Application of Effective Microorganisms (EM) and Organic Amendments on Vegetable Production in Indonesia

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Abstract
Field research programs and surveys were carried out in the vegetable production regions to determine the effect of EM and organic amendments on the production of vegetables in Indonesia. The field studies illustrated that the use of Bokashi made with cattle manure at a rate equivalent to 50% of that of cattle manure alone produced higher bulb dry weight in onions when compared to those grown without amendments. Application of EM and organic anrendments also increased yields of pepper. The most significant results were obtained with 10 MT of EM Bokashi, followed by the application of 30 MT of cattle manure, Application of other amendments produced lower yields. The results highlight that EM could increase yields and net incomes of farmer vegetable allotments, when used for the cultivation of many types of vegetables.

INTRODUCTION

The development of agriculture in terms of vegetables is directed to increase the income and standard of living of the farmer, broaden employment and business opportunity, fulfil and extend the natural and international market of vegetable product through advanced and efficient technology.

Some constraints in the vegetable cultivation in Indonesia are: (1) declining of soil fertility often leading to soil degradation, (2) high cost of production due to excessive use of fertilizer and pesticides. Excessive use of chemical fertilizer coupled with regular application of pesticides, has also directly or indirectly "destroyed soils" of their living microorganism/biota which further the results in a decline in vegetable crop production.

CHEMICAL AND ORGANIC FERTILIZERS

Compared to Europe, Japan and North America, Indonesia like all other countries of South East Asia are newcomers in the field of fertilizer use. However, fertilizer use developed at much faster rate on it did in the traditional usage areas. Trends in NPK consumption and expected usage by the year 2000 are given in Table 1. As shown in Table 1, N uses increase from a low basis of 21 mill tons in 1956 to more then 1900 mill tons at present and as to exceed the 2250 mill tons level by the year 2000, similar trends can be observed for the other nutrients as well.

Table 1. N, P and K Consumption, ASEAN 1956 - 2000 (.000 mt.N).

Country	1956	1976	1990	2000
Indonesia				
N	21	351	1520	2250
P_2O_5	11	107	615	900
K_2O	2	23	270	750
Malaysia				
N	12	90	275	390
P_2O_5	1	119	267	240
K_2O	3	141	330	480
Philippines				
N	35	177	380	520
P_2O_5	27	40	42	100
K_2O	9	55	55	80
Thailand				
N	4	136	365	640
P_2O_5	3	80	158	230
K_2O	1	34	140	165

Source: Uexkull, 1990.

Table 1 also shows NPK consumption in Indonesia and the other ASEAN Countries. From this table the great country to country differences in total consumption and NPK ratio become obvious.

Indonesia is by far the largest nitrogen consumer both in terms of total quantity as well as in usage rate per unit area. Malaysia stands out as the largest potash user, again both in terms of total usage as well as in usage rate per unit area.

The high nitrogen, phosphorus and potassium usage level in Indonesia can be explained by the predominance of rice in the agricultural economy. The well irrigation system, well directed government programs and fertilizer subsidies and a good domestic supply source for nitrogen. The use of chemical fertilizers in vegetable cultivation could result soil degradation and soil and water pollution (National Research Council, 1989). The rapid development of industrial sector, has added kinds and quality of problem (Sukmana, 1996). Nitrate (urea), P (TSP), heavy metals such as Hg, Cd and Pb (Industrial waste products) has detrimental effect on human health who consumed vegetable product from this polluted soil.

Besides chemical fertilizers, vegetable production in Indonesia is also supported by usage of animal manure. Chicken dung, cow dung, sheep dung has always been used in the planting of vegetables. This has been found to be essential complement to the use of chemical fertilizers in order to obtain a good vegetable crop. However, animal manure need to be used in a large quality in order to achieve the desired result. Utilization of raw animal manure will lead to few undesirable effects among this such as; acidification of soil, poor sanitation that cause negative effect on human health and increased incidence pest and diseases and weed problem.

