Effect of EM on Weed Populations, Weed Growth and Tomato Production in Kyusei Nature Farming

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Abstract.

The adverse effects of weeds on tropical crop yields are generally more pronounced in organic farming systems because farmers rely mainly on cultural and mechanical weed control measures in lieu of herbicides which have a more dramatic effect. Nevertheless, more effective non-chemical weed control methods are urgently needed to improve the sustainability of organic farming systems. Effective Microorganisms (EM) has been reported to effectively control weeds in Kyusei Nature Farming systems. Thus, a study was conducted to determine the effect of EM on weed populations, weed growth, and yield of tomato (*Lycopersicon esculentum* L,) grown with organic amendments during the dry season of three consecutive years. The application of organic amendments alone suppressed weed growth, although the variation between years was not significant. EM applied with organic amendments enhanced weed growth the first year which then declined significantly with time. EM applied with a green manure (i.e., *Gliricidia* leaves) significantly increased tomato yields throughout the study; in the third year, the yields due to EM were comparable to those obtained with chemical fertilizer.

Introduction

Weeds are present in all food crop systems, irrespective of the intensity of crop management (Schroeder et al., 1993). Thus, weed control is vital to achieving high yields. In tropical cropping systems the presence of weeds is very pronounced because of large soil weed seed-banks, and a favorable environment for their growth and development (NRC, 1993). Weeds have traditionally been controlled by manual and cultural methods. With the development of synthetic agrichemicals in the 1940's, the reliance on chemicals to obtain weed-free cropping systems increased. However, the excessive use of synthetic chemicals has led to pollution problems in most agricultural environments, and more importantly, the development of herbicide-resistant and problematic weed species (MOSS and Rubin, 1993).

Modem biological agricultural systems using organics as additives do not permit the use of synthetic herbicides for weed control because of their potential to become environmental pollutants and harmful residues in the food chain. Thus, biological and organic farmers rely mainly on ecological principles and cultural practices to control and manage weed populations (Vogtmann, 1984). Generally, weed control in these systems is achieved through a number of operations including plant densities, competition, inter-cropping, and the use of mulches (Andres and Clement, 1984).

Effective Microorganisms (EM) consists of mixed cultures of naturally-occurring, beneficial microorganisms that can enhance soil quality and the growth and yield of crops in organic farming systems (Higa, 1991). There is also evidence that EM can stimulate seed germination and early growth of food crops (Sangakkara and Higa, 1994) and can create a more favorable root surface-rhizosphere environment for crop plants that improves plant growth and protection (Sangakkara, 1996).

It is likely that all of these documented beneficial effects of EM on crop plants would also be extended to weeds, and could enhance weed seed germination, early growth and development, and their level of infestation. Consequently, there is considerable interest in whether EM through these processes, over time, could reduce soil weed seed-banks.

Because this issue has not been scientifically investigated, a three-year study was conducted to determine the effect of EM on weed populations, weed growth and tomato production in an organic farming system.

Materials and Methods

The field study was conducted at the University of Peradeniya, located in the mid-country intermediate zone of Sri Lanka, during the dry seasons (May to August) of 1990, 1991 and 1992. Mean climatic parameters for the dry season were: rainfall, 284 mm $\pm$ 24.5 mm; daily temperature, 32.4^{o}C $\pm$ 2.8^{o}C; relative humidity, 68.4% $\pm$ 3.8%; and pan evaporation, 4.38 mm $\pm$ 0.21 mm/day. The soil was an Ultisol with pH (1:2.5 H_2O) 6.82; organic matter content, 0.76%; and total N content, 0.16%. The experimental site had been cultivated with various food crops for the previous five years using chemical fertilizers and pesticides. The test crop was tomato (*Lycopersicon esculentum* L., var. Marglobe) with the following treatments applied each season:

1. Chemical fertilizer (NPK).
2. Gliricidia leaves (C:N Ratio 14.2).
3. Rice straw (C:N Ratio 56.3).
4. Gliricidia leaves + EM.
5. Rice straw + EM.
6. EM alone.
7. Control (no chemical or organic amendments applied).

