Impact of Effective Microorganisms on Dry Matter Partitioning in Maize (Zea mays L).

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Abstract
Field experiments were carried out during three consecutive cropping seasons to elucidate the efficiency of dry matter partitioning in maize (Zea mays L) as affected by Effective Microorganisms (EM). EM was sprayed after diluting to 1/1000, 1/500 and 1/200, at a rate of 10 1/ha as a basal spray and at time of flowering of maize, to plots supplied with sheep dung at the rate of 6 t/ha. Plots with only sheep dung or chemical fertilizer or without soil amendments were used as control treatments.
Plots with no soil amendments or only sheep dung resulted in the lowest growth and grain yield (761 – 981 kg/ha), and inefficient dry matter partitioning in maize. During the first two seasons, application of EM did not produce any significant effect on growth or yield of maize when compared to chemical fertilizer. However, in the third season, EM when applied after diluting to 1/1000 and 1/500 gave similar yields, but 1/200 gave significantly higher yields when compared to that of the conventional plots. The dry matter partitioning to maize cobs in EM treated plots (1/200) was significantly higher when compared to the chemical fertilizer treatments. The starch and sugar analysis also supported these findings.
The results indicate that EM increases growth and grain yield of maize with time. Application of EM after diluting to 1/200 at a rate of 10 1/ha together with sufficient organic matter in consecutive seasons could be a viable technique to increase maize production via efficient dry matter partitioning.

Introduction
Addition of organic amendments to soil including crop residues, animal manures, green manures, composted organic wastes of both plant and animal origin markedly improve soil productivity, fertility and tilth. It is also well known that such amendments can significantly increase the number of beneficial microorganisms in the soil that are involved in biological nitrogen fixation, organic matter decomposition, mineralization, nitrification and antagonism to soil borne plant pathogens.
Exploration of organic methods for more sustainable agriculture was proposed by Higa (1991). The basic principle behind this system is the use of mixtures of beneficial microorganisms (Effective microorganisms; EM) to enhance soil quality and health. The major theories on this aspect such as disease suppressiveness, organic energy supplement, inorganic nutrient solubilization, balancing of soil microbial populations and the photosynthetic and nitrogen fixation capabilities are well documented (Higa and Wididana 1989).
Maize (*Zea mays* L) is a traditional cereal crop in the dry regions of the tropics. Ransom (1989) reported that the greatest scope for expansion of this crop lies in the un-irrigated highlands under smallholder farming conditions of the tropics. In Sri Lanka, maize has been reported as an important cereal crop, second only to rice (Anon 1993) which is largely confined to the highlands in the dry zone and is utilizing minimal amounts of inorganic fertilizers and agrochemicals.
Low grain yield of maize in the tropics (Fisher and Palmer 1980) is attributed to problem of dry matter distribution within the crop and to sensitivity of both net photosynthesis and partitioning to environmental stress (Downey 1971; Boyer 1976). Although the physiological developments and mechanisms of dry matter distribution in maize are relatively well documented (Hofstra and Nelson 1969) little is known of quantitative partitioning to roots in field environments under normal management conditions.
The results of preliminary investigations carried out in Sri Lanka indicate that maize grown in production systems that use EM with organic matter give equivalent yields to conventional systems. However, the physiological basis of yield improvement is not well understood. The present study was carried out to investigate the impact of EM on dry matter partitioning in maize in order to elucidate the causal factors for yield increment.

Material and Methods

Field experiments were carried out at the University Experimental Station (7°N, 28-30°C, 480 m above sea level) for three consecutive seasons from October 1995 to March 1997. The soil was an ultisol with a pH (1:2.5 H_2O) 5.7 – 6.2, organic matter 1.46 percent $\pm$ 0.21 percent and Cation Exchange Capacity 406 m eq/100g soil. The mean annual rainfall of the region is 1675 mm.

Maize seeds (*Zea mays* L var. Bhadra) were planted in 4 x 5 m^2 plots with two seeds per hill at a 60 x 25 cm spacing. The plants were thinned out to one plant per hill after emergence to a final population of 70,000 plants per ha.