This situation has lead to the search of a better alternative agricultural practices that produce high quality of vegetables, safe food for human consumption, and at the same time are environmental friendly, sustainable and beneficial to farmers. Professor Teruo Higa from

University of Ryukyus, Okinawa Japan has developed a technology, where by mixtures of co-existing, beneficial to microorganisms to 10 genera and 80 species are applied to plants and soils. These microorganisms are reported to improve the availability of soil nutrients, and the growth, yield and healthy of crops. He has termed this mixtures of co-existing microorganisms as Effective Microorganisms (EM). It has been reported that if EM is used for a few consecutive years it can significantly reduce the need for chemical fertilizers and also the use of insecticides at herbicides. EM can improve conditions in the plant rizosphere as reported by other scientists.

EFFECTIVE MICROORGANISMS

Effective microorganisms or EM are mixed culture of beneficial microorganisms that can be applied as inoculant to increase the microbial diversity of soils and plants, which in turn can improve soil health, growth, yield and quality of crops.

In Indonesia studies on EM was started in 1989. EM was applied on various crops with different agro-ecological conditions.

In connection with the Indonesia National Agricultural Policies and Strategic Planning of Research Institute for Vegetable until 2020, the vegetable productivity could be increased through the use of beneficial microorganisms including EM and at the same time produce higher yield and better quality which is safe for human consumption. The followings are experimental findings from some of previous research on EM and organic amendments.

Effect of Agricultural waste Bokashi on the requirements of NPK fertilizers hot pepper

Land for production i.e. hot pepper was generally used intensively. An intensive land use without any effort to increase and maintain soil fertility gave negative effect on land productivity (Lal and Greenland, 1979).

The application of organic manure is one of methods to increase and maintain soil fertility. Animal dung has been known as organic amendments for long time by farmers. The use of animal dung for hot pepper productions varied from 20 to 30 t ha^{-1}. The capability of animal in producing animal dung is limited so that animal dung become costly and difficult to obtain. Meanwhile, a large quantity of agricultural wastes in the field is potential to be used as organic amendments, and has not been used yet for hot pepper production. Several kinds of agricultural wastes found in the farm area are grass, organic garbage, rice straw, weeds, plant remainder, etc.

The use of agriculture wastes will give a positive impact on land resources in sustainable agriculture. Results of the experiment indicated that several kinds of agriculture wastes inoculated by EM4 such as sugarcane, mushroom media, city garbage wastes, gave higher yield in terms of fruit weight of hot pepper compared to control (without organic manure) and did not give any different yield from cow dung treatment.

Like cow dung (stable manure), agriculture waste products contain macro and. micro nutrient that is needed by plants. Based on that, an experiment deal with the use of NPK fertilizers and several kinds of organic amendments has been conducted in the dry season from July to

December 1996 which was arranged in split plot design with three replications. Treatments consisted of 3 rate of NPK fertilization as main plot and eight kinds and rate organic amendments as subplot. The results showed that the application of EM and organic amendments could increase fruit yield of hot pepper (Table 1).

The best significant increase in yield occurred with 10 t ha^{-1} of cow dung Bokashi addition (227 percent) when balanced fertilizer was used (Table 2). This indicates that the application of EM along with cow dung manure and N, P and K at least at standard application gave more nutrient release than other treatments.

Table 2. Effect of organic amendments and rate of NPK fertilization application on healthy fruit weight of hot pepper in oxisols.

Type of organic amendments	Rate of N, P, K fertilizers				
	Rate of organic amendments	0.5 x Std	1.0 x Std	1.5 x Std	Average
	t ha^{-1}				
Check (no organic amendments)	0	3.78	2.48	2.75	3.00
Farm waste Bokashi	10	4.09	4.38	4.81	4.42
	20	4.18	5.18	4.79	4.71
Rice straw Bokashi	10	6.36	7.17	6.83	6.79
	20	6.76	7.59	7.64	7.33
Cow dung Bokashi	10	8.26	10.40	10.82	9.81
	20	8.78	8.19	10.51	9.16
Cow dung manure (farmers practice)	30	8.15	8.75	9.89	8.93
Average		6.30	6.77	7.26	

Remarks: Std = Standard fertilization (200 kg N, 90 kg P_2O_5, 100 kg K_2O and 100 kg S ha^{-1})

Effect of Effective microorganisms on chemical fertilizer and pesticides and resistance of hot pepper against pest and diseases.

