



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 12, December 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

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www.ijirset.com

Effect of Copper Toxicity on Growth and Morphology of Different Plants

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ABSTRACT: Copper is an essential micronutrient for plant growth and development. It acts as a catalyst in photosynthesis and respiration and plays an important role in the formation of lignin in the cell wall. Nevertheless, at high concentrations copper can become extremely toxic for plants causing symptoms such as chlorosis and necrosis, stunting, leaf discoloration, and inhibition of root growth. The majority of the plants do not survive the application of 400 μM Cu. Biomass production declined consistently with application of each additional increment of Cu. Root growth was more severely inhibited than shoot growth. Cu adversely affected the root morphology of the plants, however, root surface area and number of root tips increased slightly at low levels of Cu. Root cell ultrastructure and organelles changed significantly under Cu stress, in particular, cell walls, mitochondria, and xylem parenchyma were affected. Cu can become extremely toxic causing symptoms such as chlorosis and necrosis, stunting, leaf discoloration and inhibition of root growth. At the cellular level, toxicity may result from

- i) binding to sulfhydryl groups in proteins, thereby inhibiting enzyme activity or protein function;
- ii) induction of a deficiency of other essential ions;
- iii) impaired cell transport processes;
- iv) oxidative damage

Cu can cause disorders in plant growth and development by adversely affecting important physiological process in plants. In particular photosynthetic electron transport is altered under both Cu deficiency and excess Cu conditions. Toxic levels of Cu occur naturally in some soils whereas others may contain high levels of Cu as a result of the anthropogenic release of heavy metals into the environment through mining, smelting, manufacturing, agriculture and waste disposal technologies. At concentrations above those required for optimal growth Cu was shown to inhibit growth and to interfere with important cellular processes such as photosynthesis and respiration. Plants grown in the presence of high levels of Cu normally show reduced biomass and chlorotic symptoms. A lower content of chlorophyll and alterations of chloroplast structure and thylakoid membrane composition was found in leaves under such growth conditions.

KEYWORDS : copper , toxicity, effect, plant, morphology, growth, alterations

I. INTRODUCTION

Copper toxicity means high level of copper supply to the plant. This becomes a negative impact. Various alterations in plant occur due to copper toxicity. In particular, degradation of grana stacking and stroma lamellae, increase in the number and size of plastoglobuli, and appearance of intrathylakoidal inclusions were observed. It was proposed that Cu interferes with the biosynthesis of the photosynthetic machinery modifying the pigment and protein composition of photosynthetic membranes. Furthermore, lipid peroxidations, decreases of lipid content and changes in fatty acid composition of thylakoid membranes were observed. As a consequence of such modifications, alteration of PSII membrane fluidity was found. The presence of excess Cu can cause oxidative stress in plants and subsequently increase the antioxidant responses due to increased production of highly toxic oxygen free radicals. Accordingly, it was observed that excess Cu in plants led to oxidative stress inducing changes in the activity and content of some components of the antioxidative pathways (*i.e.*, ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione reductase (GR), superoxide dismutases (SODs), guaiacol peroxidase). The ascorbate-glutathione cycle has been reported to be involved in response to excess Cu. [1]

Copper is an important heavy metal pollutant, with strong toxicity and great harm, which is easy to accumulate in the plant body and is difficult for degradation. Copper pollution has become a worldwide problem in recent years: copper is



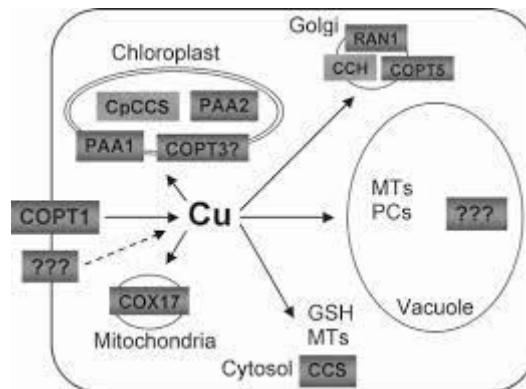
not degraded by microorganisms in the soil, so it is generally difficult to eliminate the pollution; the high rate of copper residue in the soil can cause many serious problems to the environment and human health; copper is an important heavy metal pollutant, with strong toxicity and great harm, which is easy to accumulate in the plant body and is difficult for degradation. [2,3] Copper pollution problem has aroused extensive attention.



