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ROLE OF PLANT GROWTH REGULATORS IN THE GROWTH AND DEVELOPMENT OF DIFFERENT PLANTS AGAINST BIOTIC AND ABIOTIC STRESS: A REVIEW

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ABSTRACT

Abiotic and biotic stresses are the main factors which are responsible for mutation in the plant growth anatomically and morphologically. Abiotic stress includes the disturbances occurringdue to environmental factors such as high and low temperature, high intensity of light, heavy rainfall, drought and flood conditions. Besides this, biotic stress includes disturbances bymicro-organisms like fungi, bacteria, nematodes, parasites, weeds and other wild crops. These stresses are the main reason for the reduction of crop yield and their nutrition. To get rid of these stresses, plants are treated with different osmolytes such as jasmonic acid, proline, salicylic acid, ascorbic acid etc. Osmolytes reduces the reactive oxidation species (ROS) and free ion radicals. This paper focuses on the importance of osmolytes in the growth and development of plants.

***Keywords*:** Abiotic and biotic stresses, micro-organisms, osmolytes, reactive oxidation species (ROS), free ion radicals.

Introduction

Stress in plants can be defined as any undesired state or substance which harms the growth, development and metabolism of plants. These stresses occur naturally in the environment i.e. water stress, heavy metals, temperature, light and some of other stresses are due to human activity like over chemical use, less knowledge about crop production etc. Basically, stresses are of two types: abiotic stress and biotic stress. Term abiotic stress signifies those stresses which come from environmental surroundings of the plant. Abiotic stresses are due to the irregularity in the range of water, salinity, temperature, heavy metals (Arias *et al*., 2010). Nowadays, main reason for abiotic stress is due to heavy metal. Heavy metals are those whose either atomic no. should be 20 or the specific weight should be greater than 5g/cm3. Heavy metal stresses comes from mining, industries, sewage sludge or due to soil acidification. Heavy metal accessibility impels ionic stress in plants which is dissimilar from salinity. Heavy metals affect the plants growth by their own toxicity at a lower concentration i.e. 10^{-3} or lower but not affected by decreasing the osmotic potential of the substrate. Due to presence of extreme level of these heavy metals may affect the physiological and metabolic mechanism in plants like damage of cell membrane, variation in enzymatic activities and inhibit the root growth.

Mechanism of lead tolerance in plants

Lead affect the plant in several ways: bind to the root, bind to the cell and inaugural of antioxidants. Some of the antioxidants are there which show the response toward the plant like proline, glutathione, ascorbic acid etc. and some are antioxidant enzymes APX (ascorbate peroxidase), CAT (catalase), SOD (superoxide dismutase), GR (glutathione reductase), and GPX (guaiacol peroxidase) but these responses depend on the metal concentration, exposure, and the plant species.Lead perforated into the root when treated with small amount and increases the thickness of cell walls (Krzeslowska *et al*. 2010; Mayers *et al*., 2008). Cell wall is made up of pectin having pectin carboxyl group which bind with the lead and causes toxicity (Jiang and Liu, 2010; Mayers *et al*., 2008). Lead bind to the JIM5-P in the cell and act as a physical barrier for the lead entering into the plasma membrane in *F. hygrometrica* reported by Karzeslowska *et al*., 2009 but lead bind to JIM5-P remobilized by endocytosis, together with the pectin isotope stated by these authors. Currently, it was discovered that there are some transporter proteins prent in the plants and perform a vital role in the detoxification of metals. They cause the excretion of metals into the extracellular spaces. (Vadas and Ahner 2009; Maestri *et al*., 2010). DMT1(divalent metal transporter 1) transport the lead across a pH dependent process in plants (Kim *et al*., 2006). Some ATP cassettes are AtATM3 at ATP binding site in Arabidopsis involved in the lead resistance. (Cao *et al*. 2008; Liu *et al*., 2009). But this is not yet clearly confirmed. The non-enzymatic antioxidants are glutathione (GSH) and cysteine present in plants. The increased concentration of cysteine causes lead toxicity (Verbruggen *et al*., 2009) whereas the function of glutathione is to protect the plant from toxicity of lead in plants reposted in *A. thaliana* (Gupta *et al*., 2010; Kranner *et al*., 2010). Exposure of lead produced GSH genes like -reductase, glutamylcysteine synthetase, -peroxidases and glutathione synthetase. The other function of glutathione is to increase the cumulation of proline content in treated plants which damages the protein content and membranes (Sharma and dubey 2005; Maestri *et al*., 2010). Lead is found naturally in the earth crust as an ore

