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RESEARCH ARTICLE

THE ROLE OF GIBBERELLIC ACID IN ALLEVIATING SALT STRESS IN CEREAL CROPS

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ABSTRACT

Salinity stress is one of the most serious problem in arid and semi-arid region of the world, which limits the growth and productivity of crop plants. Its harmful effects can be minimized by application of various chemicals mainly phytohormones i.e.-auxins, cytokinins, brassinosteroids, GA3 etc. Gibberellic acids are plant growth regulators that are also known to induce various physiological responses in plants. Gibberellic acid interacts with other hormones to regulate various metabolic processes in the plant. Application of these hormones increases the nutrient uptake, dry weight, plant height, leaf area and yield of wheat under saline condition. The alleviating effect of gibberellic acid has been shown to be through increasing the water status of the seedling and partially by sustaining protein and RNA level. In this review article, the alleviating effects of GA3 on-germination and seedling growth, leaf area, photosynthesis, chlorophyll contents, mineral nutrition, proline content under salt stress were reviewed.

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INTRODUCTION

Cereals is the most important source of food in human life that is including 65-70% carbohydrates, proteins and too much B vitamins and trace mineral (Afrigan *et al*., 2013). Most of cereals food are supplied by grain and dairy product. There are six cereals-rice, wheat, maize, barley, oats and rye are belong to the family Gramineae (Poaceace). Yield components and growth parameter also show differential responses to salinity stress. Shannon *et al*. (1994) had reported that the salinity often affects the timing of development. In wheat, sorghum and oat, ear emergence, anthesis and rye maturity is unaffected by salinity. Wheat is the most important stable crop in the world and its productivity in saline soils is considerably reduced due to improper nutrition of plants as well as osmotic and drought stress (Shannon, 1998). Rice is one of the main staple food in India and mostly for Asians people is susceptible to salt stress (Munns and Tester, 2008; Anbumalarmathi and Mehta, 2013), particularly during the early seedling stage (Li and Xu, 2007).

Plants are sessile organisms and are directly exposed to environmental stress such as salinity, drought, low temperature (Munns and Termatt, 1986; Dadkhah, 2011). Salt stress induces over production of reactive oxygen species (ROS) (Khan *et al*., 2012). Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crops plants are sensitive to salinity caused by high concentration of salt in the soil (Munns and Tester 2008). Inhibition of plant growth is considered to be due to toxic effect of the NaCl, to the ability of the root system to control entry of ions to the shoot and to slowing down water uptake of plant (Lamber, 2003).The primary effects of salt stress are caused by the presence of ions in rhizosphere limiting extraction of water by roots and reduced plant growth, while the secondary effects are caused by ionic disequilibrium resulting in inactivation of enzyme, nutrition starvation, ionic toxicity in tissue (Nazar *et al*., 2011; Khan *et al*. 2012).

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Salinity adversely affects plant growth and development hindering seed germination (Dash and Panda, 2001), seedling growth (Ashraf *et al*., 2002), enzyme activity (Seckin *et al*., 2009), DNA, RNA, protein synthesis (Anuradha and Rao, 2001) and mitosis (Tabur and Demir, 2010). However, plant species differ in their sensitivity or tolerance to salt stress (Ashraf and Harris, 2004). They have been numerous studies of the effect of salt tolerance in plant (Jamil *et al*. 2007 and Duan *et al*., 2008). Recently, investigations have focused more on the mechanisms of salt tolerance in plants (Dajie, 2006). Recently, the researchers try to improve plant tolerence to salinity injury through either chemical treatment as plant hormones (Shaddad *et al*., 2013). Gibberellic acid has been shown to alleviate the effects of salt stress on pigment content, hill activity and water use efficiency (Iqbal *et al.,* 2011). Gibberellic acid (GA_3), a safe plant growth regulators (PGR), alleviates salinity-induced inhibition of seed germination of glycoiphytic plants (Basalah and Mohammad, 1999). Minimize the harmful effects of NaCl on seed germination (Tipirdamaz *et al.,* 1995) and seedling growth (Kaur *et al*., 1998) due to exogenous gibberellic acid are attributed to the stimulation of A-amylase activity. So attention is now focused on uses of gibberellic acid in regulating plant response to the external environmental condition and controles a number of stress-induced genes (Naqvi, 1999). Gibberellins (GA_3) are generally involved in growth and development. They control seed germination, leaf expansion, stem elongation and flowering (Magome *et al*., 2004).