Chlorosis due to copper toxicity

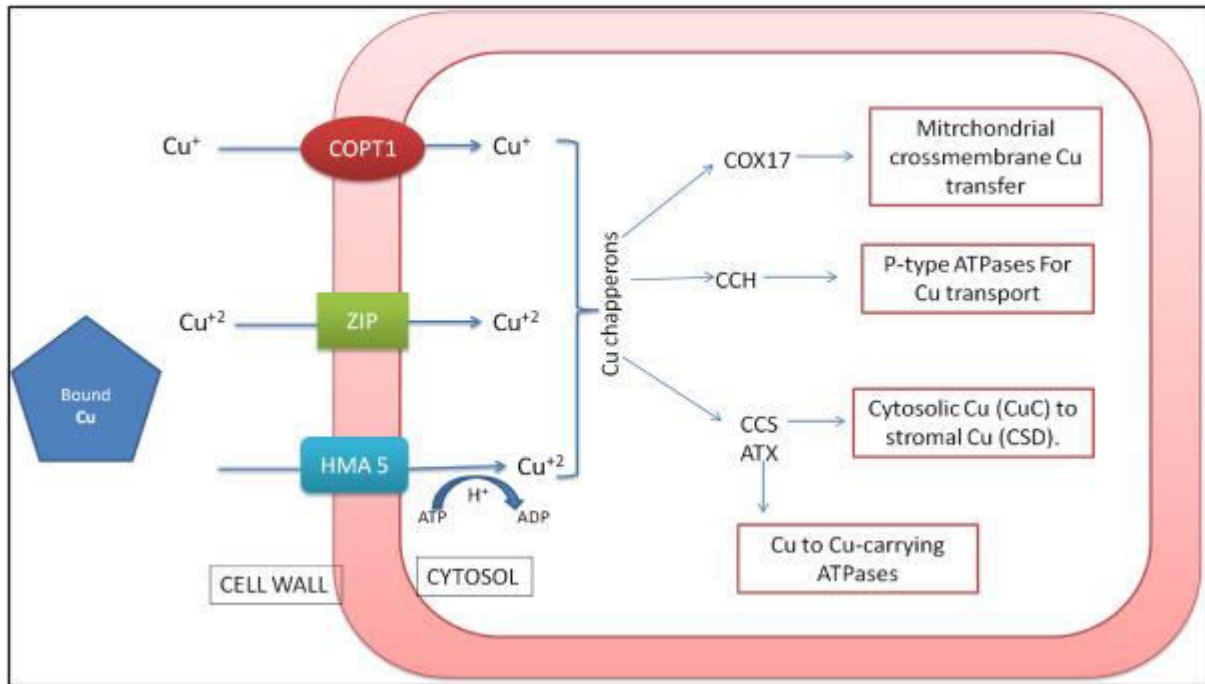
II. OBSERVATIONS

The heavy metal copper at high concentrations to the plants show the blue to brown or yellow in colour and growth is stunted. Excess copper levels decrease plant vigour, iron intake and seed germination. Various problems arise during the neutralizing copper in soil. The copper toxicity is due to continuous use of fungicides. The persistence of copper in soil is many years and has solubility is low.[4]



