Toxic Effect of Cadmium on Growth and Metabolism in Wheat (*Triticum aestivum* L.) seedling

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Abstract- An exposure of wheat plants to rising Cd concentration effect the growth of the plants and those effects are described, with special attention being given to chloroplast morphological changes, nutrient concentration, chlorophyll concentrations, chlorophyll fluorescence responses and growth changes of the whole plant. The symptoms which are because of heavy metal toxicity are showed by those plants which are treated with 1 mM Cd. The root, shoot length and the biomass of root and shoot- leaf progressively reduced by the increase of Cd amount in the nutrient solution and growth inhibition is almost completely done when the concentration of Cd is 1 mM. Cd deposition in shoot- leaves is increased under cadmium treatments and other heavy metals like Fe, Mg and Ca, K decline in the above particular ground parts of plant which was noticed. In the upper parts of the plant the reduction of growth and chlorophyll content and photosynthesis inhibition are observed. Cadmium treatment in plant damage the ultrastructure of chloroplasts by the distorted shape and dilation of thylakoid membrane of wheat plant. Premature senescence was induced by cadmium probably which is suggested by the morphological changes of plant.

Keywords-Wheat, Cadmium; antioxidant enzyme; photosynthetic pigments; oxidative damage

I.INTRODUCTION:

The toxicity of cadmium, which has become increasingly venturesome among the harmful pollutants of the environment, to humans and animals is well documented (Adriano, 1986; Wagner, 1993). In mammals, for the accumulation of cadmium, the principal target organs are represented by the kidney and liver. While on the fishes and other aquatic organisms an extensive range of pathological effects of cadmium has been reported (Iger et al. 1994). Environmental burdens from industrial, agricultural, energy and municipal sources have been increased, as a result of this increasement cadmium has received important and considerable attention over the past years (Adriano 1986). The health of the terrestrial and aquatic organisms are threatened by the general increase in the levels of cadmium in the environment and therefore it has become a crucial topic of toxicological research. At around 70% or more of the cadmium ingestion by humans arises from the plant foods (Wagner 1993).

Roots take up the cadmium ions readily and cadmium ions are translocated and moved into the leaves in many plant species, although it is not vital for the growth of the plant (Marshner 1983). Potentials mode of entry is represented also by foliar absorption and direct stem ingestion (Haghiri 1973; Greger et al 1993). While the toxicity of cadmium for plants is a major environmental problem, that has been proven. The mechanism of it's action, how the cadmium act to spread toxicity to the plants, that has not been fully investigated. The germination of seeds are generally averted by cadmium (Rascio et al. 1993) as well as growth of the plant (Stiborova et al. 1987; Greger et al. 1991), nutrient distribution (Moral et al. 1994) and photosynthesis (Baszynski et al. 1980; Clijsters and Van Assche 1985; Krupa et al. 1993) are also inhibited and activities of several enzymes are increased, e.g. glucose - 6- phosphate dehydrogenase (Van Assche et al. 1988), whereas the activities of the other enzymes are influenced differently by the effect of cadmium on plant (Karataglis et al. 1991). Since, in leaves the Cd⁺ iobs are accumulated than in other parts of the plants (Marschner 1983). Most of the research in the phytotoxic effects od cadmium has been focused on the photosynthesis inhibition.

The effects of cadmium on functions of stomata (Barcelo et al. 1988; Costa and Morel 1994), on electron transport and on calvin cycle (Weigel 1985; Sheoran et al. 1990), have been shown by the experiments (Baszynski et al. 1980; Siedlecka and Baszynski 1993). An important factor to understand the physiological alterations which is induced by the metal is what little information is available on the effects of cadmium on chloroplast organization, which is because of the relationship between the structure and the function of the thylakoid system. Chlorophyll synthesis may be affected by the exposure of whole plants to cadmium for the long-term. Thus in both the development of chloroplast in young leaves and the photosynthesis inhibition (Stobert et al. 1985; Barcelo et al. 1988; Padmaja et al. 1990; Boddi et al. 1995), it has an important role. The disorganization or disorder of grana and increased number and size of plastoglobuli in chloroplasts as well as increased cell and vacuole size and induced vesiculation in the cytoplasm (Baszynski et al. 1980; Reese et al. 1986; Barcelo et al. 1988; Rascio et al. 1993), are related by the ultrastructural and morphological studies.

