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Mini Review

Role of Brassinosteroids (BRs) in plants

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ABSTRACT:

It is thought that the plant growth and development are organized by five hormone groups: auxins, gibberellins, cytokinins, abscisic acid, and ethylene, however, research proved that Brassinosteroids (BRs) are the sixth group of the plant hormones. They are a group of steroidal substances isolated firstly from the pollen grains of Vape (*Brassica napus* L.). Some studies refer to the unique capability of Brassinosteroids in increasing the crop yield significantly by protecting the plants against the environmental stresses and gene manipulation. This confirms the value of investigating the Brassinosteroid role in enhancing plant growth and productivity.

Keywords:

Brassinosteroids, BRs, Plants.

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INTRODUCTION

Brassinosteroids are natural compounds formed in various plant parts. They are precisely found in a pollen grain extract (Grove *et al*., 1979). Thus, they represent a group of growth hormones (Yokota and Takahashi, 1985). Brassinosteroids are available in plants as molecules associated with sugars or fatty acids (Bajguz, 2007). As a result of the large amounts of brassinosteroid, they have been given figures to distinguish between them (BR_1 refers to the brassinolide compound followed by BR_2, BR_3 and BR_n of the same series). Brassinolide, 24-EPibrassinolide, and 28-homobrassinolide are considered the three vital compounds used frequently in physiological studies (Rao *et al.*, 2002). Chon *et al*. (2008) reported that brassinolide is a naturally occurring compound widely distributed among many plants and has high biological efficacy in very low concentrations and far more potent than IAA when testing the plumule curvature of the rice plant. The results refer to the stimulating effect of the brassinolide hormone similar to the animal steroid hormones that are produced at low concentrations stimulating the cell division greatly, particularly in the meristematic regions such as root and shoot tips consequently increasing the growth of shoot and root systems (Zandi, 2012). Studies proved that brassinolides play an important role in plant growth and development through their effect and participation in many various growth process (Hussein, 2018) as well as they have several physiological and morphological influences on plants including:

a. Cell division and elongation.
b. Constructing the cell wall components.
c. Stimulating the adventitious roots.
d. Enhancing the seeds' vitality and fertility
e. Seed germination.
f. Branch growth.
g. Flowering and yield increase (Sasse, 2002)

Brassinolides also enhance a varied group of physiological responses including the enzymatic activities and stimulating the construction of DNA, RNA and proteins (Krishna, 2003; Ryu *et al.*, 2007; Bajguz and Hayat, 2009; Mona *et al.*, 2011). Moreover, they help in nitrogen fixation and stress tolerances and in particular, water stress (Anjum *et al.*, 2011; Li *et al.*, 2009; Mahesh *et al.*, 2013), saline stress (Krishna, 2003**;** Bajguz and Hayat, 2009; Hayat and Ahmad, 2011; Marakli *et al.*, 2014), and high or low temperature stresses (Wang *et al.*, 2012) in addition to many other physiological effects and functions.

Biotic construction of brassinolides

The biotic pathway for synthesizing and constructing brassinolide begins from the campestrol compound, which is derived from cycloartnol, where campestrol first converts into campestanol through steps in which de-etiolated (DET2), is used. Then campestanol converts into castasterone (CS) through one of two paths called early and late C-6 oxidation pathway. The two pathways are merged to form campestanol that later on would convert into Brossinolide (BL). The early and late C-6 oxidation pathways existed together, so they can link to each other in different locations of rice plants; furthermore, the presence of these two pathways linked may further complicate the biotic synthesis and construction of brassinolides and may be useful under various physiological conditions such as different types of stresses. The following is an explanation of the most important physiological effects of brassinolides, which may participate in the effects of other plant growth regulators.

