Effects of Organic Fertilization and EM Inoculation on Leaf Photosynthesis, Fruit Yield and Quality of Tomato

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***Abstract** : An experiment was conducted to examine the effects of applications of Bokashi, and chicken manure as well as EM inoculation to Bokashi and chicken manure on photosynthesis, fruit yield and quality of tomato. EM inoculation to both Bokashi and chicken manure increased photosynthesis and fruit yield. Concentrations of sugars and organic acids were higher in fruits of plants fertilized with Bokashi than in fruits of other plots. Vitamin C concentration was higher in fruits of chicken manure and bokashi plots than in those of chemical fertilizer plot. EM inoculation increased vitamin C concentration in all fertilization treatments. It is concluded that both quality and yield increasing effects could be expected from EM inoculation to the organic materials and application to the soil directly.*

Introduction

Excessive use of chemical fertilizers has caused many problems in environmental pollution and soil degradation. With these concerns, many farmers in Japan have adopted nature farming. The concept and principles were proposed by Okada more than 60 years ago (Okada, 1993). Because chemical fertilizers and untreated animal products are not allowed in nature farming systems, in crop or vegetable production with nature farming practices, it is not easy to achieve a yield equal to or higher than that with chemical farming. First, the growers must seek an alternative nutrient source. An organic fertilizer often used by farmers is called Bokashi, which is fermented using oilseed cake, rice bran and fish processing by-product (Yamada et al., 1997). A microbial culture called Effective Microorganisms or EM is often inoculated to Bokashi before fermentation (Higa, 1994). This kind of organic material with EM inoculated is called EM Bokashi. It has shown its merit on nutrient sustainability, but the many aspects of EM Bokashi need to be elucidated. Therefore, a research project was set up to examine the performance of EM Bokashi in vegetable production. The first experiment was conducted to examine the effects of EM inoculation to Bokashi and chicken manure on fruit yield and quality of tomato.

Materials and Methods

Materials and Treatments

Tomato (*L. esculentum* L. cv. Momotaro T 96) seedlings with 5 leaves were transplanted into plastic pots each with a surface area of 0.02 m^2 and a height of 0.25 m. The pots were arranged randomly in a glasshouse. Six fertilization treatments each with 33 pots were as follows. 1) chicken manure; 2) chicken manure with EM (Effective Microorganisms, EM1) inoculated before fermentation treatment; 3) anaerobic Bokashi (anaerobically fermented organic materials such as rice bran, rapeseed mill cake and fish processing by-product); (4) anaerobic Bokashi with EM inoculated before fermentation; (5) chemical fertilizer (ammonium sulfate 5.3 g, superphosphate 13 g and potassium sulfate 5 g per pot; (6) the same amount of chemical fertilizer as in treatment (5) with 80ml EM applied together. The amounts of N-P-K were adjusted to the same levels for all treatments.

Photosynthetic Measurement

Photosynthesis was measured using Li- 6400 portable photosynthesis system (LI-COR Inc. Lincoln, NE, USA) at 50th day and 90th day after tomato plants were transplanted. The 5th leaf from the top was used for measurements for each sampled plant. The maximum gross photosynthetic capacity (P_C), the quantum yield (Y_Q=KP_C) and dark respiration rate (R_D) were analyzed from light response curve modeled using an exponential equation, $P_N = P_C\,(1- e^{-KI}) - R_D$, where K is constant and I is the photosynthetic photon flux (Xu et al., 1995).

Preparation of Plant, Soil and Fruit Samples

The whole plant was sampled with leaves and stem separated on the 50th and 90th day after tomato plants were transplanted. The samples were dried in an oven at 105 ºC for 2 h and under 85 ºC over 24 h. The dry mass of whole plant was recorded and the dry material was ground with a vibrating sample mill. A prepared sample of 5 g was used for measurements of mineral salts and other nutrients. The tomato fruits were picked once a week when they began to ripen 2.5 months after transplanting. The fruit yield, the crick rate and single fruit mass were calculated. A slice representing the whole fruit was used for quality analysis. The soil samples were taken at the same time as the plant samples were taken.