Datta *et al*. (1998); Sastry and Shekhawa, (2001) and Afzal *et al*. (2005) reported that pre-socking wheat seed with plant growth regulators like, IAA, gibberellins alleviated the growth inhibiting effect of salt stress. Khan and Weber, (1986) and Gul *et al*. (2000) also observed that the plant growth stimulating compounds such gibberellic acid, zeatin, and ethephon can alleviate the effect of salinity on germination and growth of *Ceratoides lanata, Salicamia pacifica, Allenrolfea accidentalis* (Khan *et al*., 2001, 2004). Recently, the GA-promoted desstabilization of DELLA proteins is modulated by environmental signals (such as salt and light) and other plant hormone signaling (such as auxin and ethylene), which reveals the mechanisms of this cross-talking at molecular level (Archard *et al*., 2006). Gibberellic acid accumulates rapidly when plants are exposed to both biotic (McConn *et al*., 1997 and abiotic stresses (Lehmann *et al*., 1995).

Gibberellic acid is one of the most important growth regulators that reduce the harmful effect of salt stress (Basalah and Mohammad, 1999; Hisamatsu *et al*., 2000). For instance, gibberellic acid (GA_3) has been reported to be helpful in enhancing wheat and rice growth under saline condition (Parashar and Varma, 1988; Prakash and Prathapasenan, 1990). These results show that GA_3 application could improve salinity tolerance in crop plants grown under saline condition. Gibberellic acid interacts with other hormones to regulate various metabolic processes in the plant. However, many conflicting theories have been put forward concerning (Vanhuizen *et al*., 1997; Javid *et al*., 2011; Misratia *et al*., 2013 and Iqbal *et al.,* 2014).The present review focuses on the involvement of gibberellic acid in alleviating salt stress in cereals.

Germination and seedling growth

Seed germination and early seedling growth under saline condition are considered as major factor limiting the establishment of crops (Kitajima and Fenner, 2000). Germination of seeds is one of the most crucial and decisive phases in the growth cycle of plant species since it determinate plant establishment and final yield of the crops. Poor germination and seedling establishment are the results of soil salinity. It is an enormous problem adversely affected growth and development of crop plants and results in to low agricultural production. Salinity, in general, has inhibitory effect on germination of seeds (Zhang *et al*., 2010; Abari *et al*., 2011; Kaymakanova, 2009; Akbarimoghaddam *et al.* 2011 and Kaveh *et al*., 2011).

Earlier, it was also reported that salinity decreased germination of seeds of barley, wheat and rice (Kumar *et al.,* 1988; Begum *et al*., 1992; Queiroz and Nakagawa, 1992). Exogenous application of plant hormones through foliar or presoaking seed is good option to alleviate the adverse effect of salinity stress on crops (Ashraf *et al*., 2008). Seed primimg a counter act the salinity effects in many crops because of its simplicity, low cost and effectiveness (Wahid *et al*., 2007 and Afzal *et al.,* 2011).

The favorable effect of gibberellic acid has been shown to be through increasing the water status of the seedling and partially by sustaining protein and RNA level (Banyal and Rai, 1983). Gibberellic acid is reported to alleviate the inhibitory effect of salinity on germination. GA_3 at 6 uM concentration induces increased germination and seedling growth under salt stress.The delay in germination is mainly due to higher Na^+ accumulation in the seeds of wheat (Begum *et al*., 1992 and Akbarimoghaddam *et al*., 2011). GA_3 application increased the nutrient uptake, dry weight, plant height, leaf area and yield of wheat under saline condition. There is also evidence that gibberellic acid can significantly relieve NaCl-induced growth inhibition in rice.

