EFFECTS OF MYCORRHIZAE AS A SUBSTITUTE FOR INORGANIC FERTILIZER ON GROWTH AND YIELD OF TOMATO (LYCOPERSICON ESCULENTUM L.) AND SOYBEAN (GLYCINE MAX L.), AND SOIL MICROBIAL ACTIVITY

CJ Alawathugoda and Dahanayake Nilanthi*
Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka

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ABSTRACT

A greenhouse experiment was conducted to determine the influence of mycorrhizae as a substitute for inorganic fertilizer on growth and yield of Tomato (Lycopersicon esculentum) and Soybean (Glycine max) and soil microbial activity. Four doses of inorganic fertilizers viz recommended dose [Tomato: Urea:TSP:MOP=65:325:65 kg/ha and Soybean Urea:TSP:MOP=35:130:35 kg/ha], 1/2 and 1/4 of recommended dose and 0 dose] were applied to soil with standard dose of mycorrhizae (2 g/5L water). The above four treatments were tested in a Completely Randomized Design (CRD) with five replicates.

Results indicated that there was no significant difference in all parameters tested on plants treated with recommended dose and 1/2 of recommended dose of inorganic fertilizer with standard dose of mycorrhizae. The highest fruit wet weight (556 g/plant - 69% higher than the lowest) in tomato plants and the highest pod wet weight (18 g/plant) in soybean was observed with 1/2 of the recommended dose of inorganic fertilizer and lowest was observed in plants treated with standard dose of mycorrhizae without inorganic fertilizer (tomato - 329 g/plant and soybean 4 g/plant). However the highest pod dry weight (8 g/plant) and seed dry weight (7 g/plant) were observed in 1/2 of recommended dose of inorganic fertilizer with standard dose of mycorrhizae in Soybean. The highest soil microbial activity was recorded in soil treated with standard dose of mycorrhizae without inorganic fertilizer (464 CO₂ mg/kg of soil - 61% higher than the recommended dose of inorganic fertilizer) and the lowest was observed in soil treated with recommended dose of inorganic fertilizer (287 CO₂ mg/kg of soil). The activities of soil microorganisms were lower in soils treated with inorganic fertilizers considering the growth parameters and soil microbial activity it can be concluded that 1/2 of the recommended dose of inorganic fertilizer with standard dose of mycorrhizae is the best fertilizer mixture for crops, tomato and soybean. Addition of mycorrhizae to the field soil increases the soil microbial activity significantly.

Key words: Soybean, Mycorrhizae, Inorganic fertilizer, Tomato

INTRODUCTION

Inorganic fertilizer application enhances plant growth and yield because it absorbs quickly to soil and plants. Therefore, farmers apply maximum amount of inorganic fertilizers to their crops to achieve a higher yield. As a result of the excessive applications of inorganic fertilizer leaches to the ground causes water pollution. To minimize this situation, a combination of inorganic fertilizer with biological ingredients can be a better alternative for crop cultivation (Urban Creeks Council, 2001). Mycorrhiza (family Endogone) is a symbiotic association between mycorrhizal fungi and higher plants roots an act as an organic fertilizer/bio fertilizer. Mycorrhizae improve crop yield and increase the use of inorganic fertilizer by forming a bridge between the roots and the soil (University of Washington, 2006). It indirectly enhances the structure of the soil and improves air and water infiltration.

Tomato (Lycopersicon esculentum: Solanaceae) is the second most important vegetable crop next to potato. Present world production of tomato is about 100 million tons from 3.7 million hectares of cultivated land. Tomato is rich in many nutrients and is a primary ingredient in many Sri Lankan curries and sometimes paired with fish, prawns, okra etc.

Soybean (Glycine max: Fabaceae) is a mycotrophic (mycorrhizal) plant native to East Asia.

*Corresponding author: nilanthi@agbio.ru.ac.lk
which is much depended on mycorrhizal symbiosis. Soybean is a profitable crop that is
grown commercially for human consumption because it is rich in protein and other nutrients.
At present soybean is one of the five major

grain legumes cultivated in Sri Lanka. It is rec-

ognized as a potential food crop that can bridge

the gap between the national needs and the

availability of protein, as well as edible oil re-

quirement in Sri Lanka (Arulandy, 1995).

