

Effect of Foliar Application of Manganese, Zinc and Copper on Growth and Yield of Chilli (*Capsicum annum* L.)

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Abstract Chilli (*Capsicum annum* L.) is an important spice crop grown in Sri Lanka. Deficiency of micronutrients, especially Mn, Zn and Cu reported in chilli growing areas has affected adversely on chilli production. Therefore, a study was conducted to evaluate the effect of foliar application of Mn, Zn and Cu on growth and yield of chilli grown in Reddish Brown Earth soils (Rhodustalfs), in dry zone, Sri Lanka. Seven treatments were tested in a greenhouse as pot experiment. Nitrogen, phosphorus and potassium were added into all seven treatments. Manganese Zn and Cu were added separately as foliar application for three treatments. One treatment had all three elements and control treatment had only N, P and K but no any added elements. Since all micronutrients were added as their sulfate form, last two treatments had S with N, P and K to assess the effect of S on plant growth. Copper with N, P, K added treatment showed significantly higher growth and yield compared to other treatments. It showed about 25% yield increment compared to control treatment. Therefore, it can be concluded that application of Cu is beneficial to obtain a better yield in chilli in Reddish Brown Earth Soils (Rhodustalfs). However, further field studies are needed to confirm findings.

Keywords Chilli, Copper, Foliar application, Manganese, Zinc

1. Introduction

Chilli is an important cash crop grown in Sri Lanka. It is extensively grown for dry chilli production, but part of the crop is harvested as green pods. Chilli can be grown throughout the year in all agro-climatic regions in the country. Department of Agriculture of Sri Lanka has recommended several chilli varieties namely MI -1, MI -2, KA -2, MI -Hot, *Galkiriyagama* selection and *Arunalu* for green and dry chilli production. Per capita consumption of chilli in the form of dry chilli has been estimated as 2.8 kg per annum and the national annual requirement of dry chilli is around 57,500 tons (FCRDI, 2018). However, the annual production of dry chilli in Sri Lanka is about 7,500 tons. Therefore, approximately 50,000 tons of dry chilli are imported annually. The potential yield of these varieties is 2.5-3.0 t/ha, However, the national average yield is about 1.0-1.5 t/ha (FCRDI, 2018). This yield reduction is mainly attributed to the pest and disease and soil fertility related issues, especially inadequate supply of nutrients. Plants need both macro and micro nutrients to complete the life cycle.

Macronutrients are required in larger quantities compared to micronutrients which are required in lesser quantities (Benepal, 1967). Macronutrients are often provided as fertilizers. But only source of micronutrient available in the soil is the organic matter which is incorporated into the soil as organic manure.

There are seven nutrient elements defined as micronutrients (Brady and Weil, 2002). Among them Mn Zn and Cu are essential for many plant metabolic processes varying from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity and nitrogen fixation (Ballabh et al., 2013). Therefore, proper plant nutrition through micronutrient is one of the important factors in improving the growth, yield of chilli. Deficiency of micronutrients can be occurred due to multiple reasons such as intensive cropping, with introduction of high yielding varieties, loss of micronutrients by leaching and decreased use of organic manure. It is realized that productivity of crop is being adversely affected due to deficiencies of micronutrients (Bose and Triathi., 1996). In general, farmers add chemical fertilizers to provide nitrogen, phosphorous and potassium for chilli but hardly ever apply micronutrients such as Mn, Zn and Cu. This has resulted reduction of micronutrient availability in the soil. Hence, growth and the yield of the crop can be affected adversely. However, only few studies have been conducted to study the effect of

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application of micronutrients on chilli. Therefore, this study was mainly focused to evaluate the effect of Mn, Zn and Cu as foliar application on chilli under irrigated condition in the dry zone, Sri Lanka.

2. Materials and Methods

2.1. Location

The study was conducted as a pot experiment at Field Crop Research and Development Institute, *Mahaillupallama*, Sri Lanka, which is in the Low Country Dry Zone, DL₁ agro-ecological region. The altitude of the location is 117m above mean sea level and the mean annual rainfall is about 1750 mm (FCRDI, 2018). Well drained Reddish Brown Earth soils (Rhodustalfs) collected from a bare land were used for the pot experiment.

