# Effects of Chemical Fertilizers, Organic Amendments and Effective Microorganisms (EM) on Soil Fertility and Seed Cotton Production

KHIN KHIN MU

Fibre and Yarn Testing Laboratory
Cotton and Sericulture Department
Myanmar Industrial Crop Development Enterprise (MICDE)
Meikthila, Mandalay Division

## ABSTRACT

EM technology is based on the use of mixed cultures of beneficial microorganisms as inoculants that can increase the microbial diversity of agricultural soils. Mineral nutrition of cotton, various optimum conditions in soil required for cotton cultivation and the contributions made by several soil microorganisms have been critically reviewed in this experiments.

The experimental results indicated that neither seed cotton yield nor soil fertility can be sustained if no action is taken against soil degradation in consecutive cotton cropping at Lungyaw Farm. Application of chemical fertilizers significantly improved cotton yields, but soil fertility deterioration in terms of chemical and physical properties of soil under such farming practices were observed.

Applications of EM were found to magnify the positive effects of various soil basal treatments on the seed cotton production and soil fertility under consecutive seed cotton croping at Lungyaw Model Cotton Farm.


## Introduction

Cotton is a clean - culture crop, this is not much chance for an accumulation of organic matter in the soil. The long-term use of only chemical fertilizers in crop production has created serious problems such as higher cost of production with lower net income for the farmers. Many cultivated soil used for cotton growing, needs not only chemical fertilizers but also adequate organic matter to maintain optimum drainage and aeration conditions. The efficiency of added organic matter can be greatly magnified by the activity of various soil microorganisms EM technology is based on the use of mixed cultures of beneficial microorganisms as inoculants that can increase the microbial diversity of agricultural soils.

### Effective Microorganisms (EM)

EM are mixed culture of beneficial microorganisms can that be applied as inoculants to increase the microbial diversity of soil and plants which, in turn, can improve soil health, and the growth, yield are quality of crops. (Higa and Wididana, 1991)

There are two main groups of microorganisms in soil, namely harmful microorganisms and beneficial or effective microorganisms.

The soil microorganisms can be classified into major groups, such as the bacteria, actinomycetes, fungi, moulds and yeasts - the microflora; and the protozoa, worms and arthopods the microfauna and fauna.

A list of the main classes of organisms involved in the composting process in given in the Table. (A)

**Table (A) Organisms of Composting**

| **No** | **Organisms type** | **Organisms** | **Number per gm of moist compost** |
|---|---|---|---|
| 1 | Microflora | Bacteria | $10^8$- $10^9$ |
| | (Very small plants) | Actinomycetes, | $10^5$- $10^8$ |
| | | Fungi mould, yeasts | $10^4$- $10^6$ |
| 2 | Microfauna | Protozoa | $10^4$- $10^5$ |
| | (very small animals) | | |
| 3 | Microflora | Fungi (mushrooms) | |
| | (Large plants) | | |
| 4 | Microfauna | Millipedes, centipedes, | |
| | (small soil animals) | spiders, Beetles warms. | |

Source: Dalzell et al. (1987)

Harmful microorganisms cause detrimental effects on crop production and those effects can be briefly summarized as follows:

1. induction of plants diseases,
2. stimulation of soil-borne pathogens,
3. immobilization of plant nutrients,
4. inhibition of seed germination,
5. inhibition of plant growth and development, and
6. production of phototoxic substance.

Beneficial microorganisms that can integrate the soil-plant microbiological equilibrium include lactic acid bacteria, photosynthetic bacteria, actinomycetes and microrrhizal fungi.

Through useful fermentations these organisms produce organic acids, plant hormones (e.g auxin, gibberellin and cytokinin), vitamins and antibiotics.

(These products of microbial metabolism can benefit the growing plant by;)

a. solubilizing nutrients of limited solubility, eg-rock phosphate,
b. complexing heavy metals to limit their uptake by plants,
c. providing simple organic molecules such as amino acid for direct uptake,
d. protecting the plant from soil-borne pathogens, insects and diseases,
e. stimulating plant growth and increasing the yield and quality of crops, and
f. improving the chemical and physical properties of soils.