but in small quantity (Krzeslowska *et al*., 2009). Lead is denoted by a symbol Pb. Atomic number of lead is 82 and the molecular weight is 207.2 g/mol. Lead is a weak metal that's why it is unreactive as compared to other heavy metals. It is also known as post-transitional element because it belongs to the p block in the periodic table. Lead is silver in color but when exposed to air it turns into dull grey in color. Lead has low melting point and high density. The most common oxidation state of lead is +2 instead of +4 oxidation state. Lead have various properties like high density, ductility, malleability and due to passivation lead have high resistance to corrosion. Lead has four isotopes having atomic mass number 204, 206, 207, 208 and having some mixing of radioactive elements in small quantity. After giving lead stress in plants, in plants lead is responsible for various changes such as it reduces the root elongation, seed germination, pigment content, antioxidant activity, seedling, transpiration content and differentiation in the cell and tissues (Krzeslowska *et al*., 2009; Gupta *et al*., 2009; Tanton and Crowdy, 1971; Lane and Martin, 1977). Toxicity of lead in plants is depends on the different concentration of lead, stage of plant development, intensity of plant stress, and the duration of exposure. Lead uptake in plant is from soil to roots. In plants reduced uptake of lead is benefitted for the plants. Less amount of lead in plants reduces the toxicity. Once the root hairs adsorbed the lead metal it translocated in whole aerial parts of plants by apoplast pathway or by water stream pathway (Xiong *et al*. 2006; Liu *et al*. 2008).

There are some hyperaccumulator of plant species which have the capacity to transport lead of high concentration to the airy parts of plant without damaging the metabolic activity of plant like *Brassica pekinensis and Pelargonius* (Arshad *et al*., 2008; Maestri *et al*., 2010; Arshad *et al*., 2008). The capacity of the hyperaccumulator species for the accumulation of the concentration of lead is 1000ppm (Kopittke *et al*., 2007). In fact, these hyperaccumulator can release the substances which dissolve the metal and rise the uptake and transport (Tomulescu *et al*., 2004). When plants are treated with lead metal event at low concentration it will impede the germination (Islam *et al*., 2007; Kosobrukhov *et al*., 2004; Chen *et al*., 2007). Whereas high concentration of lead increases the capacity of germination. The concentration of lead can also affect the photosynthetic pigment like it can inhibit the synthesis of carotenoid and plastoquinone reported by Kosbrukov *et al*., 2004; Chen *et al*., 2007; Liu *et al*., 2008; Cenkci *et al*., 2010, interference in the ETS (electron transport system) reported by Qufei *et al*., 2009, deficiency of CO_2 across stomatal closure reported by Romanowska *et al*. 2002, 2005, 2006, increase the activity of enzyme chlorophyllase reported by Liu *et al*., 2008. Lead affect the Rubisco activity in C_3 plants which function as CO_2 assimilation without any interference in the activity of oxygenase activity, it was reported by Assache and Clijsters 1990 (Assche and Clijsters 1990). Parys *et al*. in 1998 reposted that after treatment of *Pisum sativum* with lead nitrate CO_2 concentration increases with decrease in the photosynthetic activity (Parys *et al*., 1998). In the lead treated plant it was reported that only mitochondrial respiration increases whereas photorespiration have no effect (Romanowska *et al*., 2002). After the lead treatment of plant, it was discovered that the respiration rate was increases at 20-30% in the C_3 and C_4 plants at the concentration 5mM (Qufei and Fashui 2009). Increase in the respiration means the production of ATP increases in the plants. Currently, it was discovered that lead accumulated in the photosystem II and damages the secondary structure and restrict the energy transfer in the amino acids (Pourrut *et al*., 2008). In *A. sativum* it was reported that after 48-72 h of giving treatment of lead causes loss of cristae, swelling in the mitochondria, and vacuolization of ER and dictyosomes (Grover *et al*., 2010). The consequences of lead in the *Brassica pekinensis* on the nitrogen growth and assimilation were reported by Xiong *et al*. In Pb treated plants there was reduction in the amount of shoot biomass, nitrate content, nitrate reductase activity, and amino acid content. It was stated that nitrateamount in plant tissue was decreased by the occurrence of heavy metals in the developmental parts of higher plants (Hernandez *et al*., 1997; Kevresan *et al*., 1998). The decreased in the NO_3 content in shoots from lead treatment be able to decreases the absorption of NO_3 content by roots. NO_3 intake across the plasma membrane would be the initial step of NO_3absorption. It's up on the efficiency of roots in assimilation of nitrate, that would be affected by the metabolic requirement of the plants. This step might be regulated by the feedback repression of downstream metabolites like amino acids and other metabolites (Forde, 2000; Nazoa *et al*., 2003). This decrease in NO_3 uptake seems unlikely to have been a result of the feedback repression by downstream metabolite amino acids because the total free amino acid content also declined under Pb exposure.