On the effects of Cd on development, growth, chlorophyll contents, photosynthesis and structure of the chloroplast of wheat leaves we have focused in the present work. The motive is to establish an overall picture of cadmium toxicity syndrome on the growth and structure of plants.



Mechanism of absorption of cadmium in wheat:

According to Boussen et al. (2013), anthropogenic and geogenic activities both contribute to cadmium entering the soil. About 13,000 of the 30,000 ton of yearly Cd addition to the environment comes from human activities (Gallego et al. 2012). Szolnoki et al. (2013) has reported that the content of cadmium in agricultural and garden soils was 0.01 to 0.7 and 0.27 to 2.86 mg kg⁻¹, respectively. Between 2 to 200 mg kg⁻¹ of cadmium may be found in phosphate fertilizers, whereas 15 mg kg⁻¹ of cadmium can be found in sedimentary rocks. Soil Cd contents, soil pH, organic matter, clay minerals, cation exchange capacity (CEC), and kind of fertilizers are just a few of the many variables that affect a soil's ability to hold onto nutrients (He et al., 2015; Ran et al., 2016). According to Jafarnejadi et al. (2011), there is a substantial relationship between soil Cd concentrations from DTPA extraction and organic carbon, CEC, and wheat grain Cd levels.

The most significant soil component influencing the absorption of Cd by wheat plants is soil pH (Nan et al., 2002; Li et al., 2014; Liu et al., 2015a; Ran et al., 2016). Wheat plants are mostly exposed to cadmium through their roots (Hart et al., 2006; Adeniji et al., 2010; Black et al., 2014). Wheat accumulates Cd by root exudation as well (Cieslinski et al., 1998; Greger and Landberg, 2008). According to Guo et al. (2012) and Liu et al. (2015)a, soil type, air pollution, and wheat cultivars all affect how much cadmium wheat can absorb. Dahlin et al. (2016) published a more current paper stating that chloride (Cl) might mobilize Cd in the soil and boost wheat intake, particularly through mobilizing intrinsic soil Cd. Depending on the wheat cultivar, after root absorption, a larger concentration of Cd is stored in roots and less is translocated to shoots (Adeniji et al., 2010; Ci et al., 2010a). According to (Adeniji et al., 2010), chelation with organic acids may be the cause of the higher Cd retention in roots. According to Hart et al. (2006), phytochelation may not be a limiting factor in the numerous ways that Cd is stored in wheat roots.

According to Harris and Taylor (2004, 2013), cadmium accumulation in wheat shoots rely on root-to-shoot Cd translocation, but cadmium accumulation in grains depends on root-to-shoot Cd transfer as well as a direct channel of Cd transport from roots to grain via xylem-to-phloem transfer in the stem. According to Quinn et al. (2011), higher shoot Cd content in wheat's low isolines was linked to transpiration rate, but in high isolines, Cd accumulation was unrelated to transpiration. According to Van der Vliet et al. (2007), symplastic migration of Cd into the root stele may be the cause of cadmium transfer from the root to the shoot. According to Riesen and Feller (2005), Cd might be remobilized in wheat through phloem in addition to transpiration. According to Chen and Hale (2004), total shoot accumulation was a factor in the Cd content of durum wheat grain.

Cd induced stress on wheat:

Wheat is highly toxic to cadmium, and the first toxic effect of Cd on wheat is a decrease in seed germination. Cadmium, for instance, decreased seed germination in dose- and cultivar-dependent ways in four wheat cultivars (Ahmad et al., 2012). The growth medium affects how toxic cadmium is to seed germination (Ahmad et al., 2013). According to Ahmad et al., wheat cultivation on soil produced better germination, as measured by plumule and radicle length, than filter paper cultivation at the same Cd levels. This may be because Cd is absorbed by the soil exchange sites.

