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Application of Copper Increased Corn Yield through Enhancing Physiological Functions

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ABSTRACT

Copper (Cu) is needed by the corn plant in small amount and play an active role in plant metabolism. In order to evaluate the effects of copper on corn production, an experiment was conducted in the field. In this study, the effects of Cu on corn production were studied with regard to plant parameters, relative water content (RWC), chlorophyll (Chl) content, chlorophyll (Chl) fluorescence, photosynthesis parameters, and yield parameters. Different Cu concentrations (0, 0.2, 1.5 and 3 ppm) were applied as a foliar spray on leavesof corn plants. Plants' height wasinduced by the application of different Cu applications (1.5 and 3 ppm) but not on leaf numbers. Relative water content (RWC) increased gradually with increasing Cu concentration. On the other hand, net photosynthesis rate (Pn) and photosynthetically active radiation (PAR)decreased with increasing Cu concentration. Chlorophyll (Chl) content increased in leaves of Cu-treated plants than Cu-untreated plants andChl fluorescence data showed similar to Chl content data.Cu application increased yield compared than control but higher Cu concentration showed better results. Taken together, it seems that Cu at 1.5 ppm as foliar applicationshowed better result in terms of increasing production and improving physiological function of corn plants.

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INTRODUCTION

Corn or maize (*Zea mays* L.) is a cereal crop that is grown widely throughout the world in a range of agroecological environments. Worldwide production of corn is 785 million tons with the largest producer, the United States. Essential micronutrients have been uptaken and utilized by crops in very small amounts. In micronutrient-deficient soils, foliar application of micronutrient fertilizers improve the yield and the crop quality for cereals, corn, beans, forages, and oil seeds (Malakouti, 2007). The deficiency of micronutrients in plant can reduce their yield performance and cost profitability (Fisher, 2008). Thus, micronutrients are important in plant growth, since plants need a proper balance of all essential nutrients for normal growth and obtain optimum yield. Copper is needed for the crop development and normal growth of cereal crops and absence and excess of copper inhibits the growth and yield production (Jain *et al.*, 2009).

Copper plays a vital role in photosynthetic and respiratory electron transport chains, ethylene sensing and cell wall metabolism in higher plants (Yruela, 2009). Copper plays role in signaling of transcription and protein trafficking machinery, iron mobilization and oxidative phosphorylation at cellular level of plants (Yruela, 2005). Monni*et al.*, (2000) reported that Cu function in biological system as a structural component; however higher concentration can be a stress factor which inhibit plant growth, binding of metals to sulfhydryl groups in the protein and cause disruption of the structure and inhibition of activity of the proteins (Morelli and Scarano, 2004). Cu application increases the plant's dry weight (Fageria, 2002; Mathad and Pratima, 2009).

Several researches have led to a better understanding on the effect and the importance of micronutrient in plants. Copper is an essential mineral element in plant performance and development, especially field crop. Maize is one of important cereal crops has economic value in livestock (Harris *et al.*, 2007).To date, less attention was paid on the effects of Cu on physiology and yield of corn plants. Therefore, this study focuses on the effects Cu on corn physiology and yield of corn plant.

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MATERIALS AND METHODS

Plant material and experimental design:

In this study, hybrid corn variety of L41 was used. Two seeds were sowed in a hole on pre-prepared seedbed with a spacing of 25cm X 75cm. Four Cu (0, 0.2, 1.5 and 3 ppm) concentrations were arranged according to the completely randomize design. Five replicates were maintained unless otherwise stated.

Determination of leaf numbers and plant height:

Leafnumbers were counted with visible leaf collars, beginning with the lowermost and ending with the uppermost leaf with a visible leaf collar (Ritchie *et al*., 1993). The plant height was measured from the soil surface level to the longest leaf emerged and measured with a measuring ruler alongside.

Determination of relative water content:

Fresh leaf weight was measured immediately after detached from the plants then turgid weight was taken after 24 h leaf incubation in distilled water. Dry weight of leaf was measured after 24 h of dried at 60°C in an oven. Relative water content was measured according to the following formula (Chelah*et al.,* 2011, Jahan*et al.,* 2014).

Relative Water Content (%) = [(FW-DW) / (TW-DW)] x 100

FW – Sample fresh weight
TW – Sample turgid weight
DW – Sample dry weight

Measurement of chlorophyll content and chlorophyll fluorescence in leaves of corn plants:

A SPAD-502 portable chlorophyll meter (Minolta, Japan) was used to acquire *in situ* leaf chlorophyll content from corn plants. The second uppermost collared-leaf was selected and determined chlorophyll content. Data were taken from 11 am to 1 pm to avoid wetness effects on leaf surface (Chelah*et al.,* 2011). Five replicates were implemented. A portable Junior-PAM chlorophyll fluorescence monitoring meter (Walz, Germany) was used to quantify *in situ* leaf chlorophyll fluorescence from corn plants (Jahan*et al.,* 2014). The second uppermost collared-leaf was selected and taken data from 11 am to 1 pm. Only maximum fluorescence level was recorded.