2.2. Experimental Design and Treatments

The experiment design was Complete Randomized Design with seven treatments and eight replicates. Fifty-six pots were arranged for testing of following treatments.

T1- No micronutrients + DOA recommendation NPK (Control)

T2 – Mn (MnSO₄) + DOA recommendation NPK*

T3 – Zn (ZnSO₄) + DOA recommendation NPK

T4 – Cu (CuSO₄) + DOA recommendation NPK

T5 – Mn (MnSO₄) + Zn (ZnSO₄) + Cu (CuSO₄) + DOA recommendation NPK

T6 – S powder (Avg S amount of MnSO₄, ZnSO₄ and CuSO₄) + DOA recommendation NPK (for testing the effect of added S in T2, T3 and T4 treatments)

T7 – S powder (Total S amount of MnSO₄, ZnSO₄ and CuSO₄) + DOA recommendation NPK (for testing the effect of added S in T6 treatment)

* DOA recommendation NPK- Department of Agriculture of Sri Lanka recommended rate of N, P and K for chilli

2.3. Nursery Management

A land with well-drained soil was selected for nursery preparation. It was ploughed manually and soil was incorporated with well decomposed farm yard manure. The nursery bed was sterilized by burning of paddy husk and straw. Chilli seeds (variety KA – 2) were established after treated with a fungicide. Paddy straw was spread over the nursery bed to prevent excessive moisture loss. Nursery was wetted daily at twice. Seven days after the seed establishment, mulch was removed and made cadjan shelter over the nursery. Seedlings were steadily exposed to the direct sunlight by removing shelter gradually.

2.4. Crop Establishment and Management

After four weeks, seedling was transplanted in plastic pots (24cm×30cm) which have filled with well drained, RBE soils. Basal dressing was added to the pots two days before transplanting. Equal watering and fertilization according to

the Department of Agriculture (DOA) recommendation were followed (Table 1).

The micronutrient application was done according to the rate given in table 2. All three micronutrients were applied as foliar applications in 2, 4, 6 and 8 weeks after transplanting at the rate of 100 ml at one application.

Table 1. Fertilizer application rates

Stage	Time	Urea (g/pot)	TSP (g/pot)	MOP (g/pot)
Basal dressing	2 DBP	-	2.7	1.35
1 st top dressing	2 WAP	2.7	-	-
2 nd top dressing	4 WAP	3.37	-	-
3 rd top dressing	8 WAP	3.37	-	1.35
4 th top dressing	12 WAP	3.37	-	-

(Source: Department of Agriculture)

Table 2. Micronutrient application

Micronutrient	Form of application	Nutrient concentration (%)	Time of application (weeks after transplanting)
Mn	MnSO ₄ . 4H ₂ O	0.05	2, 4, 6 and 8
Zn	ZnSO ₄ . 7H ₂ O	0.05	2, 4, 6 and 8
Cu	CuSO ₄ .5H ₂ O	0.05	2, 4, 6 and 8

Manual weeding was done before fertilizer application. Other cultural practices such as loosening up of soil and earthing up of soil were carried out at 4th and 8th weeks after planting. Chilli leaf complex was found in every growth stages of cultivation. Recommended chemicals were applied in order to mitigate casual agents for chilli leaf curl, such as thrips, mites, aphids and white flies. Chilli pods were harvested at green mature stage.