Root growth

Brassinolides have stimulatory and inhibitory effect on the root growth when they are used at high or low concentrations where the root growth inhibition depends upon the brassinolide type and its activity. The high concentrations of brassinolides stimulate ethylene production that may be one of the reasons behind the inhibitory effect on root growth, while the low concentrations of them induce root formation. Hedden and

Thomas (2006) have found that brassinolides stimulated the polar shift of top-to-bottom auxins, which stimulated the root formation and development. Fariduddin *et al*. (2011) reported that brassinolides affected strongly the root morphology including the elongation percentage and branching nature. Romani *et al*. (1983) reported that low concentrations of BRs such as EBR- epicastaster-one 24 enhanced root elongation in the wild *Arabidopsis thaliana* by 50%. Mussing *et al*. (2003) reported that the root elongation of *Arabidopsis* wild-type plants was promoted up to 50% affected by the low concentrations (0.05 and 0.5 nM) of BRs such as 24- epicastasterone and EBR, while in BR-deficient mutants such as dwfl-6, root promotion was up to 150 %.

Based on the physiological and molecular characterization of two *Arabidopsis* mutants, det2 and birl, BR participated in Aux/IAA gene- mediated root development of seeds cultured in main stem media (Kim *et al*., 2006). Hayat *et al*. (2007) illustrated the root growth changes as a response in using the concentrations of EBR (0.5, 0.05 and 0.005 ppm) where the root growth was responded to the low concentrations (0.005 and 0.05 ppm), while the higher concentration (0.5 ppm) reduced root length and the number of divisions. Romani *et al*. (1983) and Mussig *et al*. (2003) referred to root growth enhancement as a result of low concentrations of EBR, whereas the high concentrations increased the gravity curvature. Mouchel *et al*. (2006) suggested the relationship between brassinosteroid biosynthesis and auxin signals necessary for the typical root growth either embryonic or postembryonic, thus specific levels of BR are needed for the right expression of many genes by Gene BRX; moreover, the external application of BR increases root growth.

Vegetative growth

The primary study showed that brassinolides (BRs) play an important role in stimulating cell division and elongation as well as enhancing the growth of the young vegetative tissues. The study of Mona *et al*. (2011) referred that the foliar spray BRs 28 (at 50, 100, and 200 $mg.L^{-1}$) on wheat plants played an important role in metabolic activities and growth. Results obtained by Nomura *et al*. (2005) and Bajguz (2007) mentioned that applying brassinosteroide showed remarkable responses in plant growth including stem elongation. Results of Mona *et al*. (2011) showed that spraying brassinosteroide (BRs) plays an essential role in plant growth and development at the concentrations of 50, 100 and 200 $mg.L^{-1}$ which increased all growth criteria significantly compared to the control treatment.

These results were consistent with those of Fujii and Saka (2001) on rice plants, Balbaa (2007) and Mona *et al*. (2011) on Fenugreek plants and Hamid (2008) on wheat plants. Rao *et al*. (2002) mentioned that applying BRs increased seedling growth that was evident through the seedling height, fresh weight, and dry weight as well as it has a vital role in a wide group of development phenomena in plants including stem cell division and elongation and leaf senility. Braun and Wild (1984) reported that spraying BRs was more beneficial when plants subjected to stress conditions. This effect may be attributed to the positive effect of BRs on stimulating the elongation, photosynthesis pigments, fresh weight, dry weight, and branch growth in the wheat and mustard plants. Results of Sairam (1994) illustrated that spraying brassinosteroide stimulated wheat grain yield attributing to the increment of the $grain.spike^{-1}$ and 1000-grains weight.

Grain yield and its components

Results of Hathout (1996) and Hamid (2008) in wheat and of Kerrit (2005) in maize showed that spraying BR hormones increased the length of both spike and ears, number of spikes, number of $gains.spike^{-1}$ and grain weight, that was reflected on in the grain yield. The yield stimulation can be attributed to the high concentration of BRs in the leaves, stems, and roots. It was reported that grain yield is resulted from filling them with sucrose and other sugar types that was translocated to them from the leaves. Similar effects were obtained by Xu (2007) when maize plants were sprayed by epibrassinolide at the grain filling stage. The positive influence of BRs on wheat may be due to the genes controlling the BR hormones as well as the concentrations used to fill the grains and produce wheat and rice grains. Results obtained by Anwar *et al*. (2016) referred that spraying $2mgL^{-1}$ of brassinolide at the tillering stage gave the highest values of the spike number, grain number per spike, 1000 grains weight, grain yield and harvest index with an average as 205.94 m^{-2}, 66 grains, 39.89 g, 4.39 $t.ha^{-1}$ and 37.87% respectively compared to the lower concentrations, used in the study (1.5 and 0.5 $mg.L^{1}$). Results of Ali *et al*. (2008) showed that spraying homo-brassinolide increased the grain weight and yield in two wheat varieties. Results found by Ramraj *et al*. (1997) illustrated that spraying homo-brassinolide 28 significantly increased the wheat yield to reach 6.7 $t.ha^{-1}$ compared to the control treatment producing 5.7 $t.ha^{-1}$. Results of Sairam (1994) showed that spraying homo-brassinolide stimulated the wheat grain production that is attributed to the increment in the grain $number.spike^{-1}$ and 1000-grains weight