The present study was conducted to find the
growth and yield responses of tomato and soy-

bean with mycorrhizae as a substitute for inor-

ganic fertilizers. The main objectives of the

study were to develop the best fertilizer combi-

nation (Inorganic fertilizer with Mycorrhizae)

for the optimum growth and yield of tomato

and soybean and to compare the soil microbial

activity of field and treated soils.

MATERIALS AND METHODS

This study was conducted at the Faculty of Ag-

riculture, University of Ruhuna, Mapalana,

Kamburupitiya. The study site is located in the

low country wet zone (WL2) with the annual

rainfall of 1900 mm, the mean monthly tem-

perature of 27.5 °C, and relative humidity of

around 72 %.

Tomato (variety Bhathiya) and Soybean

(variety PM 25) seeds were obtained from the

Department of Agriculture. Nursery trays were

filled using 1:1 ratio of compost and sand.

Seeds were covered by thin soil layer and wa-
tered daily. After twenty one days of nursery

period, healthy equal size (5 cm) seedlings

were transplanted to pots to maintain three

plants per pot. After 10-12 days weaker plants

were thinned out and to leave two plants per

pot.

Potting medium was prepared using 1:1:1:1

ratio of top soil, coir dust, sand and compost.
Pots were filled with potting media and sterili-

ized using Tospin (Methyl 70 %) fungicide (6

g /10 L of water). Then the pots were kept wet

for seven days. Four doses of inorganic fertil-

izer; recommended level (Soybean NPK-

35:130:35, Tomato NPK- 30:150:40) without

mycorrhizae (T1), 1/2 of recommended dose of

Inorganic fertilizer with standard dose of my-
corrhizae (2g mycorrhizae/5L water) (T2), 1/4

of recommended dose of Inorganic fertilizer

with standard dose of mycorrhizae (T3) and

Standard dose of mycorrhizae without Inor-
ganic fertilizer and (T4) (2 g mycorrhizae/5L

water) were used. Each treatment was repli-
cated five times. All management practices

were conducted according to the recommenda-
tions of the Department of Agriculture from

seed germination to harvesting.

Tomato and soybean were used to investigate

the effect of soil mixture on the number of

leaves/plant (after 25th day- beginning of the

vegetative stage and 45th day- end of the vege-
tative stage), number of flowers/plant, plant

shoot height (cm), plant root height (cm), num-

ber of pods/ fruits per plant, number of nod-

ules/plant (soybean), yield (g) /plant and mi-

crobial activity of the different soil mixtures

separately.

Determination of soil microbial activity

Soil microbial activity was measured according

to the CO2 evolution method. Soil sample (10

g) from the tomato and soybean cultivated pot

was taken in to a jam bottle and mixed with 3.5

ml distilled water. The controller set was filled

with 3.5 ml of distilled water. Ignition tube was

taken and filled with 3 ml of 2N-NaOH and

then placed on the jam bottle so that the emit-
ted CO2 from the soil will be absorbed in to the

NaOH solution. Soil samples were kept in dark

room for one week. Then contents in ignition

tubes were washed in to 250 ml conical flasks

separately and mixed with 7.5 ml of 2N BaCl2.

Few drops of phenolphthalein were added and

mixtures were titrated by 0.5N-HCl. Burette

reading was taken at the point of which burette

color changes from pink to colorless.

Experiment was carried out according to com-

plete randomized block design with four repli-
cates and 8 plants per replicate. Data were ana-

lyzed using SAS statistical software (version

9.1.3).
RESULTS AND DISCUSSION

Results revealed that the highest mean number of leaves at the day 25 (beginning of vegetative stage) was recorded in treatment with inorganic fertilizer recommended dose without mycorrhizae (T1) both in tomato (13 leaves/plant) and soybean (14 leaves/plant). But, it was not significantly different from ½ of the recommended dose of inorganic fertilizer with mycorrhizae standard dose (T2) (12 leaves/tomato plant, 14 leaves/soybean plant).

The lowest number of leaves at the 25th day was recorded in the treatment mycorrhizae standard dose without inorganic fertilizer (T4) (9 leaves/tomato plant, 11 leaves/soybean plant). T2 was not significantly different from ¼ of the recommended dose of inorganic fertilizer with mycorrhizae standard dose (T3).