2.5. Sampling and Sample Analyses

In order to determine initial soil characteristics, four soil samples were obtained (0-15 cm depth) from the field area where soil collected for filling pots. Soil samples were obtained from each treatment at after harvesting. Collected samples were air dried on polythene sheet at room temperature. Visible debris like stone, plant parts were removed, and sample was crushed to break the aggregated structure. Then soil was passed through 2mm sieve and sieved samples were collected into labeled polythene bags. Samples were oven dried at 60°C and were grinded prior to analyses. Prepared soil samples were analyzed for chemical parameters such as pH, Electrical Conductivity by Potentiometry using Multi parameter analyzer. Available P by Ascorbic acid colorimetric method (Olsen et al., 1954), using UV Spectrophotometer. Exchangeable potassium by NH₄OAc extraction method using flame photometer. Available Sulphur was analyzed by turbidimetric method (Chapman et al., 1961). Total Nitrogen by Kjeldhal titrimetric procedure (Bremner et al., 1982). Organic matter content by titrimetric method (Walkley and Blank, 1934).

Manganese, Zinc, Copper of plant and soil was determined by DTPA extraction method (Lindsay and Norvell, 1978).

Leaf samples from the plants in each treatment were obtained at first harvesting for determination of Mn, Zn and Cu uptake.

2.5.1. Growth Parameters

Selected agronomic parameters such as plant height at 50% flowering stage and 1st harvesting stage, canopy width at 50% flowering stage and 1st harvesting stage, number of pods per plant and green chilli yield were measured.

2.5.2. Data Analysis

Collected data were analyzed by the ANOVA using SAS software package. Duncan's New Multiple Range Test was used for the mean separation of the treatment.

3. Results and Discussion

3.1. Soil Properties and Characteristics at Initial Stages

According to the initial soil analyses, soil pH was 6.9 and EC value was 0.03 dS/m. These values indicated that soil reaction was near neutral and no potential to develop soil salinity. Chilli can grow successfully with soil pH of 5.5 – 7.0 (Mc Collum, 1980). Therefore, soil pH was in line with the crop preferable range. Available N and P were 26 and 15 ppm respectively. However, available K content of 364 ppm showed that it was sufficient for optimum growth of the crop. A moderate level of organic matter content (3.1%) was reported at the initial soil analyses. The availability of Mn, Zn and Cu were 13.4, 21.1 and 2.2 ppm respectively (Table 3).

Table 3. Soil characteristics at initial stage

Parameter	Value
pH	6.9
Electrical Conductivity	0.03 dS/m
Exchangeable Potassium	364 ppm
Available Phosphorous	15 ppm
Available Nitrogen	26 ppm
Organic Matter	3.1%
Texture	Clay Loam
Available Manganese	13.4 ppm
Available Zinc	21.1 ppm
Available Copper	2.2 ppm
Available Sulfur	6.8 ppm

3.2. Canopy Width at 50% Flowering and First Harvesting

There was a significant difference of canopy width among tested treatments. It varied between 15.7 to 26.3 cm at 50% flowering stage (Table 4). Highest canopy width of 26.3 cm was reported in T4 treatment which had Cu with N, P, K fertilizers. The increment of the canopy width of the T4 was

30.1% compared to canopy with of control treatment (T1). This may probably due to positive response of chilli to added Cu with N, P, K fertilizers. The lowest canopy width of 15.7 cm was observed in T5 treatment. Chilli plants in T5 treatment showed blazing appearance and ultimately fallen of leaves. This may due to the high salt concentration because of the application of all three micronutrient solutions together. As a result, T5 recorded lowest plant canopy width. However, appliance of micronutrients showed significant effect on canopy width at 1st harvesting stage. There was no significant disparity among T1, T2, T3 and T6. Highest canopy width observed in T4 and lowest canopy width in T5 admiration to others (Table 5).

Table 4. Canopy width at 50% flowering stage

Treatment	Canopy Width (cm)
T1- No Micronutrients + N, P, K (control)	20.2 b
T2 – Application of Mn + N, P, K	17.7 bc
T3 - Application of Zn + N, P, K	19.7 b
T4 – Application of Cu + N, P, K	26.3 a
T5 – Application of Mn, Zn Cu + N, P, K	15.7 c
T6 – Application of Avg. S + N, P, K	18.2 bc
T7 – Application of total S + N,P,K	21.1 b
CV %	19.6

^{ab} Means denoted by same letter is not significantly different from each other