Rice is sensitive to salinity at the seedling stage and becomes tolerant at the seedling stage and very susceptible at the reproductive phase in terms of grain yield. Several chemical have been used for seed priming (Afzal *et al*., 2012). Of various priming agent for seed priming, plant growth regulators have gained much attention from researchers all over the world because of their consistent effects on seed germination as well as growth of a variety of plant species (Farooq *et al.,* 2007; Iqbal and Ashraf, 2013). Plants differ greatly in their tolerance of salinity, as reflected in their different growth responses. Of the cereals, rice (*Oryza sativa*), is the most sensitive and barley (*Hordeum vulgare*) is the most tolerant. Bread wheat (*Triticum aestivum*) is moderately tolerant and durum wheat (*Triticum turgidum* ssp.*durum*) is less (Munns and Tester, 2008). Some scientist (Bahrani and Pourreza, 2012 and Afrigan *et al.,* 2013) also reported that the effect of GA_3 on seed germination and seedling growth in crop plant under salt stress.

Leaf Growth

In cereals, the major effect of salinity on total leaf area is a reduction in the number of tillers; in dicotyledonous species, the major effect is the dramatic curtailing of the size of individual leaves or the number of branches. The decreased rate of leaf growth after an increase in soil salinity is primly due to the osmotic effect of the salt around the roots. A sudden increase in soil salinity causes leaf cells to lose water, but this loss of cells volume and turgor is transient (Munns and Tester, 2008) have suggested that the effect of NaCl on leaf expansion and gibberellic acid on leaf elongation. The harmful influences of salinity on leaf number, also increase with the increase in concentration, according to the studies by (Raul *et al*., 2003; Jamil *et al*., 2005 and Gama, *et al*., 2007). Spraying these salinized plants with any of the phytohormones (GA_3 or kinetin) mostly resulted in a marked increase in leaf area and the inhibitory effect of salinity stress was completely ameliorated especially at the relatively low and moderate salinity level. It is worthy to mention that the values of leaf area was higher than control untreated plants in wheat plant treated with either gibberellic acid or kinetin at 0.9 MPa (Abd El-Samad and Shaddad, 2013).

Photosynthesis and chlorophyll content

The rate of photosynthesis per unit leaf area in salt-treated plants is often unchanged, even though stomatal conductance is reduced. This antilogy is explained by the change in cell anatomy describe above that give rise to smaller, thicker leaves and result in a higher chloroplast per unit leaf area. The most dramatic and easily measurable whole plant response to salinity is a decreased in stomatal aperture. Salinity affects stomatal conductance immediately. In any case, the reduction in leaf area due to salinity means that photosynthesis per plant is always reduced (Munns and Tester, 2008).

The reasons of decreased photosynthetic rate might be attributed to the fall on chlorophyll contents, stomatal closure, transpiration and CO_2 assimilation by leaf tissue and finally plant growth (Misra *et al*., 2002 and Tardieu, 2005). Iqbal *et al*. (2011) reported that the GA_3 are found to enhance photosynthetic rate and invertase activity under salt stress. The photosynthetic rate significantly differed in the interaction of variety x salinity x gibberellic acid.

In present review, the chlorophyll contents significantly decreased under elevated salt stress, as the chlorophyll contents are sensitive to salt exposure and a reduction in chlorophyll levels due to salt stress has been reported in several plants, Such as wheat (Ashraf *et al*., 2002), rice (Anuradha and Rao, 2003). El-Tayeb, (2005) fount that chlorophyll a, b and carotenoids decreased significantly in NaCl treated plants in comparison to control of barley plant.