On the another side, NO_3 intake and movement can be affected by lead toxicity in plants, which results in the reduction of N_2 concentration in the shoots. NO_3 transporters carrier demand for the NO_3 uptake to pass through the plasma membrane by both symporters of low and high affinity (Craweford and Glass 1998; Daniiel-Vedle *et al*., 1998; Forde 2000). Finally NO_3 loaded into the xylem after passing from cell to cell inside the symplasm of the roots and later moved to the shoot. These steps, involve movement across the plasma membrane and H+ -ATPase and hence are energy dependent processes. ATPases are very sensitive to the different sulfhydryl reagents like lead and another heavy metals (Kennedy and Gonsalves, 1989). For this reason, ATPase related mechanisms like plasmalemma polarization and H^+ outflow may be repressed through heavy metal stress (Kenedy and Gonsalvees 1987; Ros *et al*., 1992; Obatta *et al*., 1996; Lalamas *et al*., 2000). The repression of plasma membrane polarization and H+ outflow driven by heavy metals would be detrimental to the possession of nutrients including NO_3 using these gradients as a source of energy (Kennedy and Gonsalves, 1987). Hence, the reduction in NO_3 amount in leaves under lead exposure may lie in lead inhibition of the plasma membrane polarization and H^+ outflow in NO_3 uptake by roots and in movement from roots to shoots, however the response of the H^+ ATPase in plants was not measured.

The reason that plant growth period affects the NO_3 content in leaves would be because of intake of NO_3 in plant growth or may lie in nitrate consumption combined with a decrease in nitrate uptake as a result of declined N in the soil. The rate-limiting step in the nitrate assimilation is the reduction of nitrate to nitrite catalysed by the enzyme nitrate reductase (Cambell, 1999), which finally affect the development and status of organic N_2in plants. lead and another heavy metals have been stated to disastrously affect