Both T1 and T2 treatments were significantly different from T4. The number of leaves at the 25th day in T1 was increased 44% in tomato and 34% in soybean compared to T4. The rate of releasing of nutrients are much faster in the inorganic fertilizers thus they providing major elements at the early growth stage of plant (Lucus, 2001) and this could be the reason for this observation.

The highest number of leaves at the 45th day (end of the vegetative stage) was recorded in out fertilizer (T4) (37 leaves/tomato plant, 19 leaves/soybean plant). T1 was not significantly different from ½ of the recommended dose of inorganic fertilizer with mycorrhizae standard dose (T2) (43 leaves/tomato plant, 30 leaves/soybean plant). ¼ of the recommended dose of inorganic fertilizer with mycorrhizae standard dose (T3) (39 leaves/tomato plant, 24 leaves/soybean plant) and T4 were not significantly different from each other. According to the results, number of leaves at 45 days in T2 increased 23% in tomato and 57% soybean respectively compare to T4. In mycorrhizae, nutrient content is relatively low and the nutrients are not readily available for plant uptakes (Ramanie et al 2008) compared with inorganic fertilizer.

The highest shoot height was observed in T1 (96 cm tomato and 56 cm soybean) and the lowest was recorded in T4 (79 cm tomato and 33 cm soybean) (Table 1 and Table 2a) shoot height was not significantly different from T1 and T2 (92 cm tomato; 52 cm soybean) however both treatments were significantly different from T3 (82 cm tomato, 39 cm soybean) and T4 (79 cm tomato, 33 cm soybean) (Table 1, Table 2 and Fig. 2). Plant height in T2 increased 21% in tomato and 68% soybean compared to T4. There were no significant (P>0.05) differences in plant root length among all the treatments (Table 1 and Table 2a). However, highest root length was recorded in T4 (26 cm tomato, 21 cm soybean) and lowest recorded in T1 (22 cm tomato, 17 cm soybean).

Fig. 1 Effects of different concentrations of inorganic fertilizer and mycorrhizae on number of fruits per plant of Tomato from 1st harvest

inorganic fertilizer recommended dose without mycorrhizae (T1) (48 leaves/tomato plant and 28 leaves/soybean plant) and lowest was recorded in mycorrhizae standard dose with-
cm soybean). The reason is that via mycorrhizae, plant increases root surface area as an adaptation to adverse soil conditions (Seran et al. 2010). Plant roots in T4 treatment had larger nodules in soybean while there were no nodules observed in other treatments (Fig. 3).

However the highest wet weight of fruits/

Table 1: Growth parameters of Tomato with inorganic fertilizer and mycorrhizae, Four doses of inorganic fertilizer; recommended level without mycorrhizae (T1), 1/2 of recommended dose of inorganic fertilizer with standard dose of mycorrhizae (2g mycorrhizae/5L water) (T2), 1/4 of recommended dose of inorganic fertilizer with standard dose of mycorrhizae (T3) and standard dose of mycorrhizae without inorganic fertilizer and (T4) (2 g mycorrhizae/5L water) were used.

| Treatment | No of leaves at 25 days | No of leaves at 45 days | Plant shoot height (cm) | Plant root length (cm) | No.of flow- ers/plant | No of fruits/plant | Wet weight of fruits/ plant (g) | Soil microbial activity (CO₂ mg/kg soil) |
|-----------|------------------------|------------------------|------------------------|------------------------|-----------------------|-------------------|-------------------------------|----------------------------------------|
| T1        | 13a                    | 48b                    | 96c                    | 22c                    | 32d                   | 27c                | 556c                          | 287d                                  |
| T2        | 12b                    | 43b                    | 92d                    | 22d                    | 30b                   | 25c                | 548c                          | 349c                                  |
| T3        | 11b                    | 39b                    | 82e                    | 24f                    | 26g                   | 21h                | 379g                          | 373c                                  |
| T4        | 09b                    | 39b                    | 79h                    | 26g                    | 23i                   | 18j                | 329k                          | 464a                                  |
| T5 Field soil | -                      | -                      | -                      | -                      | -                     | -                 | 419b                          | -                                     |