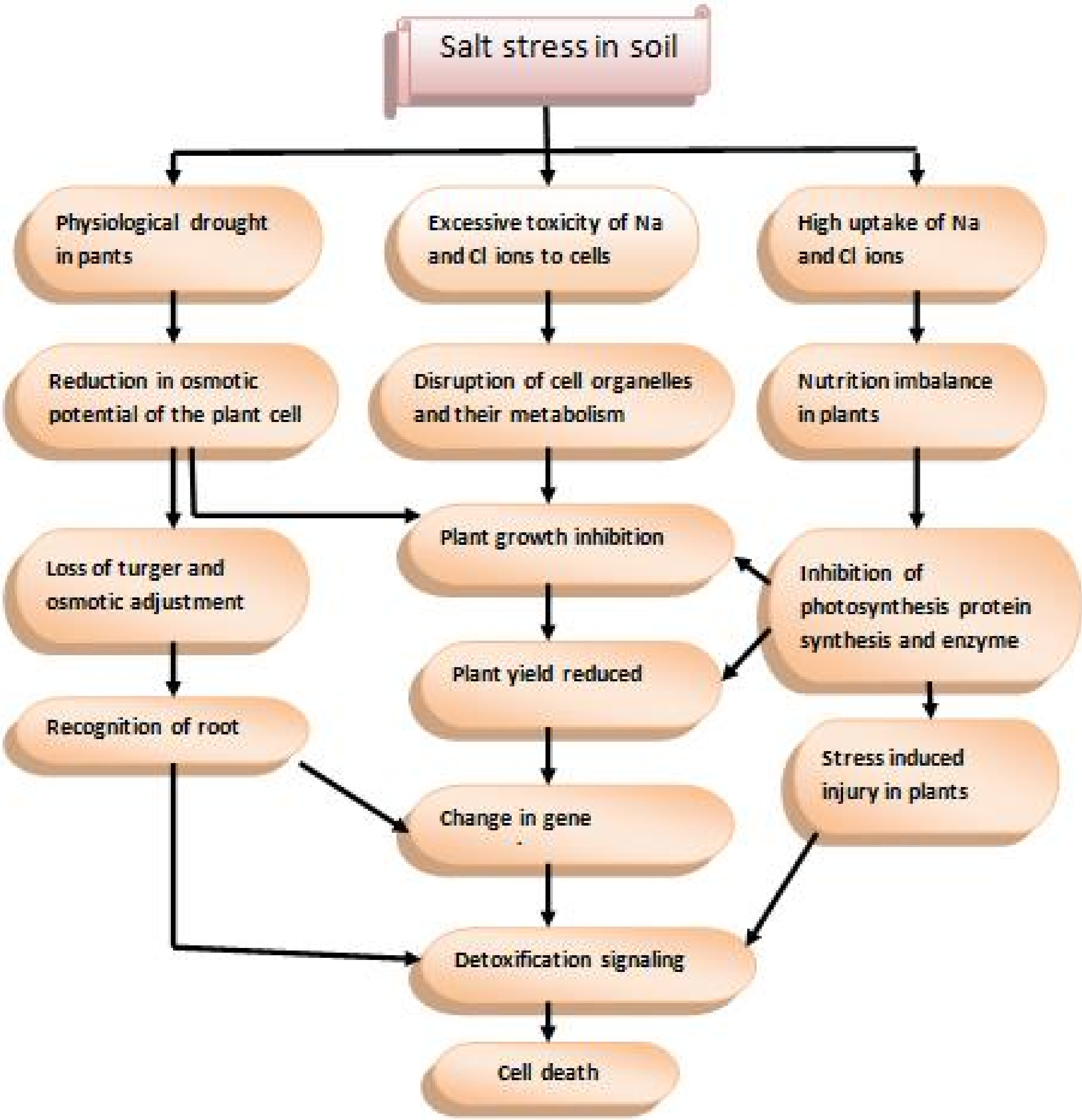

Fig. Diagram showing the processes of inhibition of growth under salt stress condition

Schutz and Fangmeir, (2001) have suggested that the reduction of chlorophyll due to stress is related to the increase of production of free oxygen radical in the cell. Chlorophyll a content positively responded to gibberellin foliar application and increased. Iqbal *et al*. (2006) had reported that the maize, wheat and cotton plant there was asignificant decrease in pigment content at all salinity level. It is adopted the view that osmotically increased water stress enhances the decay of chlorophyll. The inhibitory effect of gibberellin on chlorophyll catabolism might be partly due to the down regulation of the activities of enzymes involved in chlorophyll catabolism and the alleviation of oxidation chlorophyll bleaching (Li *et al*., 2010). Radi *et al.* (1989) argued that in maize, chlorophylls (a+b) and carotenoidsgo up due to salinity stress but gibberellic acid caused a further rise in those pigments. Zeid, (2011) reported an alleviation of adverse effect of salinity on chlorophyll in barley with gibberellic acid treatment.