EM is the mixture of the beneficial microorganisms, which have following functions;

1. fixation of atmospheric nitrogen,
2. decomposition of organic wastes and residues
3. suppression of soil borne pathogens,
4. recycling and increased availability of plant nutrients.
5. degradation of toxicants including pesticides,
6. Production of antibiotics and other bioactive compounds.
7. production of simple organic molecules for plant uptake,
8. complexation heavy metals to limit plant uptake,
9. solubilization of insoluble sources and
10. production of poly saccharides to improve soil aggregation

**Objective**

- To study the effects of chemical fertilizers, organic amendments, and effective microorganisms (EM) on the performance of cotton crop,
- To study the effects of treatments on the chemical and physical properties of cultivated soils, and
- To formulate a profitable agriculture system which will improve soil fertility and productivity without causing deterioration of the environment.

## Mateirals and Methods

| | | |
|---|---|---|
| Experimental site | - | Lungyaw Model Cotton Farm Kyaukse Township |
| Duration | - | Expt: (1) 1997, February to August.<br>Expt: (2) 1998, March to September |
| Design | - | Strip plot (2 × 6 × 4) |
| Replication | - | 4 |
| Plot size | - | Sub plot size - 7 × 9 sq m<br>Whole plot size - 3024 sq m (0.3 ha) |
| Row spacing | - | 100 × 33 cm (10 rows) = 3' × 1' - 2 Plt |
| Variety | - | Lungyaw - 3 (*Gossypium hirsutum*) |

## Treatments

(a) Main treatments (Vertical factors)

Soil basal treatments (M) = 6

$M_1$ = Control

$M_2$ = Fertilizers

$M_3$ = Farm yard Manure (F.Y.M)

$M_4$ = Rice straw

$M_5$ = Sesamum Straw

$M_6$ = Pea Straw

(b) Sub - treatments (Horizontal factors)

EM application levels (S) = 2

$S_1$ = Without EM

$S_2$ = With EM

## Preparation of Bokashi

Firstly, straw bed of about 20 cm height with rectangular shape was made. EM instant solution was spread onto the straw. A little amount of F.Y.M, and rice - bran were spread on the straw bed. The procedure was repeated unit the height of Bokashi pile reached about 1 meter. This pile was covered with a plastic sheet. The temperature of the Bokashi pile was checked frequently. If the temperature shot up above 45°C, the cover was removed for a few minutes to bring the temperature down. Under warm weather condition, it would be ready to be used in about 7-10 days.

The treatments used in this field experiments were as follows:

| Sr No | Symbol | Treatments |
|---|---|---|
| Treatment 1 | $M_1$ $S_1$ | Control |
| Treatment 2 | $M_1$ $S_2$ | EM only |
| Treatment 3 | $M_2$ $S_1$ | Chemical fertilizers only |
| Treatment 4 | $M_2$ $S_2$ | Chemical fertilizers + EM |
| Treatment 5 | $M_3$ $S_1$ | Farm yard manure (F.Y.M) only |
| Treatment 6 | $M_3$ $S_2$ | Farm yard manre (F.Y.M) + EM |
| Treatment 7 | $M_4$ $S_1$ | Rice straw only |
| Treatment 8 | $M_4$ $S_2$ | Rice straw Bokashi + EM |
| Treatment 9 | $M_5$ $S_1$ | Sesamum straw only |
| Treatment 10 | $M_5$ $S_2$ | Sesamum straw Bokashi + EM |
| Treatment 11 | $M_6$ $S_1$ | Pea Straw only |
| Treatment 12 | $M_6$ $S_2$ | Pea Straw Bokashi + EM |

**Preparation of EM Instant Solution**

(a) EM instant solution was prepared at the 1:4:95 ratio with EM concentrate solution, molasses and water. The mixture was thoroughly shaken. The container was sealed to have an airtight conditions. When the dark colour of molasses turned to straw colour, the solution was ready to the used. It usually takes about 3 to 5 days from the time of preparation. It can be applied directly into the soil and can also be used as foliar spray.

(b) EM instant solution was prepared at the 1:1:98 ratio with EM concentrate solution, molasses and water respectively. The mixture was thoroughly shaken. This EM instant solution is to be used for making Bokashi, which is EM fermented compost.