Copper in plants

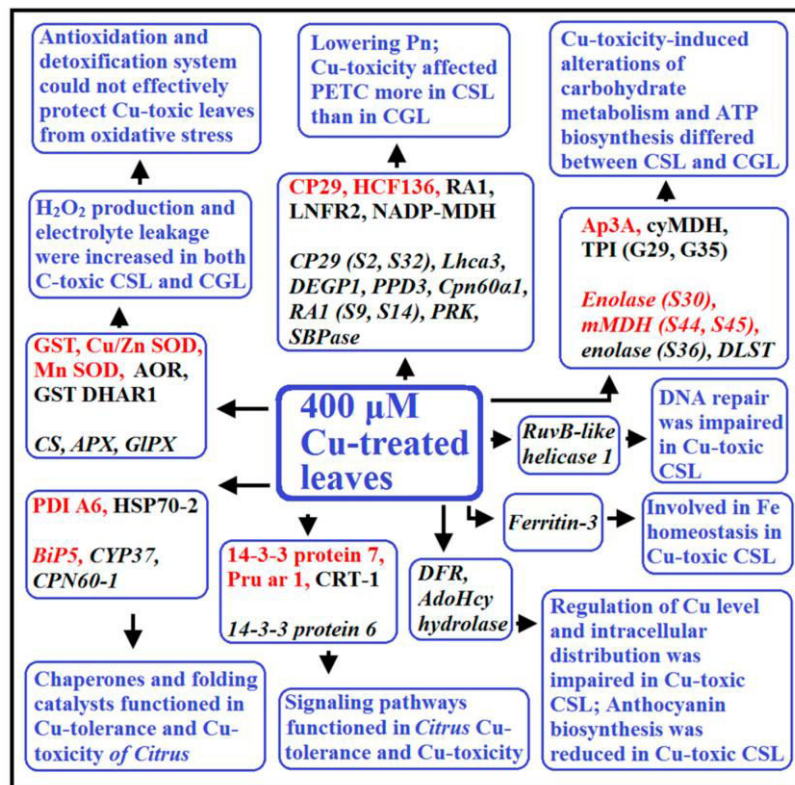
Copper toxicity is a problem of both agricultural and environmental significance. Sources of copper contamination by agrochemicals, agricultural wastes, urban, smelting, mining and industries. The indicator of bioavailability of copper is Cu^{2+}



The antioxidant activities such as nitrate reductase activities to the seaweed extract by foliar application provides the assimilation of biostimulant by leaves such as growth hormone or other metabolites that were responsible for enhancement of nitrate reductase activity, the foliar application of seaweed extract increased this enzymatic activity . Increasing concentrations of Cu in the soil also resulted in an increased number of stomata mm^2 , particularly on the lower leaf surface. Experiments showed that guard cell length was reduced by about 30 % on both the upper and lower leaf surfaces.[5,6] Comparison of transverse sections through control leaves and those of Cu treated plants showed an increase in lamina thickness in leaves of plants grown under high concentrations of Cu. The increase in the spongy cell biomass occurred partly at the expense of intercellular spaces. Chloroplasts of chlorotic leaves grown in excess Cu did not contain starch grains, had larger plastoglobuli, a well-developed grana/intergranal thylakoid system and a darker stroma . In some cases, on the side of the chloroplasts facing the cell wall, an elaborate system of small tubular elements formed locally. No alteration in the typical organization of the chloroplast internal membrane system was found, with the exception of the double membrane around the chloroplast that became dilated. The chlorophyll content of chlorotic leaves of Cu-treated plants was investigated. Total chlorophyll (a + b) was found to decline with increasing concentrations of soil Cu.[7,8]