the enzymatic mechanism of NO_3 reductase in a diversity of plant variety (Hernandez *et al*. 1997; Keversan *et al*., 1998; Goeuia *et al*., 2000; Vajpaye *et al*., 2000; Singh *et al*., 2002). It was also state after thetreatment of Chinese cabbage plant to lead, a substantial reduction in the activity of Nitrate reductase occurs. The possible explanation for this would be the regulation of gene expression of Nitrate reductase. It is well-known that NO_3 inducethe gene encoding NO_3 reductase, and rising in transcription of the gene is accompanied by increased nitrate reductase protein and activity (Stitt, 1999). Hence, decrease in nitrate reductase expression following lead exposure might result from a decrement in the nitrate reductase gene transcription rate because of restricted availability of nitrate from lead toxicity. The production of ROS like superoxide radicals, hydroxyl radicals, hydrogen peroxide in the presence of aerobic micro-organisms are called as oxidative stress. These are produced due to the toxicity of heavy metals including lead (Jiang and Liu, 2010; Pourrut *et al*., 2008; Grover *et al*., 2010; Liu *et al*., 2008; Yadav, 2010; Singh *et al*., 2010). The exposure of lead in the plants increases the content of ROS which causes cell death at last.

Effect of some biotic factors

Biotic stresses are those stress which occur due to the injury affected by living organisms like bacteria, fungus, virus, nematodes, protozoans, weeds, beneficial or harmful plants, cultivated or native plants (Das *et al*., 2016). The most superior natural agents for plant diseases are fungi. They make colonies in the plant system and causes diseases. This association of plants and fungi is either beneficial or harmful for plants. Fungal plant pathogenic species belongs to the phyla Ascomycota and Basidiomycota. In Ascomycota, plant pathogens are classified into various classes like Dothideomycetes, Sordariomycetes or Leotiomycetes whereas Basidiomycota is divided into two – the rust and the smuts. Basically, fungal plant pathogens are divided into two groups biotrophic pathogens and necrotrophic pathogens. Biotrophic pathogens are those pathogens that interact with plants and consume the plant tissue as a biotrophs on the other hand necrotrophic pathogens are those pathogens that kill the plants for their extraction of nutrients. Other than these two groups there is another group called hemibiotrophic pathogens. These are the pathogens that start their activity as biotrophs and after that behave as a nectrophs. Most of the fungal plant pathogens that show interaction with plants are biotrophs and the interaction is biotrophic interaction. There symptoms are the formation of pseudo flowers, tumors, powdery appearance, rust, etc.

Effect of plant growth regulators

There are some chemical compounds that are introduced into the plants to fight against biotic stress which play a vital role in the biotic stress signaling pathways. These chemical compounds are Aminobutyric acid (BABA) or benzothiadiazole (BTH). Plant growth regulators are the plant hormones that are present endogenously or exogenously in the plants. These plants hormones are that play a major role in the growth and development of plant. Plant growth regulators are used at low concentration for improving the physiological and metabolic activity of the plants. Plants growth regulators also perform a defense mechanism against stress response. There are some plant growth regulators like jasmonic acid (JA), ethylene, auxin, cytokinin, salicylic acid (SA) and abscisic acid (ABA) are also used to protect plant against biotic stress. ABA is used inimically to the ethylene that protects the plant against pathogen attack.

Jasmonic acid is a naturally occurring plant growth hormone. It is naturally extracted from jasmine by the biosynthesis of linolenic acid. Linolenic acid forms peroxide by the lipoxygenase enzyme which further forms allene oxide in the presence of allene oxide synthetase. Allen oxide catalyzed to form a 12-oxophytodienoic acid in the presence of enzyme allene oxide cyclase. Due to β-oxidation 12-oxophytodienoic acid converted into 7-iso-jasmonic acid. This 7-iso-jasmonic acid isomerizes into jasmonic acid in the absence of enzyme. The chemical formula of jasmonic acid is $C_{12}H_{18}O_3$. The IUPAC name jasmonic acid is (1R,2R)-3oxo-2-(2Z)-2-pentenyl-cycllopentaneacetic acid. The molecular mass of jasmonic acid is 210.27g/mol. The density of jasmonic acid is 1.1g/cm^3. The boiling point of jasmonic acid is 160 ºC. The most commonly used derivative of jasmonic acid is methyl jasmonate (MeJA) which is used by most of the researchers. Jasmonic acid plays a most effective role in the defense mechanism against insect herbivore and fungal pathogens. JA is also responsible for the production of secondary metabolites such as flavonoids, alkaloids and terpenoids. Jasmonic acid is responsible for leaf senescence, coiling of tendrils, inhibits the growth, leaf abscission and flower development and differentiation. JA used as a osmolytes which is responsible for removing the reactive oxygen species (ROS), free radical ions which is harmful for plants. The gene known as Dgl gene helps to maintain the level of jasmonic acid in plants.