(c) EM instant solution 1:4:95 was applied at the rate of 250 liter / ha,

Which was equally split into four does to be applied first at the time of sowing, second at 30 DAE, third at 50 DAE, and finally at 75 DAE.

**Application of Treatments**

Chemical fertilizers were used, 126 kg / ha of urea was split applied four time as: 40% of urea applied at basal,10% of urea applied at the beginning of square formation, 25% of urea at the beginning of flowering, and 25% of urea at the peak of flowering time. Triple superphosphate was applied, 126 kg / ha, Muriate of potash was used at the rate of 63 kg/ha, There were used as the basal application. Organic amendments or crop residues and bokashi were applied at the rate of 8 tons / ha, as the basal application. Cotton seed rate was 50 kg / ha.

**Data Collection**

(a) The following yield and yield components were recorded;

1. plant height (cm),
2. No. of leaf per plant (No. / plt),
3. No. of branches per plant (No. / plt),
4. Fresh weight per plant (g / plt),
5. Dry weight per plant (g / plt),
6. No. of squares per plant (No. / plt), and
7. yield of seed cotton (Kg / ha)

(b) Soil sample Analysis

1. Determination of soil texture,
2. Soil organic carbon,
3. total nitrogen content in soil,
4. available phosphorous content in soil,
5. available potassium content in soil,
6. bulk density of soil,
7. maximum water holding capacity of soil.

(c) Organic materials before and after composting Analysis;

1. Organic carbon %,
2. Total nitrogen %,
3. C:N (Carbon, nitrogen ratio),
4. Total $P_2O_5$ %,
5. Total $K_2O$ %.

## CONCLUSION

Among the four organic manures, pea straw application was found to be the most effective soil amendment in cotton production. When the organic manures were fermented with EM, before they were applied to the soil, the effects of organic manures on cotton productions were found to be magnified. Control plots which did not receive any organic residues or any chemical fertilizers showed degradation of chemical (eg. negative balances of some plant nutrients in soil) and physical (eg. increased bulk densities of soil and decreased maximum water holding capacities) properties of soil under consecutive cotton growing. Application of chemical fertilizers resulted in positive balances of some plant nutrients budget (such as available $P_2O_5$, available $K_2O$ etc) in soil after growing cotton. However repeated used of chemical fertilizers in consecutive cotton growing resulted in significant degradation of soil physical properties such as bulk densities and maximum water holding capacities due to the compaction of soil. Addition of organic manures as soil amendments increased cotton yield to a considerable extent when compared to control. Among the four types of organic manures being investigated pea straw bokashi addition produced seed cotton yield almost as good as chemical fertilizers application If pea straw is not readily available either F.Y.M + EM, addition or rice straw boksahi may be chosen as second most suitable substitutes for chemical fertilizers.

Addition of organic manures improved not only chemical properties but also physicals properties of soil.

Hence, the experimental results indicated that addition of pea straw bokashi at the rate of 8 tons / ha may be considered as a profitable farming method which will improve or sustain not only crop productivity but also soil fertility in consecutive cotton growing at Lungyaw Farm, Kyaukse.

## Reference

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Table (1) Effect of chemical fertilizers, organic amendments and EM on the seed cotton yield and yield components, observed in first field experiment conducted in per-monsoon, 1997.