The organic amendments were applied to individual plots (2 x 3 m) at a rate of 8 metric tons per hectare, with or without EM, using a randomized complete block design (RCBD) with four replications per treatment. The EM-treated plots were separated from the non-EM plots by a 2-m wide border to prevent possible contamination. Each plot received the same treatment over three seasons. The organic amendments were incorporated into soil two weeks before planting and, at the same time, EM diluted 1:1,000 was applied to appropriate plots at a rate equivalent to 10 liters/ha of stock solution. Later, EM was also applied to selected plots at the V2, R1 and R4 crop growth stages.

Uniform seedlings of tomato were transplanted with the onset of rains in May of each season. Chemical fertilizers were applied to selected plots according to recommendations of the Sri Lankan Department of Agriculture (1989). Irrigation was conducted when necessary. The weed types and populations were assessed and removed three weeks after transplanting, at flowering and at harvest. The weeds were dried at 80^{o}C to constant weight. Fruit yields were determined at crop maturity. The data were analyzed statistically to determine the significance of treatment effects, using a general linear model. Weed growth indices were calculated based on weed dry weights for each plot according to treatments.

Results and Discussion

As shown in Table 1, the application of EM with the two organic amendments increased weed populations the first season. The effect of EM is apparent since it is known to enhance seed germination and provide a more favorable rhizosphere environment (Higa, 1994; Sangakkara, 1996). In contrast, plots that received only the organic amendments had the lowest weed populations which may be at least partly attributed to allelopathic and/or suppressive effects on weeds from organic matter decomposition products (Put-man, 1 985). The application of EM seems to overcome these suppressive effects and stimulates weed seed germination. Chemical fertilizers did not significantly enhance weed populations and results were similar to the untreated control plots.

During the first season, the application of EM alone increased weed populations over the control plots by approximately 30 percent. However, when EM was applied with the two organic amendments, the weed populations increased by 110 to 130 percent, compared with the amendments alone.

Table 1. Effect of EM, Chemical Fertilizer and Organic Amendments on Weed Populations.

Treatments	(No. / m2)			
	Year1	Year2	Year3	Sx
Chemical fertilizer	27	33	28	3.10
Gliricidia leaves	17	19	16	4.09
Rice straw	20	22	18	1.03
Gliricidia leaves+ EM	39	21	12	4.99
Rice straw+EM	42	18	11	2.95
EM	32	24	14	5.19
Control	25	28	31	1.06
SE mean	3.4	2.6	2.9	
CV (%)	14.6	9.7	10.8	

In the second season, weed populations in the EM-treated plots decreased significantly, but generally increased for the non-EM treatments. For example, weed numbers in plots treated with EM alone decreased by 25 percent the second season, but increased by 12 percent in the control plots. Moreover, the weed populations in plots treated with *Gliricidia* + EM and rice straw + EM decreased by 46 and 57 percent, respectively, compared with the first season. This supports the earlier conclusions by Marambe et al. (1994) that EM stimulates weed seed germination the first season, thereby reducing the size of the soil weed seed-bank in subsequent years. The effect of EM in progressively reducing weed populations was also apparent in the third season. EM alone, and with *Gliricidia* and rice straw reduced weed populations by 41, 42 and 38 percent, respectively, in the third season. Again, this confirmed the beneficial effect of EM in reducing weed populations over time; however the application of chemical fertilizer and the organic amendments alone supported significant weed populations throughout the study.

The effect of EM on weed growth in terms of biomass is reported in Table 2. In the first season, the application of EM alone increased weed biomass by approximately 20 percent over the control plots. When EM was applied with *Gliricidia* and rice straw, the weed biomass increased by approximately 40 percent compared with either organic amendment alone. Interestingly, the increase in weed biomass was significantly less than for weed numbers (Table 1). This suggests that weed numbers are enhanced to a greater extent than dry matter accumulation of individual plants. The application of chemical fertilizer increased weed biomass by approximately 18 percent compared with the control plots.

Table 2. Effect of EM, Chemical Fertilizer and Organic Amendments on Weed Biomass 30 Days After Transplanting Tomato.

Treatments	(g dry matter / m2)			
	Year1	Year2	Year3	Sx
Chemical fertilizer	175	172	190	6.97
Gliricidia leaves	142	151	156	2.94
Rice straw	151	148	162	3.05
Gliricidia leaves+ EM	198	137	86	9.71
Rice straw+EM	214	142	95	7.02
EM	179	156	114	7.94
Control	148	158	179	6.61
SE mean	12.5	9.8	7.3	
CV (%)	18.4	12.6	10.4	

Table 3. Effect of EM and Organic Amendments on Weed Growth Indices Based on Chemical Fertilizer as 100 Percent.