Effect of BRs under the stress condition

Brassinosteroids (BRs) have an important role in stimulating plant tolerance to the biotic and abiotic stresses including drought, salinity, temperature, etc., as stresses lead to morphological, physiological, biochemical and molecular changes.

Water stress

In a study related to wheat plants under the stress condition, it was found that soaking the seeds in or spraying the vegetative parts, by 0.001- 10 ppm of BRs. The plants overcame that condition and their vegetative growth and productivity was enhanced as a result of raising their capability to keep water and of increasing the enzymatic activities, especially the nitrate reductase and glutamin-ammonia ligase. Research results demonstrated 33 positive effects of BRs on reducing the water stress effect where it enhances the cell control on abscisic acid, stomata opening, transpiration as well as it keeps the plant tissue's water content. BR hormones have the ability to link to other protein types including saccharide proteins inside the endoplasmic reticulum that increase the root cells osmosis for water molecules and prevent their loss due to the stress severity (Marakli and Gozukirmizi, 2016). Many studies proved that BRs increase the enzymatic system efficiency resisting the oxidative stresses (Hayat and Ahmad, 2011) and stimulate cell division and expansion and then enhance the growth of the plants subjected to the water stress (Davies, 2010).

Saline stress

Some studies referred that spraying epiBL-24 on plants grown in saline media containing $NaCl_2$ in which epiBL-24 led to removing their poisonousness and improve the plant tolerance through enhancing the growth and carbon assimilation parameters as well as increasing the levels of the anti-oxidation enzymes and proline. Results of Mona *et al*. (2011) also reported that the foliar spray of BRs on saline-subjected wheat plants affected significantly the total chlorophyll a and b where the highest effect was obtained by spraying 200 $mg.L^{-1}$. Anuradha and Rao (2003) mentioned that spraying BRs alleviated the inhibitory saline stress on the total chlorophyll that may be a reason behind the growth stimulation.

Vardhini and Rao (1999) and Upreti and GSR (2004) the ability of the BRs, epibrassinolide (EPL) and homo-brassinolide (HpL) to enhance the root nodes in peanut plants. It is known that BRs play a vital role in organizing the ion absorption (Khripach *et al*., 2000) and they are also used for limiting the accumulation of heavy metals and radioactive elements (Khripach *et al.*, 1996). Bajguz and Hayat (2009) indicated that spraying BRs inhibited the saline effect on seed germination and seedling growth of rice. Results of Braun and Wild (1984) revealed that the effect of BRs was more beneficial under the stress conditions and positively affected in stimulating the stem elongation, photosynthesis pigments, and the fresh and dry weight of the vegetative parts of wheat and mustard plants. Results of Sasse *et al*. (1995) and Anuradhaahd and Rao (2001) showed that brassinosteroid hormones alleviate the effect of the saline stress on seed germination and seedling growth. Moreover, the studies of Talaat and Shawky (2013), Marakli *et al*. (2014), Fariduddin *et al*. (2014) and Divi *et al*. (2015) confirmed that spraying BRs reduce the saline stress effect on ROS and on nutrient absorption.