Determination of net photosynthesis rate and photosynthetically active radiation in leaves of corn plants leaves of corn plants:

Net photosynthesis rate (Pn) and photosynthetically active radiation (PAR) was measured using a CI-340 portable photosynthesis meter (CID Biosciences, Inc.). Data taking procedures were followed according to the manual. These measurements were done in between 11 am to 1 pm. Five replicates were maintained.

Yield and yield parameters:

Plant height, number of leaves, length and weight of cob were determined after the yield produced. The number of corn cob was counted and weight was taken by using digital measuring instrument for each treatment.

Statistical analysis:

Data were analyzed for differences of mean value among treatments by ANOVA procedure and LSD and T-test using Minitab-16 and MS Excel software. Differences at $P < 0.05$ were considered significant.

RESULT AND DISCUSSION

Effect of Cu on plant height and leaf number:

Fig 1 showed data of plant height and leaf numbers. Weekly data presented that the height of corn plant enlarged with increasing plant age (Fig. 1a). There was no effect of Cu on plant height was observed when compared between Cu-treated and Cu-untreated corn plants until 8^{th} weeks of planting age. But, thereafter, plants' height increased in case of higher Cu treatments are 1.5 and 3 ppm, than other treatments. This result suggests that Cu might increase plant height.

Weekly data of leaf numbers showed no difference with increasing plant age (Fig. 1b) Taken together this result suggests that Cu might not affect leaf numbers as well as plant height.

Effects of Cu on relative water content and photosynthesis rate in leaves of corn plants:

Relative water content decreased significantly in leaves of Cu-untreated plants compared than that of leaves of Cu-treated plants (Fig. 2a). This result indicates that this may cause of Cu-treated plants perform their metabolism functions well than that of Cu-untreated plants. On the other hand, Cu did not affect relative water content in leaves of among Cu-treated corn plants.

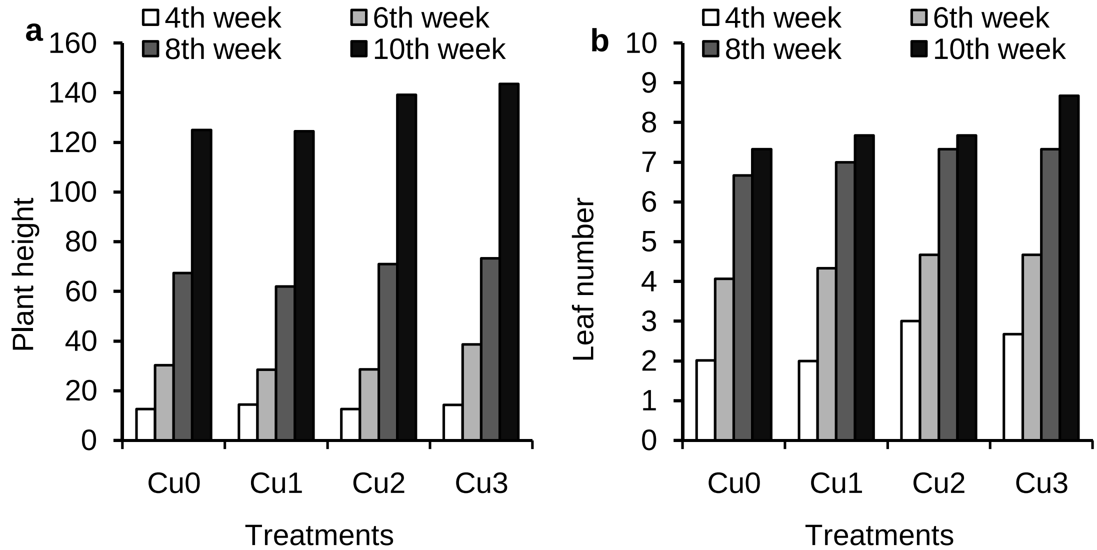

Fig. 1: Effects of different concentrations of Cu on plant height (a) and leaf numbers (b).