III. DISCUSSION

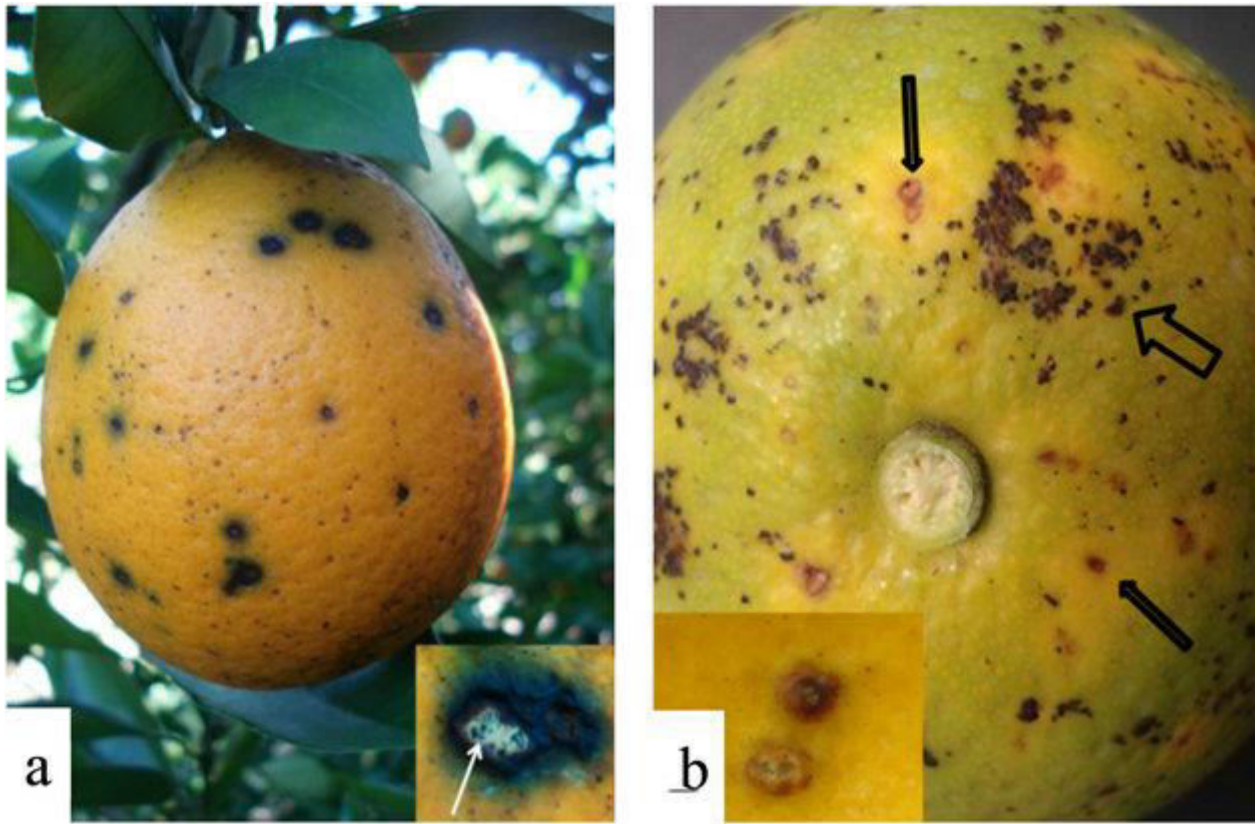
Leaf chlorosis is closely associated with morphological and physiological alterations in the chloroplasts. Mesophyll chloroplasts in Cu-treated plants are dramatically reduced in volume and number, as shown by anatomical and morphometric studies. Additionally, copper toxicity can cause damage to the roots of plants. Roots may be short and thick and have a barbed-wire appearance. When roots are damaged, plants are likely to grow more slowly, wilt or even die. Copper (Cu), a toxic metal pollution found in the soil and water of industrialized areas, causes continuous issues for agriculture product contamination and human health hazards. However, information on copper phytotoxicity and its accumulation in vegetables is largely unknown. To evaluate the related agricultural loss and health risks, it is necessary to assess copper phytotoxicity and develop prediction models for copper concentration in vegetables. [9,10]



Water spinach, amaranth, pakchoi, and garland chrysanthemum in copper-contaminated soil. The plant's height and fresh weight is dramatically reduced when the soil copper concentration is over $\sim 250 \text{ mg}\cdot\text{kg}^{-1}$. This yield reduction and copper accumulation are associated with an increase of soil copper concentration, suggesting high copper phytotoxicity levels in plants and soil. Copper contamination has the highest numbers of reported cases, in which copper contamination occurs in 5684 sites out of a total 7460 heavy metal contamination sites. With an increase in copper concentration, wheat germination is greatly affected in its percentage, total chlorophyll content and the number of its lateral roots. When cabbage is exposed to high copper concentrations in a nutrient solution, copper toxicity leads to a chlorosis of its leaves, and subsequently reduces the biomass in both its shoots and roots. Recent publications increasingly focus on vegetables as healthy foods, but vegetables still face exposure to toxic metal contamination. Lipid peroxidation increases when soil copper concentration exceeds. [11]