Analysis of Fruit Quality

Fresh fruit tissue was homogenized with distilled water in a ratio of 1:4. The homogenate was centrifuged at 8000 g for 15 min at 4 ˚C and the supernatant passed through 0.45 μm filter. Sugars were meas ured by HPLC (Jasco) with RI-930 Detector and a column of Shodex SC1011 at a column temperature of 80˚C and a flow rate of 1ml min^{-1}. Organic acids were measured by HPLC (Jasco) with UV-970 Detector and column of Shodex RSPark KC-811 at a column temperature of 40˚C and a flow rate of 0.75 ml min^{-1}. Vitamin C was determined by a reflectometer (RQflex, Merck).

Results and Discussion

At the early growth stage, plant growth or fruit yield was lower in Bokashi plot but turned higher at later growth stages, compared with the chemical fertilized plants. This might be due to the low nutrient availability at the beginning, which limited the plant growth. In the present study, the organic fertilizer is an anaerobically fermented organic material. Nutrients, especially nitrogen, are not mineralized immediately after fermentation. The mineralization of the nutrients takes a period of time even applied into the soil. That is why the plants fertilized with organic materials grew worse than those fertilized with chemical fertilizers at earlier stages. Therefore, the growers should take some measures to make the nutrients in organic materials available before plants begin to grow. Nutrients in chemical fertilizers are immediately available when applied to the soil but the sustainability is low. The nutrients may leach out together with the irrigation water at the early growth stages. On the contrary, organic materials sustain the nutrients for longer time than chemical fertilizers. Moreover, organic materials also contain micro-nutrients in addition to the macro-nutrients that are available in chemical fertilizers. Therefore, at the later growth stages, plants fertilized with organic materials grew better that those fertilized with chemical fertilizers. The chicken manure used in the present study was aerobically treated before application and no growth limitation was observed at the early stages.

EM inoculation increased plant growth and fruit yield in all treatments (Table 1). EM was inoculated to the organic materials or chicken manure before anaerobic fermentation. The microorganisms were reproduced and changed the properties of the organic materials. Some microorganisms produce plant growth regulators (Arshad and Frankenberger Jr. 1992). Even if the EM liquid was directly applied at the same time with chemical fertilizers, it showed growth promotion and yield increasing effect.

The sugars in tomato fruits are mainly glucose, fructose and sucrose. The concentration of sugars in fruits varied with fertilizations. As shown in Table 2, the fruits in plots fertilized with chicken manure had the highest concentrations of sugars and those in chemical fertilizer plots had the lowest concentrations. EM inoculated to the organic materials or applied directly with chemical fertilizers to the soil did not show significant effect on fruit sugar and organic acid concentrations per unit of dry mass. However, EM treatment increased fruit yield. Usually, a factor that increasing fresh yield might also dilute the active substances. If the fruit sugar and organic acid concentrations are calculated as per plant, the effect of EM in increasing sugar concentration becomes apparent.

Table 1. Fruit Yield and Number, Abnormal and Green Fruit and Fruit Size as well as Photosynthetic Capacity (P_C), Respiration (R_D) and Quantum Yield (Y_Q) at Later Growth Stage of Tomato Plants under Different Fertilizations.