| **Treatments** | **Plant height (cm)** | **no. of leaves/plt (no. / plt)** | **no. of branches/plt (no. / plt)** | **Fresh weight/plt (g / plt)** | **Dry weight/plt (g / plt)** | **no. of squares/plt (no. / plt)** | **no. of bolls/plt (no. / plt)** | **Seed cotton yield (Kg / ha)** |
|---|---|---|---|---|---|---|---|---|
| ($M_1$) Control | | | | | | | | |
| Without EM | 80.9 c | 52.8 d | 12.9 de | 135 e | 63.8 d | 9.1 d | 9.7 d | 1228 de |
| With EM | 84.5 bc | 56.4 cd | 12.9 de | 165 bcde | 74.5 bcd | 9.9 bcd | 9.8 d | 1364 abcd |
| ($M_2$) Fertilizers | | | | | | | | |
| Without EM | 89.8 ab | 71.0 ab | 14.5 ab | 217 ab | 99.5 ab | 11.6 ab | 12.7 ab | 1410 abc |
| With EM | 94.9 a | 73.3 a | 15.0 a | 240 a | 116.0 a | 12.6 a | 13.5 a | 1489 a |
| ($M_3$) F.Y.M | | | | | | | | |
| Without EM | 82.7 bc | 63.2 bc | 13.6 cde | 137 e | 70.5 bcd | 9.6 cd | 10.4 cd | 1353 abcd |
| With EM | 84.4 bc | 65.0 abc | 14.0 bc | 200 abcd | 96.0 abc | 10.9 cd | 10.6 cd | 1421 abc |
| ($M_4$) Rice Straw | | | | | | | | |
| Without EM | 81.5 bc | 59.8 cd | 12.8 cde | 152 cde | 64.0 d | 9.6 cd | 9.7d | 1193 e |
| With EM | 86.2 bc | 62.0 c | 13.2 de | 200 abcd | 84.5 abcd | 11.1 abc | 11.6 cd | 1275 cde |
| ($M_5$) Sesamum Straw | | | | | | | | |
| Without EM | 78.5 c | 58.1 cd | 13.4 de | 142 e | 64.8 cd | 10.2 bcd | 9.7 d | 1239 de |
| With EM | 80.6 c | 59.1 cd | 13.6 abc | 175 bcde | 76.5 bcd | 11.0 abcd | 10.2 d | 1289 bcde |
| ($M_6$) Pea straw | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Without EM | 83.5 bc | 62.1 c | 13.7 bcd | 145 de | 70.5 bcd | 11.6 ab | 11.3bcd | 1371 abcd |
| With EM | 86.0 bc | 63.1 bc | 14.2 abc | 207 abc | 96.3abc | 12.6 a | 12.3 ab | 1443 ab |

Treatment means in a column sharing the same letters are not significantly different at the 5% level of probability.

Table (2) Effect of chemical fertilizers, organic amendments and EM on the seed cotton yield and yield components, observed in second field experiment conducted in per-monsoon, 1998.

| **Treatments** | **Plant height (cm)** | **no. of leaves/plt (no. / plt)** | **no. of branches/plt (no. / plt)** | **Fresh weight/plt (g / plt)** | **Dry weight/plt (g / plt)** | **no. of squares/plt (no. / plt)** | **no. of bolls/plt (no. / plt)** | **Seed cotton yield (Kg / ha)** |
|---|---|---|---|---|---|---|---|---|
| ($M_1$) Control | | | | | | | | |
| Without EM | 65.9 c | 40.4 e | 16.0 d | 112 f | 55.3 e | 10.0 d | 9.8 d | 798.8 g |
| With EM | 68.3 bc | 42.1 de | 16.8 bcd | 129 def | 64.5 de | 12.5 de | 11.6 cd | 935.3fg |
| ($M_2$) Fertilizers | | | | | | | | |
| Without EM | 78.1 ab | 54.5 abc | 17.8 bc | 178 b | 86.8 b | 15.5 abc | 15.6 ab | 1352.5 ab |
| With EM | 86.3 a | 60.6 a | 19.5 a | 212 a | 108.3 a | 17.7 a | 17.4 a | 1491.3 a |
| ($M_3$) F.Y.M | | | | | | | | |
| Without EM | 73.2 bc | 45.5 de | 16.9 bcd | 123 def | 61.5 de | 12.5 cd | 11.9 cd | 1070.3 cdef |
| With EM | 74.7 bc | 48.6 bcde | 18.0 b | 139 def | 69.5 cde | 13.7 bc | 12.9 bc | 1187.8 bcd |
| ($M_4$) Rice Straw | | | | | | | | |
| Without EM | 72.0 bc | 42.1 de | 16.8 bcd | 128 def | 64.8 de | 12.9 cd | 11.9 cd | 1018.0 def |
| With EM | 73.8 bc | 47.7 bcde | 17.1 bcd | 150 bcd | 73.3 cde | 13.5 bcd | 13.0 bc | 1137.0 de |
| ($M_5$) Sesamum Straw | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Without EM | 69.8 bc | 46.4 cde | 16.5 cd | 120 ef | 61.3 de | 13.2 cd | 12.2 c | 906.0 fg |
| With EM | 71.3 bc | 49.1 bcd | 17.0 bcd | 145 cde | 73.0 cd | 14.7 abc | 13.2 bc | 977.8 efg |
| ($M_6$) Pea straw | | | | | | | | |
| Without EM | 73.4 bc | 49.7 bc | 17.4 bcd | 145 cde | 73.5 cd | 14.1 bc | 12.9 bc | 1074.3 cdef |
| With EM | 77.7 ab | 55.6 ab | 18.1 ab | 171 bc | 84.8 bc | 16.9 ab | 16.5 a | 1220.3 bc |