Problems encountered by farmers in increasing hot pepper production are high input of fertilizers and incidence of pest and diseases such as virus, thrips and Anthracnose . Until now, farmers is considering that pesticide and Chemical fertilizer N, P, and K is guarantee in succeeding hot pepper cultivation.

Field experiment was conducted at Alluvial lowland to study the use of EM and MVA on the efficiency of NPK fertilizers and pesticides and to study resistance of hot pepper plant against pest and diseases as a results of EM use. Treatment consisted of 4 kinds of fertilizer and pesticides use. i.e.: balanced fertilization (200 kg N, 90 kg P_2O_5, 100 kg K_2O and 100 kg S per hectare) without controlling pest and disease, balanced fertilization + pesticide control, without fertilization nor pesticide use; and without fertilization and pesticide control. Pesticide control was based on control threshold. The other factors consisted of inoculation of VAM (Vesicular Arbuscular Mycorrhiza), EM4 and without VAM nor EM4.

Statistical analysis the effect of fertilizer/pesticide and inoculation of beneficial microorganisms VAM and EM on fruit weight of hot pepper is presented in Table 3.

Table 3. Effect of balanced fertilization/pesticide and inoculation of Mycorrhiza/EM on hot pepper fount weight

Balanced fertilization/ Pesticide use	VAM (t/ha)	EM (t/ha)	(-MVA -EM) (t/ha)
BF –pesticide	6.09 bc	5 74 bc	5.51 bc
BF +pesticide	9.05 a	8.96 a	7.83 ab
-BF –pesticide	5.25 bc	5.24 bc	4.95 bc
-BF +pesticide	3.75 c	4.65 c	3.75 c

Remarks: BF - Balanced fertilization (200 kg N, 90 kg P_2O_5, 100 kg K_2O and 100 kg S ha^{-1})

Table 3 shows that hot pepper plant treated by balanced fertilization and pesticide use in combination with EM and Mycorrhiza gave the best fruit yield. Without pesticide or chemical fertilizer, inoculation of EM and VAM did not give positive effect on fruit yield. It seems that inoculation of Mycorrhiza and EM was more effective when was combined with balanced fertilization and chemical control by using IPM concepts.

Although fruit yield of hot pepper in treatment EM or VAM is almost the same as treatment no EM/VAM, population of pest and diseases or level of plant damage is different from each other except for thrips pest incidence. Table 4, 5 and 6 revealed that percentage of leaf damage by thrips, Aphid and *Cercospora capsici* was generally more serious in check treatment (-EM -VAM) than that of EM or VAM treatment

Table 4. Effect of inoculation of EM and Mycorrhiza on the percentage of leaf damaged caused by Thrips pest.

Percentage of leaf damage				
Treatment	5wat	6wat	7wat	8wat
EM	0.992a	0.50a	0.86a	1.03a
VAM	0.992a	0.72a	0.94a	0.99a
-EM-VAM	1.042a	0.55a	0.91a	1.11a

Remarks: Mean score followed by the same letter are not significantly different according to DMRT at five percent level, wat = Weeks after transplanting.

Table 5. Effect of inoculation of EM and VAM on percentage of leaf damage caused by Aphid.

Percentage of leaf damage by Aphid					
Treatment	4wat	6wat	8wat	10wat	12wat
EM	1.25a	4.20ab	12.03a	15.18a	9.27b
VAM	1.60a	3.95b	12.38a	14.65a	18.40a
-EM-VAM	2.63a	6.80a	12.90a	16.00a	21.70a

Remarks: Mean score followed by the same letter are not significantly different according to Duncan's multiple range test at five percent level.