Table 5. Canopy width at first harvesting

Treatment	Canopy Width (cm)
T1- No Micronutrients + N, P, K (control)	26.8 b
T2 – Application of Mn + N, P, K	25.5 b
T3 - Application of Zn + N, P, K	23.3 b c
T4 – Application of Cu + N, P, K	32.7 a
T5 – Application of Mn, Zn Cu + N, P, K	20.8 c
T6 – Application of S + N, P, K	22.7 b c
T7 – Application of S + N,P,K	25.7 b
CV %	18.3

^{abc} Means denoted by same letter is not significantly different from each other (p<0.05)

3.3. Number of Pods per Plant and Fresh Weight

The number of pods per plant is an important yield parameter of chilli to achieve optimum yield. Chilli plants underwent significant variation in number of pods per plant under different treatment conditions. Highest number of pods per plant was observed in T4 while the lowest number of pods per plant was given in T5 treatment (Table 6). Highest canopy width at 50% flowering and first harvesting stage were also reported in T4 treatment. It may increase the bearing points of plant and may help to increase the number of pods per plant in T4 compared to other treatments. Among three micronutrients, Cu added treatment showed highest number of pods per plant compared with others indicating positive response of chilli plants to added Cu. (Patil *et al.*, 2010).

Table 6. Number of pods per plant

Treatment	No of pods/plant
T1 - No Micronutrients + N, P, K (control)	34 b c
T2 – Application of Mn + N, P, K	36 a b
T3 - Application of Zn + N, P, K	18 b c
T4 – Application of Cu + N, P, K	47 a
T5 – Application of Mn, Zn Cu + N, P, K	15 c
T6 – Application of S + N, P, K	26 a b
T7 – Application of S + N,P,K	27 a b
CV %	23.4

^{abc} Means denoted by same letter are not significantly different from each other (p<0.05)

3.4. Average Fresh Yield

The treatments were significant (p< 0.05) on the fresh yield under different nutrient combinations. A significant increment (109 g/plant) of fresh chilli yield was observed in T4 treatment (Table 7). It showed nearly 25% yield increment compared to control treatment (T1). Increased yield due to Cu application may be attributed to enhanced photosynthesis activity and favorable effect on vegetative growth and retention of flowers and fruits, which increased number of fruits per plant (Dongre *et al.*, 2000). The lowest green chilli yield of 34 g/plant was recorded in T5 treatment. The reason could be retarded growth of T5 treatment due to high salt content adding of three nutrient solutions.

Table 7. Average yield

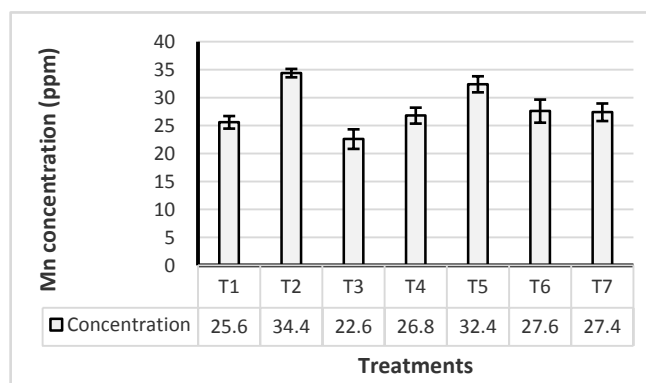
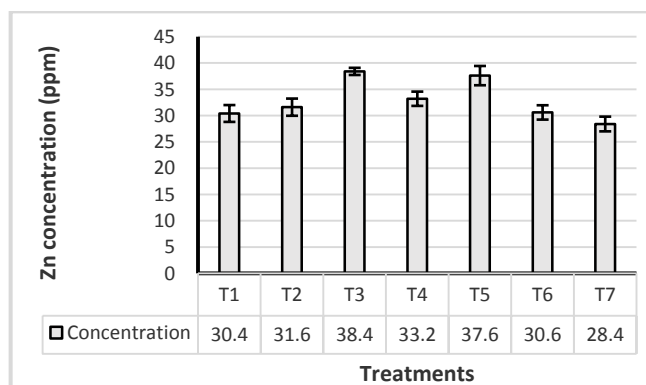
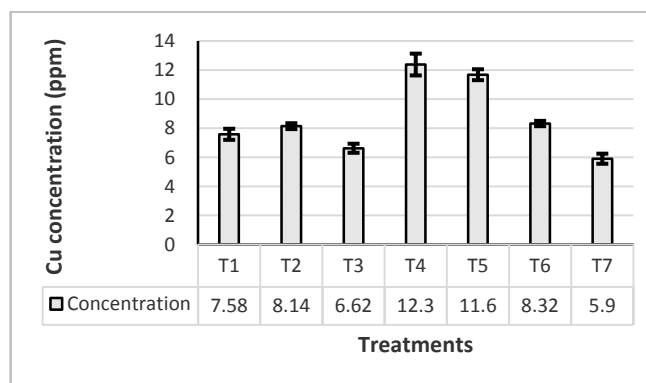
Treatment	Average yield (g/plant)
T1 - No Micronutrients + N, P, K (control)	87 b
T2 – Application of Mn + N, P, K	89 b
T3 - Application of Zn + N, P, K	47 cd
T4 – Application of Cu + N, P, K	109 a
T5 – Application of Mn, Zn Cu + N, P, K	34 d
T6 – Application of S + N, P, K	58 c
T7 – Application of S + N,P,K	54 c
CV %	23.4