Plant growth regulators like SA, JA and ethylene shows a major involvement in the defense mechanism against pathogen stress and abiotic stress like water stress, heat stress etc. Jasmonic acid is a naturally occurring fatty acids which perform a signaling pathways involved in the various features of plant development like microbial pathogens, insects, wounding and ozone (Wu *et al*., 2008). There are some genes which depend on the jasmonic acid and encode for the proteins that are related to the pathogenesis. There are some mutants which are isolated currently *cev 1(constitutive expression of VSP1), cet (constitutive expressor of thionin), joe (jasmonate overexpressing).* (Ellis and Turner 2001; Jensen *et al*., 2002). These mutants increased the production of jasmonic acid or rise the flux through signaling pathway of jasmonic acid. These constitutive mutants of jasmonic acid manifest increased resistance to the necrotropic pathogens. *A.thaliana*overexpresses the *PDF 1.2* jasmonic biosynthetic gene constitutively and rising the resistance to *B.cinerea* (Seo *et al*., 2001). Jasmonic acid performs various functions like leaf senescence, flower differentiation and development, lead abscission, fruit ripening etc. According to Ling Qufei & Hong Fashui 2009, it was proved that the light absorbtion of PSII is declined in the lead treated *S. polyrrhiza* species and the reason for that is $PbCl_2$ deteriorate the structure of PSII and in the reduction in the total chlorophyll amount. The $PbCl_2$ decreases the excitation energy which is transfer from cysteine to tyrosine residue in the photosystem II.

Xiong *et al*. 2006, reported that the toxicity of lead in *Brassica pekinensis,* involved in nitrogen assimilation and development lead treatment reduce the biomass of shoot, activity of nitrate reductase enzyme and the content of amino acids and nitrate ions. This reduction in the uptake of nitrate