Table 6. Effect of inoculation of EM and VAM on percentage of leaf damage caused by *Cercospora capsici.*

Percentage of leaf damage by *Cercospora capsici*					
Treatment	4wat	6wat	8wat	10wat	12wat
EM	0	0	1.00a	1.08ab	17.68b
VAM	0	0	1.75a	0.83a	16.10b
-EM-VAM	0	0	1.58a	1.65b	19.50a

Remarks: Mean score followed by the same letter are not significantly different according to Duncan's multiple range test at five percent level.

Effect of organic amendments on shallots in two soil types.

The need of organic amendments in terms of cow dung for shallot varied depending on type of soil and organic amendments. Shallot crops can be grown both in paddy land and in upland. The Alluvial is more preferable and followed by andosol type. The last result of the experiment indicated that the need of chemical fertilizers on Alluvial soil type was 10 t ha^{-1} of cow dung (Asandhi and Koestoni, 1994). However, to apply 10 t ha^{-1} of cow dung in farmer's field is not easy due to in-availability of this material. Organic manure was often need in an environmentally friendly agriculture because it could supply nutrient on shallot. However, sometime this material did not clearly give a benefit result on shallot because decomposition of organic matter was so slowly so that the nutrient can not release perfectly. The EM technology was expected to overcome this problem. Higa (1994) stated that when all of beneficial effects of microbial metabolisms are integrated it can optimize soil productivity and crop production less even without the use of chemical fertilizers and pesticides.

An experiments using four kinds of organic amendments was conducted on two soil types (Alluvial lowland and Andisol highland). Results of the experiment showed that the addition of organic amendments slightly increase bulb dry weight of shallots (Table 7).

Table 7. Effect of organic amendment on bulb dry weight of shallot.

Treatment	Alluvial	Andisol
No. organic amendment	16.0a	11.3a
Cow dung manure (10 t ha^{-1})	15.8a	11.9a
Cow dung manure + EM4 (5 t ha^{-1})	17.3a	12.4a
Cow dung manure + EM4 (10 t ha^{-1})	16.4a	11.8a

The highest significant increase in bulb dry weight occurred with cow dung manure + EM4 (cow dung manure Bokashi) at a rate of 5 t ha^{-1} both in Alluvial and in Andisol. However, it seems that there is not significantly different among the treatments.

Effect of agriculture wastes on tomato production

Organic matter is used in vegetable cultivation to improve soil structure and supply plant nutrient. In Indonesia, the use of organic amendments has been a vital component. The tomato plant (*Lycopersicum esculentum* L.) requires good soil structure, fertile and high organic content. Organic matter that are available in farmer's field can be farm yard manure, and several kinds of farm waste such as rice straw and corn stem. An experiment was carried out in oxisols at about 730 meter above sea level. A randomized block design with three replicates was used. Treatments consisted of control, faun yard manure (FYM), rice straw compost (RSC), maize stem compost (MSC), FYM + EM, RSC + EM, and MSC + EM. The results revealed that the best increase in fruit yield of tomato were noticed in the plot treated by FYM + EM. Plot treated with FYM alone still increase tomato yield compared to control (No Organic amendment treatment) (Table 8).

Table 8. Effect of organic amendments on the yield of tomato fruit.

Treatment	Fruit yield (t ha^{-1})	% increase with EM
Check plants	7.53c	-
Farm yard manure (FYM)	13.27ab	-
Rice straw compost (RSC)	10.35ab	-
Maize stem compost (MSC)	11.56ab	-
FYM + EM	15.89a	19.7
RSC + EM	10.24ab	-
MSC + EM	12.02ab	4

The results clearly indicates that an increase in tomato yield could be obtained by the application of organic amendments along with EM which relatively contain high nutrient. Table 9 below indicates the results of farm yard manure and agriculture waste compost.

Table 9. Results of agricultural waste compost analysis.

Agriculture waste	C	N	P	K	Ca	Mg	SO_4	Mn	Cu	Zn	C/N
	(%)					(ppm)					
Farm yard manure	10.2	2.6	0.3	1.1	2.9	0.5	0.8	485	33	48	4
Rice straw compost	17.5	1.2	0.3	1.0	1.8	0.4	0.7	578	13	42	14
Maize stem compost	6.3	0.4	0.2	0.4	0.5	0.1	0.5	214	18	56	18

Source: Subhan. 1997.