Chlorosis, necrosis, browning of root tips, and decreased plant growth are the primary visible signs of Cd-induced toxicity in wheat (Rizwan et al. 2016) and even the death of plants, particularly at higher Cd concentrations in the growth medium (Ci et al., 2009; Rizwan and other, 2016b). Cadmium poisonousness decreased the root and shoot lengths of wheat plants and shoot length was exceptionally delicate to compact disc stress when contrasted with the rootlength (Cao et al., 2007; Ahmad et al., 2012; Jin and co., 2015). The toxicity of cadmium had an effect on the morphology and growth of the wheat roots (Wang and Zhou, 2005; Ci and co., 2010a). According to Khan et al., 2007 excess Cd decreased the number and area of wheat plant leaves. Cadmium poisonousness diminished yield qualities, earnumber, ear weight, ear length, spikelet number and grains perear, of wheat (Khan et al., 2007). However, the dose and duration of Cd exposure, as well as other factors, affect the threshold of phytotoxic Cd concentrations.

The presence of Cd caused a decrease in photosynthetic colors in wheat leaves, for example, chlorophyll a, chlorophyll b and carotenoid focuses (Ci et al., 2010a; Chen and others, 2014). In a dose- and time-dependent manner, excess Cd reduced the leaf

net photosynthetic rate (Pn), stomatal conductance (Gs), and transpiration rate (Tr) (Khan et al., 2007; Ci and co., 2010a; Shafi et al., 2011; Li and other, 2015). However, wheat genotypes varied in their inhibition of gas exchange characteristics (Shafi et al., 2011).Cadmium poisonousness in the development medium hindered wheat nourishment and changed supplement proportions in the wheat tissues (Jalil et al.,1994; Ouzounidou et al., 1997; Rizwan and other, 2016b). The concentrations of manganese (Mn), zinc (Zn), and potassium (K) decreased in wheat roots and shoots when there was an excess of Cd (Jalil et al.,1994). In wheat shoots, toxicity with cadmium resulted in dose-dependent decreases in the concentrations of iron (Fe), magnesium (Mg), calcium (Ca), and potassium (K) (Ouzounidou et al., 1997). Cadmium treatmentdiminished the macronutrient, N, P, K and Ca, fixations in wheat plants in a portion subordinate way (Yourtchi and Bayat,2013). Cadmium treatment diminished net nitrate amassing by wheat plants (Stolt and Oscarson, 2002). Album interceded decrease insupplement take-up by wheat may be because of consummation of Cd with supplements during take-up by plants at the root surface or potentially byrepressing the carriers/channels of stacking different componentsinto the elevated piece of the wheat. In wheat shoot and root, toxicity to cadmium increased the concentration of free amino acids while decreasing total soluble sugar concentrations (Ci et al., 2009).All in all, Cd poisonousness diminished wheat development and biomassby restraining the leaf photosynthesis, diminishing gas tradequalities and adjusting the mineral supplement take-up by wheat.However, depending on the genotype and the amount of Cd stress applied, wheat's response to Cd toxicity varied.

Cadmium poisonousness systems in wheat:

The disc interceded decline in wheat development and biomass maybe because of various poisonousness components in wheat at physiological furthermore, atomic levels. In writing, there is expanding proof that over the top creation of responsive oxygen species (ROS) is the significant Compact disc poisonousness component in wheat and different plants (Dey et al.,2007; Chen and others, 2010; 2010 by Gajewska and Skodowska; Wang and others, 2011; Lu et al., 2013). Malondialdehyde (MDA) content in wheat shoots and roots increased excessively as a result of excess Cd (Dey et al., 2007; Ci and Co., 2009; Chen and others, 2010, 2014). Groppa and others Thiobarbituric acid reactive substances (TBARS) were found to be higher in wheat plants exposed to Cd toxicity than in control plants. Khan and others (2007) reported that wheat root and leaf contained more H_2O_2 and TBARS than the control, but the response varied between the two cultivar studies. Cadmium stress caused layer underlying harm of wheat which could diminish mineral supplement take-up by plants. Take, for instance, Milone et al. K-leakage, a sign of membrane damage, was found to be more prevalent in the Adamello cultivar of durum wheat than in the Ofanto cultivar, which suggested that the Ofanto cultivar had a lower free circulation of Cd ions, possibly as a result of the Cd's vacuolar compartmentalization.