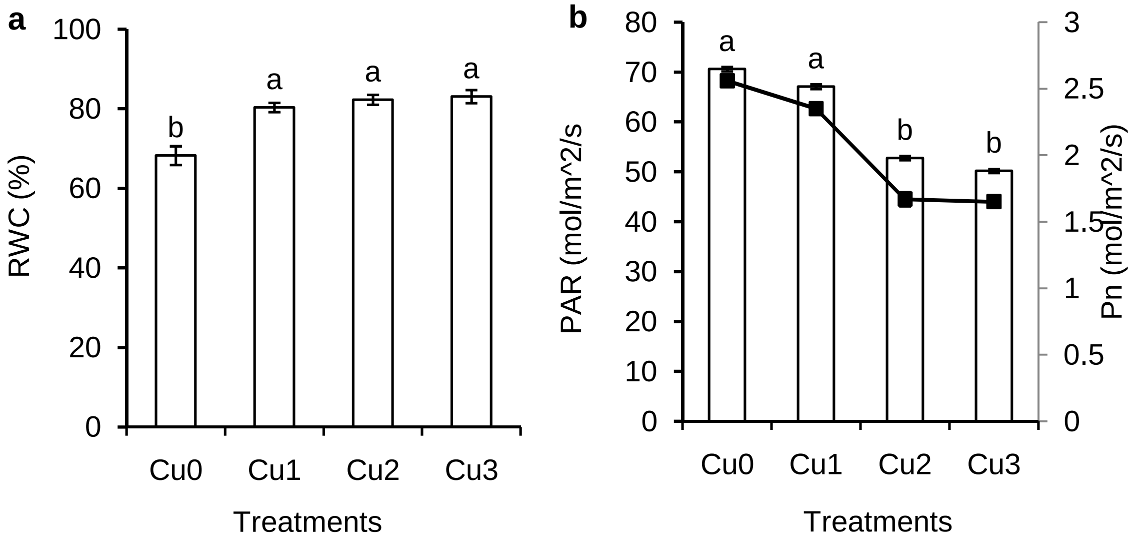

Fig. 2: Effects of different concentrations of Cu on RWC (a), photosynthesis rate (b; line graph) and photosynthetically active rediation (b; bar graps). Vertical bars represent standard deviation. Different letters denote significant differences with different treatments at $p < 0.05$.

We also determined the PAR and Pn rate in leaves of corn plants under different Cu conditions (Fig. 2b). We found that Cu treatment significantly decreased Pn rate compared than that of Cu-untreated plants (Fig. 2b, line graph). This result is consistent with previous result that Cu affects photosynthetic parameters through metabolic processes (Maksymiec, 1997) and affects the activity of enzymes (Savini*et al.*, 1990). This result suggests that foliar application of Cunegatively functions on plants' net photosynthesis rate. Similar results were observed in case of PAR measurement (Fig. 2b, bar graphs) which supports Pn data. Taken together, it is suggested that Cu might decrease plant photosynthesis rate.

Effects of Cu on chlorophyll content and chlorophyll florescence:

Whether Cu application affected chlorophyll (Chl) content, we measured Chl content in leaves at different growing stages are 14, 28, 42and 56days after planting (DAP). The positive effect of Cu treatments on Chl content was observed in leaves of corn plants at different times. But Cu (Cu3)-treated plants presented highest

Chl content accumulations in leaves under different observation times (Fig. 3a). These results suggest that Cu application might increase Chl accumulation in leaves of corn plants and support that Cu might show positive function on light related reaction in plants. Previously, Jahan*et al*. (2014) stated that light harvesting antenna of photosystem II increased chlorophyll content in *Arabidopsis* plants. It is also possible that Cu-induced enzyme might mediate photoreduction of O_2 by PS1 (Vauhgn*et al.,* 1988).In plants, Cu participates in the structure of photosynthetic proteins and enzymes. Cu affects the splitting of photosystem II (PSII) that necessary electrons are provided for photosynthesis (Pádua, 2010).But during stress, Cu damages the photosynthetic apparatus in photosystem II (Pádua, 2010). On the other hand, chlorophyll fluorescence data showed similar to chlorophyll content data (Fig. 3a) where Chl fluorescence supports Cu-induced Chl content oscillation in leaves of corn plants. Cu-treated plants showed differentiate levels in terms of Chl fluorescence accumulation but gradually increased with increasing Cu concentration(Fig. 3b). These results support that Cu might functions onChl content and Chl fluorescence through modification of light function in photosystem II.