The plots under conventional cropping system received inorganic fertilizers as a basal dressing (equivalent to 50kg urea, 100kg concentrated super phosphate and 50kg muriate of potash) and as a top dressing of 100kg of urea at 4 weeks after planting according to the recommendations of the Department of Agriculture, Sri Lanka. In the organic system, plots received sheep dung at the rate of 6 t/ha as a basal dressing. Kyusei EM 1 was applied to organically amended plots at dilution rates of 1/2000 or 1/500 or 1/1000, at a rate of 10 1/ha of the diluted solution at time of organic matter application and at flowering. The plots were kept weed free manually. Plots were demarcated with 30cm deep. 1m wide furrows to avoid cross contamination. All other cultural practices were carried out according to recommendations made by the Department of Agriculture, Sri Lanka. A plot with no soil amendments was maintained as a control. Leaf area per plant and shoot and root dry matter was measured at 4, 6 and 8 weeks after planting (WAP). The yield components, dry matter distribution at final harvest, and starch and soluble sugar contents (Anthrone method; Yoshida et al 1976) in stem of the maize plants at time of flowering and maturity were also measured.

The experiment was conducted using a randomized complete block design with 3 replicates. The SAS statistical package was used to carry out the analysis of variance and the treatment means were compared using Duncan's New Multiple Range Test at p=0.05.

Results and Discussion

The results of the experiments indicated that there was no significant effect of EM on growth and development of maize when compared to conventional system during the first two cultivating seasons. However, significant improvements in crop growth and development were observed during the third cultivating season. Thus, only the results of the third season are presented in this paper.

Leaf Area of Maize

The maize plants in plots with no soil amendments had the lowest leaf area per plant (Table 1) at time of flowering (8 weeks after planting ; WAP). The plots amended with only sheep dung gave a significantly higher leaf area in maize when compared to the unamended control. However, poor canopy was observed in comparison to plots treated with EM or with conventional management practices. Increasing concentrations of EM enhanced the canopy development of maize. Similar results were reported by Marambe et al (1994) for food legumes. The conventional system gave a 92 percent higher leaf area per plant and the organic system, (1/200 EM + sheep dung) gave 87 percent higher leaf area per plant when compared to the plots without any soil amendments.

Table 1. Leaf Area (cm^2/plant) of Maize in the Third Successive Cultivating Season

Treatment	4 WAP*	6 WAP*	8 WAP*
Control	108 a	196 a	295 a
Sheep Dung (SD)	140 b	288 b	436 b
EM (1/1000) + SD	152 c	329 c	514 c
EM (1/500) + SD	160 c	319 c	526 c
EM (1/200) + SD	196 d	374 d	587 d
Conventional	187 d	367 d	592 d

* Weeks after planting

Within each column means denoted by the same letter are not significantly different by the Duncan's New Multiple Range Test at p=0.05.

Dry Matter Partitioning : Shoot and Root Dry Weights

The lowest and highest shoot and root dry weights were recorded in plots with no soil amendments and conventional system, respectively (Table 2). The plots treated only with organic matter (sheep dung) recorded a significantly higher shoot and root dry matter compared to the control plots but significantly lower dry weights when compared to plots amended with EM, or conventional system. Increasing concentrations of EM enhanced the plant dry matter production. The highest shoot and root dry matter were observed in plots treated with EM (1/200) + sheep dung which were 102 percent and 56 percent higher, respectively, than those observed in the unamended control plots. Interestingly, there were no statistically significant differences of the shoot and root matter contents between the plots treated with EM (1/200) + sheep dung and conventional system.

The shoot : root ratio of all the treatments increased upt to the time of flowering (Table 2). At time of flowering, the highest shoot : root ratio was observed in plots with EM (1/200) + sheep dung and the result was significantly higher than that of the plots treated with conventional management practices. Application of EM increases the nutrient availability in organic agricultural systems (Sangakkara et al 1993). Shortage of nutrients increases the proportion of dray matter allocated to the above ground vegetative parts (Squire 1993). The results of the present experiment indicate that higher dry matter in maize plants treated with EM (1/200) + sheep dung could be due to higher nutrient availability through development of a conducive environment for soil microbes as explained by Higa (1991).

Table 2. Shoot and Root Dry Weights (g/plant) and Shoot /Root Ratio of Maize During Different Growth Stages in the Third Successive Cultivating Season.