Decrease in photosynthetic shades may be because of Cd mediated harm of chloroplasts design and capability of leaf photosystem. The leaf photosystem II (PSII) was reportedly damaged by Cd stress (50 mM for 24 days) (Ci et al., 2009,2010a). According to Ouzounidou et al.,1997, another study, Cd toxicity affected the structure of chloroplasts, as evidenced by their distorted shape and dilated thylakoid membranes.

The subcellular distribution of Cd, structural changes in proteins, and overproduction of signalling molecules may also be to blame for the toxic effects of Cadmium on wheat plants. Groppaand co.(2008) suggested that the inhibition of wheat root growth caused by Cd stress may be caused by the formation of nitric oxide (NO) in the roots. Li et.al, 2011announced that Disc focuses expanded inmetal delicate portions, heat-denatured protein organelles while diminished in detoxified parts, heat-stable protein þCd rich granule, with expanding Disc levels in the development medium. The creators proposed that Album harmfulness to wheat roots emphatically dependsupon subcellular Album conveyance. Overabundance Cd caused underlying adjustments in proteins and repressed the exercises of specific qualities (Cebeci et al., 2008). In a nutshell, the primary causes of Cd toxicity in wheat plants are an excess of ROS production, changes to the structure, and genotoxicity.

Mechanisms of wheat tolerance to cadmium:

Improvement in cancer prevention agent catalyst exercises is one of theprincipal Disc resilience components in plants including wheat(Mühling and Läuchli, 2003; Khan et al., 2007; Chen and others, 2010;Poghosyan and others, 2014). In wheat under Cd stress, there are two kinds of antioxidant enzymes: enzymatic antioxidants and non-enzymatic antioxidants. The exercises of superoxidedismutase (Grass), catalases (Feline), and peroxidases (Unit) expandedin wheat shoots and roots with expanding Disc focuses in thesoil up to 10 mg Disc kg1 of soil and afterward diminished with higher Album

levels in the development medium (Chen et al., 2014). Under 50 mM Cdstress for 24 days, leaf Feline movement diminished in the Album delicatelines of wheat while expanded in lenient lines (Ci et al., 2009). The activities of SOD, CAT, guaiacol peroxidase (GPX), ascorbate peroxidase (APX), and glutathione reductase (GR) did not change at lower Cd concentrations (less than 3.3 mg kg1), but they did increase at 10 mg Cd kg1 of soil and then decreased with higher Cd levels (Lin et al., 2007). APX activity in wheat leaves increased at a moderate Cd level (2.69 mg kg1) in comparison to the control, while it decreased at a higher Cd stress level (9.48 mg kg1) in the soil (Li M. Rizwan et al. /). Ecotoxicology and Environmental Safety 130 (2016) 43–53 2014). Milone et al. (Under Cd stress, the activities of APX, GPX, and syringaldazine peroxidase (SPOD) were always higher in roots than in leaves, according to a 2003 study. Under Cd stress, these enzymes' activities increased in the leaves of the Ofanto cultivar, whereas they remained at control levels or slightly increased in Adamello cultivar leaves, particularly at the highest Cd levels. Yannarelli and co. Cd stress increased the activity of glutathione reductase (GR) in wheat roots, according to a 2007 study. The responses among wheat genotypes varied, but the aforementioned studies suggested that Cd tolerance in wheat might be linked to the activation of the antioxidant system.