Treatment	Fruit characteristics					Photosynthetic parameter		
	Yield (g plt^{-1})	No. (plt^{-1})	Abnormal (%)	Green (%)	Size (g)	P_C (μmol m^{-2} s^{-1})	R_D (μmol m^{-2} s^{-1})	Y_Q (mmol mol^{-1})
ChM	823	8.0	9.8	8.1	94.5	17.6	1.02	19.5
	±32	±0.4	±3.4	1.7	±2.5	±1.2	±0.02	±2.7
ChM+EM	935	8.8	9.5	5.9	100.4	19.3	1.31	24.3
	±63	±0.6	±2.0	1.3	±3.0	±1.7	±0.02	±2.9
Org	622	6.2	17.3	20.0	81.1	20.4	1.05	31.2
	±36	±0.4	±2.8	3.9	±3.9	±2.1	±0.01	±3.4
Org+EM	723	7.3	17.2	18.5	81.6	23.1	1.84	34.4
	±59	±0.7	±3.9	2.7	±2.5	±1.6	±0.02	±1.8
Che	818	7.1	12.4	11.4	102.4	18.4	1.12	30.7
	±21	±0.2	±3.5	2.9	±2.5	±1.3	±0.03	±2.5
Che+EM	1012	10.1	8.7	9.4	91.2	20.2	1.65	34.5
	±30	±0.3	±1.8	1.8	±2.8	±0.9	±0.02	±2.9

Table 2. Sugars and Organic Acids in the Ripe Tomato Fruit of Different Fertilization Treatments

Treatment	Sugars (g kg^{-1})				Organic acids (g kg^{-1})				
	Sucrose	Glucose	Fructose	Total	Citric	Malic	Total	Ascorbic	Sugar/aci
ChM	1.01	33.4	29.8	64.2	6.32	1.80	8.12	0.16	7.91
	±0.62	±1.8	±1.0		±0.42	±0.42		±0.019	
ChM+EM	0.68	33.0	30.7	64.4	6.41	1.99	8.40	0.19	7.66
	±0.45	±0.4	±0.5		±0.09	±0.28		±0.010	
Org	1.43	30.7	27.0	59.1	6.98	1.85	8.83	0.12	6.70
	±0.21	±4.3	±1.5		±1.22	±0.85		±0.004	
Org+EM	1.70	29.5	29.1	60.3	6.96	1.69	8.65	0.14	6.97
	±0.55	±1.8	±1.1		±1.35	±0.03		±0.007	
Che	0.24	25.1	25.2	50.5	6.57	1.48	8.05	0.11	6.28
	±0.11	±3.7	±2.1		±1.06	±0.25		±0.004	
Che+EM	0.64	26.6	26.9	54.1	6.69	1.24	7.93	0.12	6.78
	±0.17	±4.2	±1.9		±0.78	±0.18		±0.009	

Data show means ±SE (n=9)

Compared with other fertilization treatments, the organic acid concentration of fruits in Bokashi fertilized plot was higher than other plots. The ratio of sugars to organic acids was higher in fruits with chicken manure treatment, resulting in a sweeter taste of fruits. The ratio of sugars to organic acids in Bokashi treatments was similar to that in chemical fertilizer treatments, but fruits of Bokashi fertilized plots were more tasty since both the sugars and organic acids were higher. As shown in Table 2, vitamin C (ascorbic acid) concentration was lower in chemical fertilizer treatment than other treatments. EM had good effect of increasing fruit vitamin C concentration. If the nutrients in organic materials were available, both chicken manure and Bokashi could be used as substitute for chemical fertilizer with a comparable yield and higher quality. Both quality and yield increasing effects could be expected from EM inoculation to the organic materials and application to the soil directly.

Conclusions

Plant growth and fruit yield were low in Bokashi plot at earlier stages but turned high at later growth stage because of the low nutrient availability at the beginning and high nutrient sustainability at the later stage. Concentrations of sugars were highest in fruits of plants fertilized with chicken manure and lowest in fruits of plants with chemical fertilization. Organic acid concentration was higher in fruits of Bokashi fertilized plants than in fruits of other plots. Vitamin C (ascorbic acid) concentration was higher in fruits of plants fertilized with chicken manure and Bokashi than in those fertilized with chemical fertilizer. EM inoculation increased fruit yield and vitamin C concentration. If the nutrients in organic materials were available, both chicken manure and Bokashi could be used as substitutes for chemical fertilizer with a comparable yield and higher quality. Both effects in increasing yield and improving quality could be expected from EM inoculation either to the organic materials or to the soil directly.

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