lycopersici* and their comparative biocontrol. *World Journal of Microbial Biotechnology*, 26, 1079-1085.

Muslim, A.H., Horinouchi, Hyakumachi, M., 2003. Biological control of fusarium wilt of tomato with hypovirulent binucleate Rhizoctonia in greenhouse conditions. *Mycoscience* 44, 77-84.

Oelofse, M., Høgh-Jensen, H., Abreu, L. S., Almeida, G. F., Qiao, Y. H., Sultan, T., de Neergaard, A. 2010. Certified organic agriculture in China and Brazil: Market accessibility and outcomes following adoption. *Ecological Economics*, 69, 1785-1793.

Oren, A., 2004. A proposal for further integration of the cyanobacteria under the bacteriological Code. *Int. J. Syst. Evol. Microbiol*. 54, 1895-1902.

Osunlaja, S.O., 1989. Effect of organic soil amendments on the incidence of brown spot disease in maize caused by Physoderma maydis. *Journal of Basic Microbiology*, 29, 501-505.

Raviv, M., Reuveni, R., Zaidman, B.Z., 1998. Improved medium for organic transplant. *Biology and Agriculture Horticulture*, 16, 53-64.

Relwani, L. L., Manna, G. B. 1964. Effect of blue-green algae in combination with urea on paddy yield. *Ibid*, 33, 687.

Relwani, L. L., Subrahmanyan, R., 1963. Role of blue-green chemical nutrients and partial soil sterilization on paddy yield. *Ibid*, 32, 441-43.

Relwani, L. L.,1963. Role of blue-green algae on paddy yield. *Current Science*, 32, 417-418.

Relwani, L. L.,1965. Response of paddy varieties to blue-green algae and methods of propagation. *Ibid*, 5, 34.

Rodelas, B., González-López, J., Pozo, C., Salmerón, V., Martínez-Toledo, M. V. 1999. Response of Faba bean (Vicia faba L.) to combined inoculation with *Azotobacter* and *Rhizobium leguminosarum* bv. *Viceae*. *Applied Soil Ecology*, 12, 51-59.

Rojo, F.G., Reynoso, M.M., Ferez, M., Chulze, S.N., Torres, A.M., 2007. Biological control by Trichoderma species of Fusarium solani causing peanut crown root rot under field conditions. *Crop Protection*, 26, 549-555.

Sabuquillo, P., De Cal, A., Melgarejo, P., 2006. Biocontrol of tomato wilt by *Penicillium oxalicum* formulations in different crop conditions. *Biological Control*, 37, 256-265.

Schroeder, G.L., Wohlfarth, G., Alkon, A., Halevy, A., Krueger, H., 1990. The dominance of algal-based food webs in fish ponds receiving chemical fertilizers plus organic manures. *Aquaculture*, 86, 219-229.

Shen, Y.W., Liu, Y. D., Wu, G.Q., Ao, H. Y., Qiu, C. Q., 2005. Efficiency test on organic and inorganic fertilizers with cyanobacteria (Microcysits) in several crops. *Acta Hydrobiologica Sinica*, 29, 400-405.

Sohn, S.M., Han, D.H., Kim, Y.H., 1996. Chemical characteristics of soils cultivated by the conventional farming, greenhouse cultivation and organic farming and accumulation of NO3- in Chinese cabbage and lettuce. *Journal of Korean Organic Agriculture*, 5, 149-165.

Spolaore, P., Joannis-Cassan, C., Duran, E., Isambert, A., 2006. Commercial applications of microalgae. *J. Biosci. Bioeng*. 101, 87-96.

Stewart, I., Falconer, I. R., 2008. Cyanobacteria and cyanobacterial toxins. Walsh, P.J., Smith, S.L., Fleming, L.E., Eds, Oceans and human health: risks and remedies from the seas, Academic Press.

Suárez-Estrella, F., Vargas-Garcia, C., Lopez, C.M.J., Capel, J.M., 2007. Antagonistic activity of bacteria and fungi from horticultural compost against *Fusarium oxysporum f. sp*. melonis. *Crop Protection*, 26, 46-53.

Subrahmanyan, R., 1964a. Observations on the role of blue-green algae on rice yield compared with that of conventional fertilizers. *Ibid*, 33, 485-486.

Subrahmanyan, R., 1964b. Role of blue-green algae and different methods of partial soil sterilization on rice yield. *Process of Indian Academcy for Science*, 60b, 293-297.

Subrahmanyan, R., Sahay, M. N., 1964b. Observations on nitrogen-fixation by some blue-green algae and remarks on its potentialities in rice culture. *Process of Indian Academcy for Science*, 60b, 145-154.

Subrahmanyan, R., Sahay, M. N., 1965. Observations on nitrogen-fixation and organic matter produced by *Anabaena circinalis Rabh* and their significance in rice culture. *Process of Indian Academcy for Science*, 61b, 164-169.

Weller, D.M., Raaijmakers, J.M., Mc Spadden Gardener, B.B., Thomashow, L.S., 2002. Microbial populations responsible for specific soil suppressiveness to plant pathogens. *Annual Reviwe of Phytopathology*, 40, 309-348.

Whipps, J.M., 1997. Developments in the biological control of soilborne pathogens. *Advance in Botany Research*, 26, 1-134. .

Yan, S. Z., Yang, Q. Y., Chen, Y. Y., 2004. Antagonism of complex microbial fertilizer and functional actinomycetes against soil-borne plant pathogenic fungi. *Chinese Journal of Biological Control*, 20, 49-52.

Ying, J.F., Herridge, D.F., Peoples, M.B., Rerkasem, B., 1992. Effects of N fertilization on N_2 fixation and N balances of soybean grown after lowland rice. *Plant Soil*, 147, 235-242.

Zhang, Q., Qin, T., Zhang, H.Y., Luan, X. W., 2005. The progress of microbial fertilizer application. *Xinjiang Agricultural Science* (in Chinese), 42, 159-180.

Zhao, Q., Dong, C., Yang, X., Mei, X., Ran, W., Shen, Q., Xu, Y., 2010. Biocontrol of *Fusarium* wilt disease for Cucumis melo melon using bio-organic fertilizer. *Applied Soil Ecology*, 47, 67-75.

Zhuang, S.D., 2003. The status, problem and strategy on the development and application of microbial fertilizer. *Fujiang Agricultural Science and Technology*, 1, 34-45.