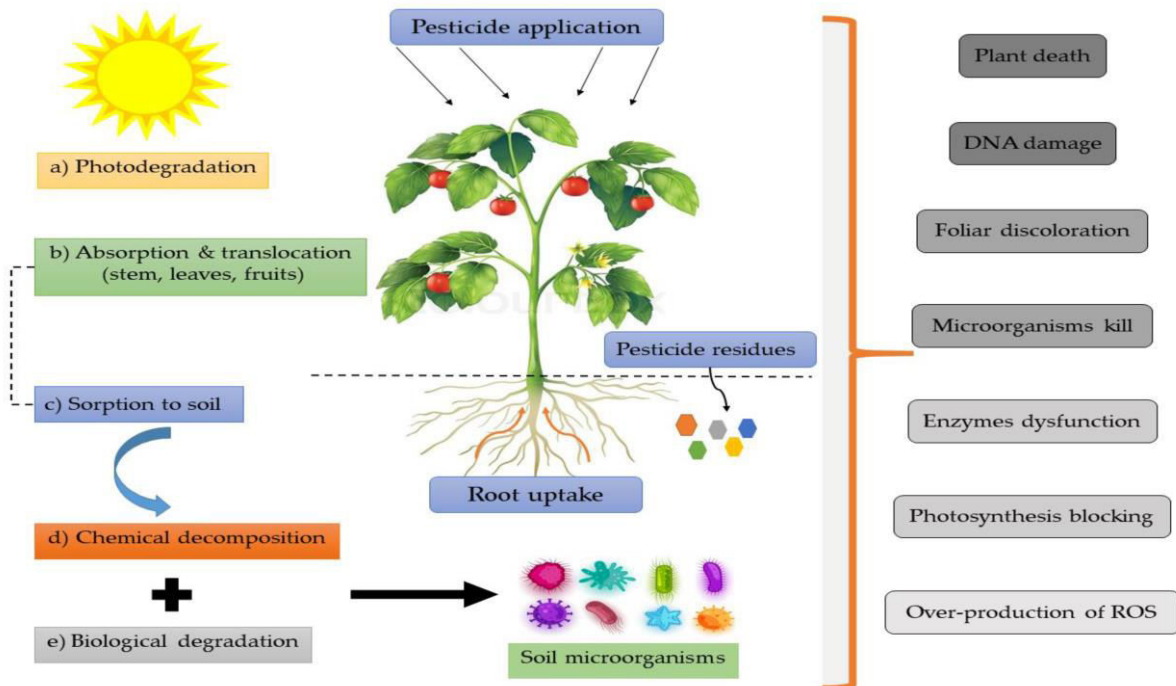
IV. RESULTS

Other than a reduction of agricultural production, the accumulation of copper in crops could produce a risk to human health. To decrease the risk of copper intake from vegetables (apart from assessing the phytotoxicity of copper in vegetables), it is necessary to quantify the copper contents in vegetables cultivated in copper-contaminated soil. Copper accumulation in the aerial parts of plants increases as the soil copper levels in all test vegetable varieties increase.



Copper toxicity on citrus causind disease citrus black spot

Reduction of the chlorophyll content, observed in the treated plants, could be linked to reduced absorption of iron with which the copper toxicity interferes.[12]