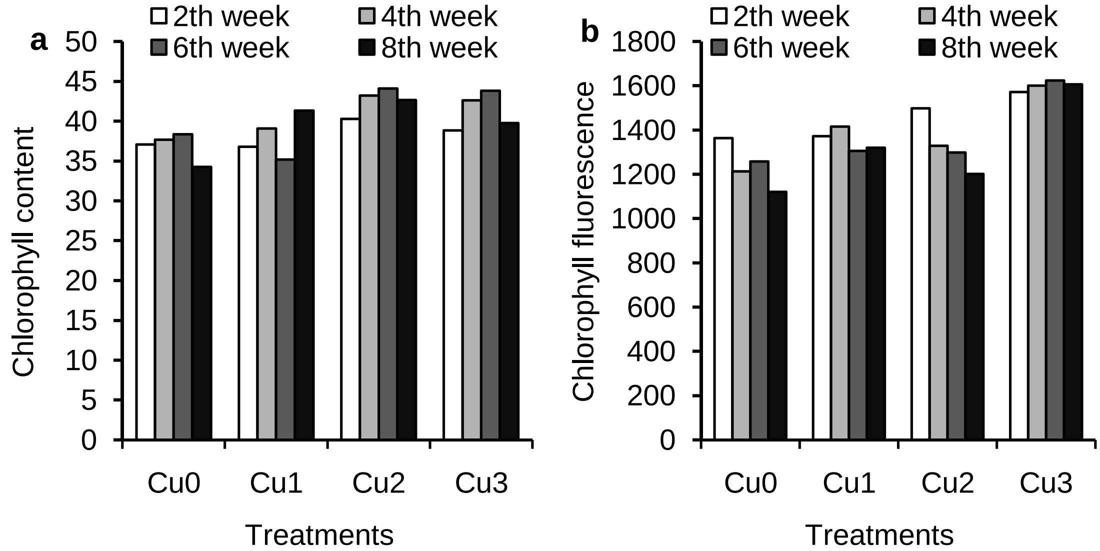

Fig. 3: Effects of different concentrations of Cu on Chl content (a) and Chl florescence (b).

Effects of Cu on corn yield:

The yield and yield parameters were determined based on the weight and length of corn fruit which were shown in Figure 4. The yield gradually increased with increasing Cu concentration (Fig. 4a). Yield significantly increased in Cu-treated plants than Cu-untreated plants. In addition, different Cu concentrations differentiate corn yield where higher Cu concentration significantly increased corn yield compared than lower Cu concentration. This result showed consistent with Pn data (Fig. 2) that higher Chl content might contribute in increasing yield of corn plants. Consequently, Cu3 showed best performance in terms of yield production. In case of length of corn fruit, 1.5 of Cu-treated plants (Fig. 4b) showed larger size than that of Cu-untreated plants and others Cu-treated plants. Increasing cob of corn plant supports increasing yield.

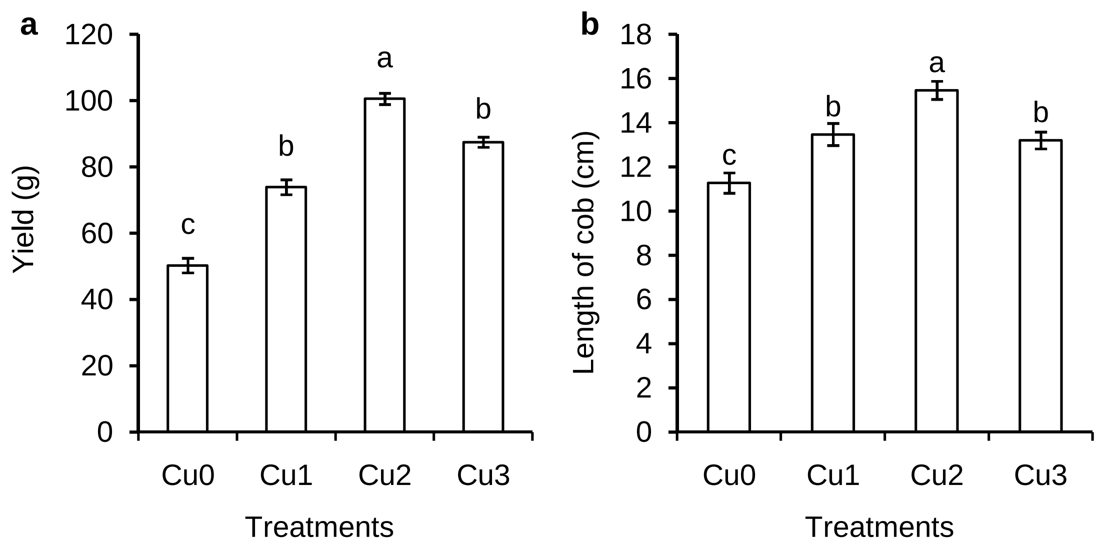

Fig. 4: Effects of different concentrations of Cu on yield (a) and cob length (b) of corn plant.

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In conclusion, this study confirms that Cu application enhanced RWC but not PAR, and Pn rate in leaves of corn plants. The treatment of Cu increased yield as well as increased light related parameters, Chl content and Chl fluorescence which triggers to increase cob weight. Therefore, Cu at 1.5 ppm might an optimal dose as foliar application for corn plants at field condition.

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