Treatment means in a column sharing the same letters are not significantly different at the 5% level of probability.

Table (3) Effect of EM on the *Organic Carbon Content of soil* cultivated with cotton in pre-monsoon seasons of 1997 and 1998.

| **Treatments** | **First field experiment, 1997** | | | | **Second field experiment, 1998** | | | |
|---|---|---|---|---|---|---|---|---|
| | Organic Carbon % | | difference | Percent increase due to EM | Organic Carbon % | | difference | Percent increase due to EM |
| | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ |
| ($M_1$) Control | 1.60 | 1.61 | + 0.01 | + 0.63 % | 1.48 | 1.51 | + 0.03 | + 2.03 % |
| ($M_2$) Fertilizers | 1.65 | 1.63 | - 0.02 | - 1.21 % | 1.57 | 1.69 | + 0.12 | + 7.64 % |
| ($M_3$) F.Y.M | 1.60 | 1.71 | + 0.11 | + 6.88 % | 1.64 | 1.73 | + 0.09 | + 5.49 % |
| ($M_4$) Rice Straw | 1.62 | 1.68 | + 0.06 | + 3.70 % | 1.67 | 1.68 | + 0.01 | + 0.60 % |
| ($M_5$) Sesamum Straw | 1.60 | 1.72 | + 0.12 | + 7.50 % | 1.66 | 1.75 | + 0.09 | + 5.42 % |
| ($M_6$) Pea Straw | 1.68 | 1.71 | + 0.11 | + 6.88 % | 1.69 | 1.84 | + 0.15 | + 8.88 % |
| **(S) Mean** | **1.63** | **1.68** | **+ 0.05** | **+ 3.07 %** | **1.62** | **1.70** | **+ 0.08** | **+ 4.94 %** |

Table (4) Effect of EM on the *Total nitrogen Content of soil* cultivated with cotton in pre-monsoon seasons of 1997 and 1998.

| **Treatments** | **First field experiment, 1997** | | | | **Second field experiment, 1998** | | | |
|---|---|---|---|---|---|---|---|---|
| | Total nitrogen % | | difference | Percent increase due to EM | Total nitrogen % | | difference | Percent increase due to EM |
| | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ |
| ($M_1$) Control | 0.16 | 0.16 | 0 | + 0 % | 0.14 | 0.15 | + 0.01 | + 7.14 % |
| ($M_2$) Fertilizers | 0.17 | 0.17 | 0 | + 0 % | 0.16 | 0.17 | + 0.01 | + 6.25 % |
| ($M_3$) F.Y.M | 0.16 | 0.18 | + 0.02 | + 12.50 % | 0.18 | 0.18 | 0 | 0 % |
| ($M_4$) Rice Straw | 0.17 | 0.18 | + 0.01 | + 5.88 % | 0.10 | 0.18 | + 0.02 | + 12.50 % |
| ($M_5$) Sesamum Straw | 0.17 | 0.18 | + 0.01 | + 5.88 % | 0.16 | 0.18 | + 0.02 | + 12.50 % |
| ($M_6$) Pea Straw | 0.17 | 0.19 | + 0.02 | + 11.76 % | 0.18 | 0.21 | + 0.03 | + 16.67 % |
| **(S) Mean** | **0.17** | **0.18** | **+ 0.01** | **+ 5.88 %** | **0.16** | **0.18** | **+ 0.02** | **+ 12.50 %** |

Table (5) Effect of EM on the *Available $P_2O_5$ Content of soil* cultivated with cotton in pre-monsoon seasons of 1997 and 1998.