Column values followed by the same letter are not significantly different as determined by Duncan’s multiple range test (P=0.05)

Table 2a: Vegetative growth parameters of Soybean with inorganic fertilizer and mycorrhizae.

| Treatment | No of leaves at 25 days | No of leaves at 45 days | Leaf width (cm) | Leaf length (cm) | Plant shoot height (cm) | Plant root length (cm) | Soil microbial activity (CO₂ mg/kg soil) |
|-----------|------------------------|------------------------|----------------|-----------------|------------------------|------------------------|--------------------------------------|
| T1        | 14a                    | 28b                    | 6c              | 8c              | 56c                    | 17c                    | 250d                                |
| T2        | 14a                    | 30b                    | 6d              | 8d              | 52d                    | 17c                    | 350c                                |
| T3        | 11c                    | 24e                    | 4e              | 6e              | 39e                    | 19c                    | 370c                                |
| T4        | 11c                    | 19f                    | 4f              | 6f              | 33g                    | 21c                    | 460a                                |
| T5 Field soil | -                      | -                      | -               | -               | -                      | -                      | 411b                                |

The highest number of flowers per plant observed in T1 (32 flowers/ tomato plant, 55 flowers/ tomato plant) and the lowest recorded in T4 (23 flowers/tomato plant, 21 flowers/soybean plant) (Table 1 and Table 2b). The number of flowers was not significantly difference between T1 and T2 (30 flowers/tomato plant, 53 flowers/soybean plant). Number of flowers in T2 was 38% higher in tomato and 160% higher in soybean compared to T4.

As indicated in table 1, Fig.1 and Table 2b, the highest number of fruits was recorded in T1 (27 fruits/tomato plant, 18 pods/soybean plant). However not significantly different from T2 (25 fruits/tomato plant, 16 pods/soybean plant). The lowest mean number of fruits was recorded in T4 (18 fruits/plant, 4 pods/soybean plant). Number of fruits in T2 was increased by 47% in tomato and 283 % in soybean compared to T4.

Table 2b: Reproductive growth parameters of Soybean with inorganic fertilizer and mycorrhizae.

| Treatment | No of flowers per plant | No of pods per plant | Wet weight of pods (g/plant) | Dry weight of pods (g)/ plant | Dry weight of seeds(g)/ plant |
|-----------|-------------------------|----------------------|-------------------------------|-------------------------------|-------------------------------|
| T1        | 55c                     | 46d                  | 18c                           | 8c                            | 7c                            |
| T2        | 53c                     | 42e                  | 16d                           | 8e                            | 7c                            |
| T3        | 31f                     | 22g                  | 07f                           | 4g                            | 3b                            |
| T4        | 21b                     | 12h                  | 04b                           | 3b                            | 2b                            |

Column values followed by the same letter are not significantly different as determined by Duncan’s multiple range test (P=0.05).
The highest microbial activity (emitted CO$_2$ mg/kg of soil) was observed in T4 for both crops 464 and 460 CO$_2$ mg/kg soil for tomato and soybean respectively and was significantly different from all the other treatments. Field soil recorded the next highest microbial activity (419 – 411 CO$_2$ mg/kg of soil) because it was not treated by topsin but all the other soils in T1, T2, T3 and T4 were sterilized before planting tomato. T1 recorded the lowest soil microbial activity (287 – 250 CO$_2$ mg/kg of soil) and the same results were observed by Seran et al. (2010) where soil micro and macro organisms are reduced with the presence of inorganic fertilizers as compared to organic fertilizers. Increment of soil microbial activity of T4 was 61.08% compared to the T1. There was no significant difference between soils T2 (349 – 350 CO$_2$ mg/kg of soil) and T3 (373 - 370 CO$_2$ mg/kg of soil) for soil microbial activity. But microbial activity of both T2 and T3 were significantly different from field soil, T1 and T4 treatments.

**CONCLUSION**

Half recommended dose of inorganic fertilizer with standard dose of mycorrhizae is the best
fertilizer mixture for tomato and soybean based on plant growth parameters and soil microbial activity. Addition of mycorrhizae increases the soil microbial activity significantly compared to field soil.

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