	4 WAP *			6 WAP			8 WAP		
Treatment	**Shoot**	**Root**	**Shoot/Root**	**Shoot**	**Root**	**Shoot/Root**	**Shoot**	**Root**	**Shoot/Root**
Control	9.2	1.7	5.41 a	21.6	4.6	4.69 a	23.5	5.5	4.27 a
Sheep dung (SD)	9.7	1.7	5.70 b	30.4	5.3	5.73 b	34.6	7.1	4.87 b
EM (1/1000) + SD	10.5	1.8	5.83 b	38.9	6.9	5.63 b	41.2	8.1	5.01 b
EM (1/500) + SD	10.7	1.8	5.94 b	41.0	7.5	5.46 b	45.6	8.4	5.42 c
EM (1/200) + SD	11.1	1.8	6.16 c	46.9	7.8	6.01 c	49.5	8.6	5.75 d
Conventional	10.9	1.8	6.05 c	43.2	7.2	6.00 c	46.5	8.5	5.47 c

* Weeks After Planting

Within each column means denoted by the same letter are not significantly different by the Duncan's New Multiple Range Test at p=0.05

Dry Matter Partitioning : Starch and Sugar Contents

Starch and sugar contents in stems of maize increased from flowering to maturity (Table 3). In the control plots with no soil amendments, the starch content of stems increased from 68 percent to 81 percent indicating poor dry matter partitioning in these plots. Similar results were observed in the plots treated with only organic matter and EM (1/1000 or 1/500) + sheep dung. However, at higher concentrations of EM (1/200) + sheep dung, and the plots with conventional management, the starch content showed only a marginal increase.

The soluble sugar contents in the stems of control plots increased from 14 percent at time of lowering to 26 percent at time of maturity. Inefficient distribution of dry matter to the grain is a major problem in tropical maize when compared to temperate maize. Stem sugar content in maize has been reported to increase from time flowering to maturity (CIMMYT 1975). In the present study, the sugar content in plots with only sheep dung or EM (1/1000 or 1/500) + sheep dung increased from 15 percent at flowering to 22 percent at maturity, and in plots treated with EM (1/200 or 1/500) and conventional management from 17 to 20 percent.

Table 3. Starch and Sugar Contents in Stems of Maize Plant in the Third Successive Season

Treatment	At Flowering		At Maturity	
	Starch (% DM)*	Sugar (% DM)	Starch (% DM)	Sugar (% DM)
Control	68.0 a	11.1 a	76.8 a	18.0 a
Sheep dung (SD)	69.0 a	11.3 a	76.2 a	16.4 b
EM (1/1000) + SD	67.9 a	11.3 a	76.7 a	17.1 b
EM (1/500) + SD	68.3 a	11.0 a	75.8 a	16.9 b
EM (1/200) + SD	69.8 a	11.4 a	71.1 b	12.0 d
Conventional	69.1 a	11.3 a	72.2 b	13.1 c

* Percentage of Dry Matter Content

Within each column means denoted by the same letter are not significantly different by the Duncan's New Multiple Range Test at p=0.05

The final yield of plots treated with EM (1/200) + sheep dung was similar to that observed in the conventional system (Table 4). The grain yield of the control plots with no soil amendment was 71 – 72 percent less than that recorded in the EM (1/200) + sheep dung or conventional plots. The numbers of cobs per plant were not affected by the treatments. Increasing the concentration of EM enhanced the number of grains and grain weight per cob (Table 4) indicating high dry matter allocated to the grains which is mainly attributed to the high nutrient availability (Sangakkara et al 1993). In the plots that received only organic matter, the number of grains and grain weight per cob were reduced by 40-44 percent and 37-40 percent, respectively, when compared to the EM (1/200) + sheep dung or conventional plots. As described by Nicou and Chopart (1979) poor root growth and low leaf area in maize plants may have reduced the leaf photosynthetic rate, thus reducing the grain yield components, especially the grain number. Maize is known to have poor dry matter partitioning to the grain during stress environments (Chang 1981).

Table 4. Yield Components and Grain Yield of Corn in the Third Successive Cultivating Season.

Treatment	No. Grain per Cob	Grain Weight mg/grain	Grain Yield kg/ha
Control	207 ± 28	154 ± 17	761 ± 66
Sheep dung (SD)	246 ± 19	171 ± 21	982 ± 49
EM (1/1000) + SD	327 ± 26	208 ± 26	1617 ± 85
EM (1/500) + SD	382 ± 16	212 ± 13	1918 ± 27
EM (1/200) + SD	434 ± 11	281 ± 19	2668 ± 30
Conventional	404 ± 14	252 ± 11	2431 ± 52

Mean ± standard error

Conclusions

The results of the experiments indicate that continuous use of EM enhance growth and development of maize over conventional production systems. EM would enhance the partitioning of assimilates to the grains of maize. In this regard, application EM (1/200) with organic matter (i.e. sheep dung) would be a viable technique to enhance the productivity of maize growth in a organic agricultural system.

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