Treatments		(%)	
	Year1	Year2	Year3
Chemical fertilizer	100	100	100
Gliricidia leaves	81.1	87.2	82.1
Rice straw	86.2	86	85.2
Gliricidia leaves+ EM	113.1	79.6	45.2
Rice straw+EM	122.2	82.5	50
EM	102.2	90.6	60
Control	84.5	91.1	94.2
Sx	4.2	2	1.1

Weed growth indices are calculated from yield (g) of dry matter/m^2.

In the second season, the application of EM reduced weed biomass while that of other treatments either increased or were similar to values of the first season. Weed biomass of plots to which EM was applied alone, with *Gliricidia* and rice straw was reduced by 12, 30 and 33 percent, respectively, compared with the first season. This reduction is less than that of weed numbers (Table 1), which could be attributed to increased growth of individual plants in a lower population.

In the third season, weed biomass from EM applied alone, and with *Gliricidia* and rice straw was further reduced by 26, 37 and 33 percent, respectively, compared with the second season. Again, chemical fertilizer and the organic amendments alone increased weed biomass with time.

The beneficial effects of EM in reducing weed populations and biomass is again emphasized by the weed growth indices reported in Table 3. In the first season, the application of EM enhanced the indices significantly compared with the chemical fertilizer treatment. The increase in weed indices was greater for rice straw + EM than for *Gliricidia* + EM. A possible explanation is that decomposing legume leaves elicited allelopathic effects or phytotoxic chemicals that adversely affected plant growth (Rizvi et al., 1992). However, in the second season, EM application reduced the weed growth indices significantly compared with the non-

EM treated plots. This result is also apparent in the third season where EM application reduced weed growth indices by 40 to 50 percent compared with chemically-fertilized plots. This demonstrates that EM is effective in reducing weed seed-banks in organic farming systems under tropical conditions.

Farmers adopt improved cultural practices to increase crop yields and economic returns. The effect of EM on increasing tomato yields in organic systems is reported in Table 4. Throughout this study, chemical fertilizer produced the highest yields, and the control plots the lowest. This indicates the very low fertility status of this soil, which is somewhat typical of most intensively cultivated tropical soils. Consequently, the application of organic amendments, especially *Gliricidia* leaves, markedly increased tomato yields compared with the untreated control. Rice straw also increased tomato yield but to a lesser extent. However, when EM was applied alone, and with *Gliricidia* and rice straw in the first season, crop yields were increased by 6, 8 and 7 percent, respectively, compared with the control and the organic amendments applied alone. The most likely explanation is that EM enhanced the decomposition of the organic amendments, as well as the indigenous soil organic matter, thus, releasing available nutrients to the growing plants and developing more favorable rhizosphere conditions (Sangakkara and Higa, 1994; Sangakkara, 1996).

Table 4. Effect of EM, Chemical Fertilizer and Organic Amendments on Yield of Tomato.

Treatments	(kg/ 0.25			
	Year1	Year2	Year3	Sx
Chemical fertilizer	986	1026	942	20.4
Gliricidia leaves	684	714	720	11.2
Rice straw	615	662	685	9.4
Gliricidia leaves+ EM	747	842	904	16.5
Rice straw+EM	659	791	794	31.9
EM	440	496	528	14.3
Control	415	402	382	7.1
LSD (P=0.05)	34.9	21.7	18.6	

The effect of EM was greater in the second and third seasons where tomato yields increased significantly, especially when it was applied with the organic amendments (Table 4). This indicates that EM can significantly increase crop yields in organic farming systems, which can be partly attributed to the role of EM in reducing weed populations and in developing a more favorable environment for plant growth and yield (Sangakkara and Higa, 1994).

Conclusions

This study was conducted over three consecutive growing seasons and demonstrates that EM can effectively reduce weed populations over time. EM stimulated weed seed germination and growth in the first season. However, weed populations declined progressively in the second and third seasons, mainly from the earlier EM-enhanced reduction in the soil weed seed-bank. This is in sharp contrast with conventional farming systems where chemical fertilizers tend to maintain large soil weed seed-banks and weed populations. Results indicate that because of the decline in weed populations from EM application, EM is better able to elicit beneficial effects on crop growth and yield.

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