| **Treatments** | **First field experiment, 1997** | | | | **Second field experiment, 1998** | | | |
|---|---|---|---|---|---|---|---|---|
| | Available $P_2O_5$ % | | difference | Percent increase due to EM | Available $P_2O_5$ % | | difference | Percent increase due to EM |
| | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ |
| ($M_1$) Control | 138.92 | 140.28 | + 1.36 | + 0.98 % | 125.81 | 126.42 | - 0.61 | + 0.48 % |
| ($M_2$) Fertilizers | 215.80 | 216.34 | + 0.54 | + 0.25 % | 215.64 | 292.71 | + 77.07 | + 35.4 % |
| ($M_3$) F.Y.M | 196.28 | 196.74 | + 0.46 | + 0.23 % | 192.50 | 234.61 | + 42.10 | + 21.87 % |
| ($M_4$) Rice Straw | 108.19 | 184.12 | + 3.93 | + 2.18 % | 172.96 | 195.81 | + 22.85 | + 13.2 % |
| ($M_5$) Sesamum Straw | 159.57 | 162.39 | + 2.82 | + 1.77 % | 162.58 | 180.06 | + 17.48 | + 10.75 % |
| ($M_6$) Pea Straw | 146.72 | 156.30 | + 9.58 | + 6.53 % | 148.31 | 164.21 | + 15.90 | + 10.72 % |
| **(S) Mean** | **172.92** | **176.03** | **+ 3.12** | **+ 1.80 %** | **169.3** | **198.97** | **+ 29.34** | **+ 17.30 %** |

Table (6) Effect of EM on the *Available $K_2O$ Content of soil* cultivated with cotton in pre-monsoon seasons of 1997 and 1998.

| **Treatments** | **First field experiment, 1997** | | | | **Second field experiment, 1998** | | | |
|---|---|---|---|---|---|---|---|---|
| | Available $K_2O$ % | | difference | Percent increase due to EM | Available $K_2O$ % | | difference | Percent increase due to EM |
| | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ |
| ($M_1$) Control | 0.04 | 0.04 | 0 | 0 % | 0.03 | 0.04 | + 0.01 | + 33.33 % |
| ($M_2$) Fertilizers | 0.09 | 0.09 | 0 | 0 % | 0.09 | 0.14 | + 0.05 | + 55.56 % |
| ($M_3$) F.Y.M | 0.09 | 0.09 | 0 | 0 % | 0.09 | 0.10 | + 0.01 | + 11.11 % |
| ($M_4$) Rice Straw | 0.04 | 0.04 | 0 | 0 % | 0.04 | 0.07 | + 0.03 | + 75.00 % |
| ($M_5$) Sesamum Straw | 0.05 | 0.05 | 0 | 0 % | 0.05 | 0.06 | + 0.01 | + 20.00 % |
| ($M_6$) Pea Straw | 0.09 | 0.09 | 0 | 0 % | 0.10 | 0.10 | + 0 | + 00 % |
| **(S) Mean** | **0.07** | **0.07** | **0** | **0 %** | **0.07** | **0.09** | **+ 0.02** | **+ 28.57 %** |

Table (7) Effect of EM on the *Bulk Density of soil* cultivated with cotton in pre-monsoon seasons of 1997 and 1998.

| **Treatments** | **First field experiment, 1997** | | | | **Second field experiment, 1998** | | | |
|---|---|---|---|---|---|---|---|---|
| | Bulk Density % | | difference | Percent increase due to EM | Bulk Density % | | difference | Percent increase due to EM |
| | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ |
| ($M_1$) Control | 1.39 | 1.33 | - 0.06 | - 4.32 % | 1.40 | 1.35 | - 0.05 | - 3.57 % |
| ($M_2$) Fertilizers | 1.39 | 1.33 | - 0.06 | - 4.32 % | 1.45 | 1.35 | - 0.10 | - 6.90 % |
| ($M_3$) F.Y.M | 1.33 | 1.20 | - 0.13 | - 9.77 % | 1.22 | 1.20 | - 0.02 | - 1.64 % |
| ($M_4$) Rice Straw | 1.25 | 1.16 | - 0.09 | - 7.20 % | 1.16 | 1.13 | - 0.03 | - 2.59 % |
| ($M_5$) Sesamum Straw | 1.37 | 1.16 | - 0.21 | - 15.33 % | 1.16 | 1.10 | - 0.06 | - 5.17 % |
| ($M_6$) Pea Straw | 1.37 | 1.18 | - 0.19 | - 13.87 % | 1.15 | 1.10 | - 0.05 | - 4.35 % |
| **(S) Mean** | **1.35** | **1.23** | **- 0.12** | **- 8.89 %** | **1.26** | **1.21** | **- 0.05** | **- 3.97 %** |