is due to the result of decreases in the total amount of free amino acids under the lead treatment. The toxicity of lead also affects the transportation of nitrate and decrease in the concentration in the shoot. Qufie *et al*. 2009, performed an experiment in which they determine the effect of Pb^{+2} in the structure and function of photosystem II of *Spirodelapolyrrhiza*. They determine that lead gathered in the photosystem II of *S. polyrrhiza* and lead increases with the increase in the exposure of Pb^{2+}; the control would not spot. CD spectra advised that the secondary structure of photosystem II Pb^{2+} treated *S. polyrrhiza* was destroy, hence determine that Pb^{2+} was in fact bind to the photosystem II. *S. polyrrhiza*under the exposure of $PbCl_2$, the visible light absorption is reduced and it was indicated by some experimental research. The reason for that is $PbCl_2$ deteriorate the conformation of photosystem II, and the whole chlorophyll amount and relative content proportion of chlorophyll a and chlorophyll b prevailed decreased under the inhibition of chlorophyll production (Shearan and Singh, 1993; Ernst *et al*., 2000; Sinha *et al*., 1993; Van Assche and Clijsters, 1990; Wu *et al*., 2008). Magnesium i.e. the substitution of the central atom of chlorophyll, prevents photosynthetic light-harvesting in the affected chlorophyll molecules and resulting in a reduction of light absorbance I vivo by lead (Wu *et al* 2008, 2011). Theyproved that Photosystem II exhibits a fluorescence quality of Tyr; there was an energy movement between amino acids at 230 nm and tyrosine at 278 nm and between protein and chlorophyll-a of intrinsic protein complex of PS II. The absorption of Photosystem II at 230 nm might be attributable to polypeptide or to Cys residues of protein, which have an absorption peak at 235 nm (Zhao and Zhou, 2000; Guo, 1983). The Cys residue for the intrinsic carrier protein of Photosystem II could absorb light and excited. This excitation energy was transferred to a tyrosine group and caused the enhancement of excitation energy at 277 nm, whereas it leads to rising of excitation energy of chlorophyll a at 343 nm. The ratio of photosystem II of F278/F230 from $PbCl_2$ treated *S. polyrrhiza* reduced, proposed that $PbCl_2$ inhibit the excited energy transferred from Cys residue to Tyr residue inside photosystem II complex. On the contrary, the ratio of F278/F343 was progressively rises by the $PbCl_2$exposure, shows that $PbCl_2$ could inhibit the excitation energy transportfrom Cysresidue to Tyr residue, and from Tyr residue to chlorophyll ainside photosystem II complex; the reason for that is Pb^{2+} bind to photosystem II and the protein structure was disabled, and a rotation of protein and pigments on the thylakoid membrane was produced by Pb^{2+}. Therefore, the excited energy from amino acids was hardly moved to chlorophyll a, decrement of the excitation intensity at 343 nm takes place. The reduction of fluorescence quantum yield of photosystem II reaction centre pigment-chlorophyll a (P680)-was because the excitation energy from LHC II, CP43 and CP47 of the core antenna was inefficiently transferred to P680 upon Pb^{2+} treatment. They speculate that Pb^{2+} might harm the bound state of chlorophyll a (P680) on the photosystem II reaction centre. Pb^{2+} decreases the usage and transformation efficiency of light energy within photosystem II, this is suggested by the reduction of the fluorescence quantum yield of photosystem II. Due to the exposure of $PbCl_2$ of different concentrations results in the decrement of O_2 evolvement, demonstrate that $PbCl_2$ is the reason for the damage of energy movement among different compositions of photosystem II, decelerate the change from light energy to electron energy, and prevent the electron transport, leading to the prevention of H_2O splitting and O_2 evolution. Furthermore, $PbCl_2$ deteriorates the structure of tyrosin residues within photosystem II and destroy the function of secondary electron donors, which are believed to be attributed to tyrosine residues of D1 protein in PS II (Liu *et al*., 2008). Therefore, the harvested electrons and protons for tyrosine residues from H_2O was reduced. In the aggregate, Pb^{2+} bound to the photosystem II, which may be replaced the Mg^{2+} ions in chlorophyll or Ca^{2+}ions in the O_2-evolving centre, which results in the modifications of the structure of photosystem II and obstructs both energy transfer within Photosystem II and O_2 evolution.

Conclusion

In this advanced era, agriculture is a crucial point for survival of human beings. There are various techniques used for improving the agriculture field. But still there are some problems faced by the plants due to environmental conditions and living micro-organisms. Plants are affected by the water stress, heat stress, salinity stress and heavy metal stress i.e. abiotic stress and insects, pathogens, nematodes, wild plants are biotic stresses. Heavy metals give ionic stress to the plants and affect the growth and development of them at lower concentrations. The toxicity of heavy metals damages the DNA, causes lipid peroxidation, increases ATP production, inhibits growth and development of plants, increases ROS production, inhibits pigmentation of plants. Besides this fungal stress causes change in the metabolism of plants which involves the physiologically damage to the plants and reduces the economy and productivity of the plants. To protect plants from abiotic and biotic stress, there are some plant defense mechanism perform by different types of osmolyte. These osmolytes are the scavengers of the free radical ions and ROS species. Osmolytes decreases the rate of rising of ROS species in the plant which damage the DNA of the cells. There are some osmolytes like jasmonic acid, ethylene, salicylic acid etc. Jasmonic acid shows a defense mechanism against heavy metal stress and the pathogenic stress. Jasmonic acid works as anameliorater and decreases the content of free radical ions. Jasmonic acid perform various functions like increase growth and development of the plant, formation of tubers, seedling, differentiation and development of flowers. In short, to fight against biotic and abiotic stressesthese ameliorators are used and reduced the productivity and yield of the crops.

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