Survey of EM on Vegetable Crops

The growth and yield of vegetable for human consumption and export can not only rely on chemical fertilizer because in the long term it can give a negative impact on natural and human resources. This negative impact was always followed by the increase in production cost.

To improve this method, it is necessary to find out an alternative systems such as organic farming, low-input sustainable agriculture (LISA). The objective of these alternative systems is to provide safer vegetable product, less usage of agro-chemicals and the system itself must be environmentally friendly and sustainable.

In nature farming soil fertility is enhanced through the use of organic matter and effective microorganisms (EM). In order to expand research activities and relate such research to farmer's problems, the survey has been carried out in West Java. This survey uses case study on farmers who has already used Effective Microorganisms (EM) and has not used EM yet. The effect of EM on vegetable benefit was summarized in Table 10 which clearly showed that the application of EM can increase production, economics benefit and R/C value of potato, French bean, tomato and cauliflower. No significant different in sale price of vegetables between EM and No EM application. However, there is slight increase in total production cost by 14.7, 22.5, 22.8 %, respectively due to EM and labor cost. It can be concluded that application of EM on these kinds of vegetables is applicable to farmers.

Table 10. Analysis of vegetable farm in West Java Province in Indonesia.

No	Commodity	Farm Cost	Before using EM	After using EM
1	Potato (1 ha)	Total production cost (Rp)	6,185,936	5,775,239
		Production (kg)	15,000	18,200
		Sale price (Rp/kg)	430	430
		Gross revenue (Rp)	6,450,000	7,826,000
		Benefit (Rp)	264,064	2,050,000
		R/C	1.04	1.35
2	French Bean (0.1 ha)	Total production cost (Rp)	197,292	226,309
		Production (kg)	800	1,000
		Sale price (Rp/kg)	325	325
		Gross revenue (Rp)	260,000	325,000
		Benefit (Rp)	62,708	98,691
		R/C	1.32	1.44
3	Tomato (0.35 ha)	Total production cost (Rp)	1,706,310	2,090,610
		Production (kg)	9,000	14,000
		Sale price (Rp/kg)	300	300
		Gross revenue (Rp)	2,700,000	4,200,000
		Benefit (Rp)	993,690	2,109,390
		R/C	1.6	2.0
4	Cauliflower (0.1 ha)	Total production cost (Rp)	324,360	398,560
		Production (kg)	2,000	2,500
		Sale price (Rp/kg)	800	800
		Gross revenue (Rp)	1,600,000	2,000,000
		Benefit (Rp)	1,275,640	1,601,440
		R/C	3.9	4.02

Source: M. Iskandar Ma'moen. 1996.

CONCLUSIONS

At the first trial (one season) EM application on hot pepper could not reduce or replace the use of chemical fertilizer (N, P and K fertilizers). Cow dang Bokashi (fermented cow dung) at a rate of 10 t ha^{-1} should be combined with a reasonable amount of chemical fertilizer (200 kg N, 90 kg P_2O_5, 100 kg K_2O and 100 kg S ha^{-1}). EM could reduce the percentage of leave damage caused by aphid and *Cercospora capsici* at 12 weeks after transplanting.

EM and organic amendments did not influence bulb dry weight of shallot in A1luvial and Andisol soil types.

Organic amendments such as farm yard manure, rice straw compost and maize stem compost increased fruit yield of tomato. EM incorporated to farm yard manure (EM + FYM) could improve tomato yield.

Application of EM on potato, French bean, tomato and cauliflower increases economic benefits of farmers (applicable to farmers).

SUGGESTIONS

In view of the fact that excessive use of chemical fertilizers will cause environmental damage. The use of organic amendments in combination with effective microorganisms (EM) would indeed be applicable in order to maintain ecologically balance. However, for one season trial especially in short age vegetables such as shallot a good response did not appear yet. In order to obtain better results, it is crucial to carry out long term research in the cropping pattern systems and various agro-ecological conditions.

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