Copper toxicity in pesticides causing damage to plants

Copper pesticides are copper compounds used as bactericides, algicides, or fungicides. They can kill bacteria, oomycetes and algae, and prevent fungal spores from germinating. Common forms of fixed copper fungicides include copper sulfate, copper sulfate pentahydrate, copper hydroxide, copper oxychloride sulfate, cuprous oxide, and copper octanoate. Copper fungicides work by slowly releasing positively charged copper ions Cu^+ and Cu^{2+} in concentrations that interact with nucleic acids, interfere with energy transport, disrupt enzyme activity, and affect the integrity of cell membranes of pathogens. Both ions have fungicidal and bactericidal activity. Following absorption into the fungus or bacterium, the copper ions will link to various chemical groups (imidazole, phosphate, sulfhydryl, and hydroxyl groups) present in many proteins and disrupt their functions. Copper ions can kill pathogen cells on plant surfaces, but once a pathogen enters host plant tissue, it is no longer susceptible to copper treatments at the prescribed concentrations. The prescribed copper ion concentrations lack post-infection activity. Higher copper ion concentrations harm the host plant. Copper phytotoxicity worsens under slow drying conditions. Adding surfactants with copper fungicides may increase injury to plant foliage. Copper ions release more readily under acidic conditions and copper pesticides, except copper sulfate pentahydrate, should not be used with acid forming products. Copper fungicides can be highly effective if applied prophylactically and with complete coverage of all plant foliar surfaces, including the undersides of leaves where the pathogen typically sporulates. [11,12]

Copper pesticides must be used in quantities that minimizes long term copper accumulation in the soil. Accumulated copper in soils can inhibit root growth and adversely affect microorganisms and earthworms. Finely ground copper formulations are more active than coarsely ground formulations. Coarsely ground formulations should be avoided to limit long term bioaccumulation and toxicity. Copper occurs in soils in different forms (ionic, complexed and precipitated) depending on characteristics such as soil texture, organic matter and pH. According to the Soil Association the total copper that can be applied to organic land is 6kg/ha/year. This limit is designed so that the amount of copper in the soil does not exceed the limits specified in the Soil Association standards for heavy metals.

V. CONCLUSION

Copper is an essential elemental for metabolic processes in marine algae. It is required for electron transport in photosynthesis and by various enzyme systems. Too much copper can also affect phytoplankton or marine algae in both marine and freshwater ecosystems. It has been show to inhibit photosynthesis, disrupt electron transport in photosystem 2, reduce pigment concentrations, restrict growth, reduce reproduction, etc. The toxicity of Copper is widely recognized and is used to help prevent algal blooms. The effect of Copper is solely dependent on the free Copper the water is receiving. It's determined by the relative solubility and the concentration of the Copper binding ligands. [12]

Studies have shown that Copper concentrations are toxic when marine phytoplankton are confined to areas that are heavily impacted by anthropogenic emissions. Overuse of copper sulfate as an algicide has been speculated to have caused a copper poisoning epidemic on Great Palm Island in 1979. Copper (Cu), a redox-active transition metal, is known to be involved in protein metabolism, photosynthetic and respiratory electron transport, cell wall metabolism, antioxidant activity, nitrogen fixation, ion metabolization, and hormone perception, among others in plants. Though Cu has been listed among the essential elements, it could potentially result in complete inhibition of plant growth and development at excess concentrations. Measures available for alleviating Cu toxicity in plants . Exogenous application of nitric oxide through up-regulating the components of antioxidant defense system [catalase (CAT-EC 1.11.1.6), peroxidase (POD-EC 1.11.1.7), superoxide dismutase (SOD-EC 1.15.1.1), and ascorbate peroxidase (APX-EC 1.11.1.11) activities] and stimulating the enzyme P5CS (D1-pyrroline-5-carboxylate synthetase), which catalyzes proline biosynthesis, has been proved to stand against the adverse impacts of Cu toxicity. Addition of cations (such as Ca^{2+} and Mg^{2+}) through stimulating site-specific competition for metal ions could also prevent excess accumulation of Cu in cell interior. Silicon application, through nutrient balancing and physically blocking the apoplastic bypass flow has also been recognized to be effective in alleviating Cu toxicity. Addition of organic amendments and use of arbuscular mycorrhizal fungi as soil inoculants have also proved successful in amelioration of Cu contaminated soils. Though molecular and physiological mechanisms associated with Cu toxicity have been substantially investigated, information on the regulation of the expression of stress-related genes in key agricultural plant species is still lacking. Additional research efforts focusing at field validation of the toxicity alleviation methods are also equally important. [13]



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