Table (8) Effect of EM on the *Maximum Water Holding Capacity of soil* cultivated with cotton in pre-monsoon seasons of 1997 and 1998.

| **Treatments** | **First field experiment, 1997** | | | | **Second field experiment, 1998** | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum water holding capacity of soil % | | difference | Percent increase due to EM | Maximum water holding capacity of soil % | | difference | Percent increase due to EM |
| | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ | Without EM ($S_1$) | With EM ($S_2$) | ($S_2$ - $S_1$) | $\frac{S_2 - S_1}{S_1} \times 100$ |
| ($M_1$) Control | 57.69 | 60.34 | + 2.61 | + 4 .52 % | 50.81 | 60.08 | + 9.27 | + 18.24 % |
| ($M_2$) Fertilizers | 58.46 | 63.55 | + 5.09 | + 8.71 % | 54.90 | 63.72 | + 8.82 | + 16.07 % |
| ($M_3$) F.Y.M | 61.57 | 65.26 | + 3.69 | + 5.99 % | 63.59 | 66.19 | + 2.60 | + 4.09 % |
| ($M_4$) Rice Straw | 59.35 | 61.84 | + 2.49 | + 4.20 % | 62.39 | 62.70 | + 0.31 | + 0.50 % |
| ($M_5$) Sesamum Straw | 63.03 | 63.04 | + 0.01 | + 0.02 % | 63.40 | 64.98 | + 1.58 | + 2.49 % |
| ($M_6$) Pea Straw | 61.64 | 64.35 | +2.71 | + 4.40 % | 64.76 | 65.56 | + 0.80 | + 1.24 % |
| **(S) Mean** | **60.29** | **63.06** | **+ 2.77** | **+ 4.59 %** | **59.98** | **63.87** | **+ 3.89** | **+ 6.49 %** |

Table (9) The organic carbon, total nitrogen, C:N, total $P_2O_5$ and total $K_2O$ content of organic materials before and after composting

| Organic materials | Organic Carbon (%) | | Total nitrogen (%) | | C:N | | Total $P_2O_5$ (%) | | Total $K_2O$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1997 | 1998 | 1997 | 1998 | 1997 | 1998 | 1997 | 1998 | 1997 | 1998 |
| **Organic Materials** | | | | | | | | | | |
| Rice Straw | 54.52 | 57.15 | 0.94 | 1.07 | 58.00 | 53.41 | 0.05 | 0.27 | 1.76 | 1.17 |
| Sesamum Straw | 57.97 | 55.42 | 1.90 | 1.63 | 29.46 | 34.00 | 0.12 | 0.17 | 0.91 | 0.95 |
| Pea Straw | 55.85 | 42.89 | 2.88 | 2.09 | 19.39 | 20.52 | 0.19 | 0.18 | 2.41 | 1.55 |
| F.Y.M | - | 43.57 | - | 0.54 | - | - | - | 0.33 | - | 0.77 |
| **After Composting with EM** | | | | | | | | | | |
| Rice Straw Bokashi | 44.27 | 27.06 | 1.27 | 1.23 | 34.86 | 22.00 | 0.21 | 0.61 | 1.94 | 1.45 |
| Sesamum Straw Bokashi | 55.57 | 34.40 | 2.22 | 2.15 | 25.93 | 16.00 | 0.23 | 0.55 | 2.07 | 1.68 |
| Pea Straw Bokashi | 53.83 | 20.90 | 3.18 | 2.09 | 16.93 | 10.00 | 0.26 | 0.58 | 2.85 | 2.15 |