Alleviating effect of Ga_3 on proline accumulation under salt stress

Salinity stress has a significant effect on proline content. Proline can protect plants from stress through different mechanisms, including osmotic adjustment, protection of membrane integrity and stabilization of proteins (Ozden *et al*., 2009). For alleviation of harmful effect of salinity stress, several strategies have been adopted and efforts are made to explore mechanisms for salinity tolerance. The accumulation of compatible compound (osmolytes), proline is related to the improvement of plant tolerance to salt because of its ability to overcome osmotiv and water stress and maintain nutrients homeostasis (Nazar *et al*., 2011 and Khan *et al*., 2012). Proline plays a protective function against salinity in plants. Proline synthesis in plants occurs mainly from glutamate. Alternatively, proline can also be synthesized from ornithine, which is transaminated first by ornithine-delta-aminotransferse (OAT) producing GSA and pyrroline-5-carboxylate (P5C) and then converted to proline (Kishor *et al.,* 2005; Verbruggen and Hermans, 2008).The accumulation of free proline under salinity stress as reported in *Triticum aestivum* (Ashfaque *et al*., 2014). Goudarzi and Pakniyat, (2009) had reported that proline content in *Triticum aestivum* palnts in the response of salinity could be used to select tolerante and susceptible genotypes.

This enhanced accumulation of proline may representa major biochemical adaptation in plants osmotic adjustment (Siddiqii *et al*., 2008) and Alia and Gahiza, (2007) have found that GA treatments reduced the proline accumulation in salinity stressed *Zea mays* and *Anabaena* plants, respectively. Osmotica like proline, betaine and nitrate has some alleviating effect at highest salinity treatmebt.Thiourea, however significantly alleviated seed germination in all salinity treatment. The rate of germination was significantly increased by the treatment of gibberellic acid (Gul and Khan, 2003).It has been reported that elevated N levels increase endogenous proline content (Jang *et al*., 2008). Tuna *et al*. (2008) reported that foliar application of GA_3 increased proline content which counteracted some of the adverse effects of salinity by maintaining membrane permeability and increasing macro and micronutrient levels.

Proline and gibberellic acid plays important role in alleviating salt stress in crops plants (Iqbal *et al*., 2014).

Alleviating effect of ga_3 on mineral nutrition in cereal crops under salt stress

Mineral nutrients have shown promising potential in alleviation of salt stress. Sulfur (S) is the fourth major essential nutrient element sfter nitrogen (N), phosphorus (P) and potassium (K) that plays an important role in stress tolerance in plants. It also plays an important role in improving K^+ /Na^+ selectivity to increase the capability of calcium ions (Ca^{+2}) and to decrease the induced injurious effects of Na^+ ions (Fatma *et al*., 2013). Gibberellic acid treatment enhanced the accumulation of Na^+ and Cl^- in both shoots and roots of wheat plants under salt stress. It also caused a significant increase in photosynthetic capacity in both line at the vegetative stage under both saline and non-saline media. Interactive effect of gibberellic acid and salt stress on growth, ions accumulation and photosynthetic capacity of two spring wheat (*Triticum aestivum* L.) cultivars differing in salt tolerance (Ashraf *et al*., 2002). Salt stress only slightly influenced accumulations of Na^+,K^+, Na^+/K^+ ratio, Cl^- and ammonia cal nitrogen in young leaves, but strongly stimulated their accumulation in old leaves. Salt stress reduced NO_3^- contents in both old and young leave, with reduction in young leaves greater than old leaves of rice (Wang *et al*., 2012).

Hamdia (1994) show that salinity stress affected growth, the chlorophylls contents, saccharides nitrogen content and some minerals (Na^+,K^+,Ca^+,Mg^{++}, and P) in cucumber plants (cucumissativus). Shaddad *et al*. (2006) show that cv. Giza 168 was more salt tolerant and cv. Sohag was salt sensitive even at low salinity levels. There is a difference in growth criteria of the two wheat cultivars were mirrored by evident variations in absorption and distribution of Na^+ and K^+ among the different organs of the two wheat cultivars. Studies indicate that GA increases the use efficiency of nutrients. Eid and Abou-Leila (2006) reported that GA_3 treatment increased the N, P, K, Mg, Fe, Zn, Mn and Cu content, there increasing the mineral nutrient status of the plant. Gibberellic treatment increased the minerals nutrient levels of *Vigna unguiculata* roots and shoots 46.

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