Wheat's Cd tolerance is also greatly influenced by an excessive production of phytochelatins (PC) (Keltjens and Beusichem, 1998; Stolt et al.,2003; Ranieri and other, 2005; Ahmad and co., 2009). In wheat plants, excessive Cd led to an increase in the synthesis of glutathione (GSH), a compound with a low molecular mass (Lin et al., 2007; Groppa and other, 2008; Ahmad and co., 2009). Wheat's glutathione S-transferase (GST) activity was boosted by Cd treatment (Wang et al., 2011). According to another study

(Gajewska and Skodowska, 2010), wheat shoot and root Cd stress increased the production of non-protein thiols (NPT), GSH contents, and GST activity. According to Keltjens and Beusichem (1998), phytochelatins (PC-SH) concentrations increased in wheat plant shoots and roots up to 2.0 mM Cd in solution, whereas PC-SH concentrations remained constant or slightly decreased at higher Cd levels in the solution. Wheat roots had higher levels of ascorbate (ASC)–glutathione (GSH) cycle metabolites under Cd stress than the control (Paradiso et al., 2008).

Utilization of inorganic changes:

A few inorganic changes have been utilized for thedecrease of Cd take-up and poisonousness in wheat. For instance, Huang et al. 2015) reported that H₂S pretreatment altered the antioxidant defense system to increase wheat seed germination under Cd stress. Moreover, pretreatment with the SO₂ benefactor, Na2SO₃/NaHSO₃ (3:1), expanded wheat seed germination under Cd pressurein a portion subordinate way, ideal fixations between1 and 2 mM, by expanding the exercises of cell reinforcement catalysts insprouting seeds (Hu et al., 2015). Rehman and others In rice-wheat cropping systems, elemental S application increased Cd concentration in wheat grains under Cd-contaminated soil, whereas gypsum application decreased Cd concentration and increased plant growth and biomass. These studies demonstrated that application timing, growth conditions, S forms, H₂S, SO₂, and elemental S all play a significant role in reducing Cd stress in wheat.

Thustos and others According to their findings from 2006, liming the Cd-contaminated soil with 3 g CaO and 5.36 g CaCO₃ per kg of soil raised the soil's pH to 7.3, up from 5.7 in the control treatment. Liming reduced the amount of mobile Cd in the soil and straw and wheat grains' Cd content. This showed that liming may be one more choice todecrease Cd take-up by wheat, however its practicality to the dirt as analteration for metal decrease relies on the dirt bufferinglimit.

Morphological effects of wheat because of Cd exposure:

Cadmium treatment affect on the biomass and shoot- leaf, root length of wheat plants (Baker and Walker 1989). Cadmium treatments produced the inhibition in growth of plants. The root mainly has been affected by Cd treatments than the shoot- leaf. Root and shoot- leaf fresh weight have been inhibited by the cadmium toxicity less than their length, while no 3rd leaf under 1 mM of cadmium in wheat plants was observed; at all cadmium concentrations the 2nd one was fully expanded. A reduction of both root and shoot length and an increasement in DW/FW ratio which was basically because of the reduction of FW in rice and wheat plants which were treated with cadmium, were found by Alia and Saradhi (1991) and Moya et al. (1993).

The decrement in growth could be an outcome of Cd interference with a number of metabolic processes attached with normal development, especially: (1) protein synthesis (Stiborova et al. 1987); some important enzymes that bind to free amino, carboxylate or side groups, and/or replace some important metal ions which are connected to such groups (Van Assche and Clijsters 1990; Alia and Saradhi 1991); and (3) biosynthesis of chlorophyll (Stobart et al. 1985), activity of photosystems, or transport of electron (Murthy et al. 1990), such types of various photosynthetic processes.

Excess amount of cadmium in nutrient solution can cause lack of ions with certain visible symptoms and be injurious to the plants, which can be said according to the results and those of Greger and Lindberg (1987). However, it is impossible to confide on the beginning of certain visible symptoms which are caused by Cd toxicity, acting as a warning when food crops have deposited excess amount of heavy metals, such as Cd, which could be injurious to health, according to Alloway (1990). Relatively, large concentrations of cadmium can deposit in comestible portions except the plant showing the symptoms of stress, although a reduced rate of growth may be indicated by a numerical index of the developmental age of plants, which is called Plastochron Index (Alloway 1990). Certain visible indications of cadmium toxicity include brown stunted roots, wrinkled leaves, chlorosis, reddish brownish veins and petioles, brownish margin to leaves, general decrease in development or growth.