^{abcd} Means denoted by same letter are not significantly different from each other (p<0.05)

3.5. Mn, Zn and Cu Uptake at 1st Harvesting Stage

Manganese is a micronutrient essential to plant growth. In plants, it involves in the structure of photosynthetic proteins and enzymes. Excessive accumulation of Mn in plant tissues can change various processes, such as enzyme activity, translocation and utilization of other mineral elements (Ducic and Polle, 2007; Lei *et al.*, 2007). According to literature, the comfortable range of Mn for better plant growth varies between 20 – 200 ppm. Results revealed that no significant difference of Mn uptake at 1st harvesting stage among tested treatments (Figure 1). All the treatments including control were within the sufficient range indicating soil Mn level is sufficient for plant growth. However, treatment T2 and T5 showed increased Mn level (> 30 ppm)

compared with other treatments. These two treatments received Mn as foliar application at 2, 4, 6 and 8 weeks after transplanting. Even though zinc uptake was not significantly different, T3 and T5 treatments reported zinc uptake (> 35 ppm) at 1st harvesting stage (Figure 2). Similar to Mn, Zn accumulation in plant leaves could also be due to the foliar application in different stages. Tariq (2007) also highlighted that foliar spray of Zn, Mn significantly increase their concentrations in plant leaves.

**Figure 1.** Mn level of plant leaves at 1st harvesting stage**Figure 2.** Zn level of plant leaves at 1st harvesting stage**Figure 3.** Cu level of plant leaves at 1st harvesting stage

Treatment T4 (application of Cu) and T5 (application of Mn, Zn and Cu) were reported higher Cu content (above 10 ppm) in leaves at 1st harvesting stage compared with other treatments (Figure 3). In general, optimum Cu content required for better plant growth is about 10 ppm (Yruela, 2005). Figure 3 shows that other than T4 and T5, Cu content

of all the other treatments were below the critical level. Copper as a micronutrient involves in the process of photosynthesis and assists in plant metabolism of carbohydrates and proteins (Droppa and Horváth 1990). As such treatments in which Cu content was below the critical level showed poor performance and lower yields.

4. Conclusions

Foliar application of Cu showed significant increment of green chilli yield but application of other two nutrient did not exhibit any yield improvement. This positive response to added Cu could be due to insufficient amount of Cu available in the soil. However, treatment which had all three elements showed poor performance due to high salt content added as foliar application. Therefore, it can be concluded that application of Cu is beneficial to obtain a better yield in chilli in Reddish Brown Earth Soils (Rhodustalfs). However, further field studies are needed to confirm findings.

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