In exposed shoot leaves the concentration of cadmium has been increased with increasement of the external cadmium concentration. Also severe reduction in calcium concentration of the leaves was caused by cadmium, and since for the growth or development of the cell wall and the maintenance of the structure of cell membrane, Cd is very much essential, also growth of plant indirectly may be affected by Cd toxicity (Greger and Lindberg 1987; Greger and Bertell 1992). During Cd treatment calcium ion decreased in wheat shoots, that was reported by Trivedi and Erdei (1992), while calcium ions were translocated from the ligands in membrane preparation of animal origin by cadmium ions, which was suggested by Verbost et al. (1988). A depressed K, Fe and Mg accumulation was resulted by excess amount of heavy metal in plant tissues.

Heavy metals like Al or Cr which cause more morphological changes in the aerial parts of plants than in the root parts (Barcelo et al. 1988), are opposite to cadmium (Eleftheriou et al. 1993; Moustakas et al. 1996). Both the capacity of the roots to store cadmium in inactive form and high dynamism of cadmium within plants have explained this may be.

Growth retardation, reduced nutrient conc., morphological alterations of chloroplasts and decreased photosynthetic activity of wheat plants are resulted because of the long exposure to cadmium. With a number of metabolic processes which are associated with normal growth and development, cadmium's phytotoxic effect on wheat plants could be a consequence of its interference probably. Another observed action of cadmium consists of ethylene biosynthesis stimulation, a phytohormone with significant role, these must be pointed out.



II. CONCLUSION AND PERSPECTIVES:

In conclusion, when wheat plants are exposed to cadmium for long, chloroplasts undergo both the morphological and functional changes in plants.One of the most prevalent inorganic contaminants in the environment is cadmium. It has been recognized as a significant threat to agriculture due to its presence in the atmosphere or soil. The toxicity of cadmium inhibited wheat growth and yield. Wheat's photosynthesis, gas exchange parameters, and mineral nutrient uptake were all reduced by excessive Cd. Wheat developed genotoxicity and oxidative stress as a result of cadmium poisoning. However, the amount of Cd in the growth medium, duration of exposure, and plant growth stage all influence the severity of the toxicity. Wheat increased the production of signaling molecules and stimulated the antioxidant defense system, osmoregulation, and ion homeostasis to counteract the toxicity of Cd. Wheat's Cd uptake and toxicity have been successfully mitigated by a number of Cd strategies. Exogenous application of PGRs, proper application of essential nutrients, inorganic amendments like silicon and liming materials, and organic amendments like compost, manure, and biochar are the most common of these mitigation strategies. In order to alleviate Cd toxicity in wheat, co-cropping, the type of soil, the selection of low-Cd-accumulating cultivars, the exogenous application of microbes, and seed pretreatment with microwave and laser have been utilized. If you want grain with low Cd concentrations, you might be able to achieve this goal by cultivating low Cd-accumulating wheat cultivars, stabilizing the crop in situ, and managing the crop appropriately.

Although a number of management options have been described in the literature, additional critical research efforts, such as the ones listed below, may yield additional advantages.

- To gain a deeper comprehension of the Cd toxicity of wheat, it is necessary to identify molecular pathways of toxicity to the metal.
- More definite examinations are as yet expected to grasp the components of various revisions in lessening Disc poisonousness in wheat.
- Endeavors ought to likewise be given to recognizing and portray more alterations with Compact disc diminishing potential and their regular accessibility.
- To reduce Cd toxicity in wheat by combining the application of microbes and other amendments like biochar, additional research is required.
- The residual effects of various amendments on wheat Cd uptake need to be evaluated.

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