Temperature stress

Study results of Wu *et al*. (2014) showed that the foliar spray of BR hormones reduced the ROS levels and increased activity of the antioxidant enzymes in the high temperature subjected plants. Furthermore, other studies referred that low-temperature stresses such as frost affect the crop growth and productivity (Liu *et al*., 2009 and 2011). However, applying BRs enhance the seed vigor under the forest condition (Wang and Zeng, 1993). Applying BRs also leads to the root elongation and an increase in the root biomass of rice plants grown under low-temperature conditions (Kim and Sa, 1989; Hirai *et al*., 1991). These results are consistent with those of Krishna (2003) related to the maize as using the BRs enhanced the growth of seedlings grown under low -temperature (0-3°C). It is known that low temperature stress increases the soluble proteins, proline and sugar in plants (Ashraf and Foolad, 2007; Burbulis *et al*., 2011).

However, studies revealed that spraying BRs enhanced the protein content and thus increased the plant tolerance to the low temperature as a result of the cell membrane stability (Burbulis *et al*., 2011; Hu *et al*., 2010; Fariduddin *et al*., 2011). Applying BRs also enhanced the anti-oxidant enzymes in the plants subjected to the low-temperature stress (Ahammed *et al*., 2012). Some studies revealed that treating rice plants by the brassinosteroid epiBL-24 increased their tolerance to the low temperature by stimulating ATP, proline, and the activity of the superoxide dismutase enzyme, that clarifies the BRs role in organizing the osmosis and cell membrane stability. Wheat plants treated by the brassinosteroids became more tolerant to the high temperature due to polypeptides called heat shock proteins, i.e. brassinosteroids under the high temperature stimulate the polypeptide synthesis of the heat shook in the cytoplasm.

CONCLUSION

We can conclude that drought and salinity affect the plant growth, leaf chlorophyll content and crop yield negatively. However, spraying the BRs on the plants enhances the growth and carbon assimilation activity and then increases the grain yield. So we recommend that spraying BRs on plants subjected to stress conditions would be more beneficial than spraying them at the normal conditions.

REFERENCES

Abdel Hamid EM. 2008. Physiological effect of some phytoregulators on growth productivity and yield of wheat plant cultivated in new reclaimed soil. Ph. D. degree, botany department University College of Women for Arts, Science and Education-Ain Shams University, Cairo, Egypt.

Ahammed GJ, Yuan HL, Ogweno JO, Zhou YH, Xia XJ, Mao WH, Shi K and Yu JQ. 2012. Brassinosteroid alleviates phenanthrene and pyrene phytotoxicity by increasing detoxification activity and photosynthesis in tomato. *Chemosphere*, 86(5):546–55.

Ali Q, Athar H and Ashraf M. 2008. Modulation of growth, photosynthetic capacity and water relations in salt stressed wheat plants by exogenously applied 24 epibrassinolide. *Plant Growth Regulation*, 56(2): 107–116.

Al-Saedi AJH and Al-Mentafji HNH. 2016. Relations between water stress, selenium and brassinolide hormone on some vegetative parameters and elements content of coriander plant *Coriandrum sativum* L. *Ibn Al-Haitham Journal for Pure and Applied Science*, 29(2): 376-386.

Anjum SA, Wang LC, Farooq M, Hussain M, Xue LL and Zou CM. 2011. Brassinolide application improves the drought tolerance in maize through modulation of enzymatic antioxidants and leaf gas exchange. *Journal of Agronomy and Crop Science*, 197(3): 177–85.

Anuradha S and Rao SR. 2001. Effect of brassinosteroid on salinity stress induced inhibition of seed germination and seedling growth of rice (*Oryza sativa* L.). *Plant Growth Regulation*, 33(2): 151-153.

Anuradha S and Rao SS. 2003. Application of brassinosteroids to rice seeds (*Oryza sativa* L.) reduced the impact of salt stress on growth, prevented photosynthetic pigment loss and increased nitrate reductase activity. *Plant Growth Regulation*, 40(1): 29-32.

Anwar S, Khan I, Hussain S, Anjum MM, Iqbal B, Hussain A, Iqbal MO and Ali N. 2016. Wheat response to different levels of humic acid and brassinolide. *Pure and Applied Biology*, 5(4): 822-829.

Ashraf M and MR Foolad. 2007. Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environmental and Experimental Botany*, 59 (2): 206-216.

Bajguz A. 2007. Metabolism of brassinosteroids in plants. *Plant Physiology and Biochemistry*, 45(2): 95-107.

Bajguz A and Hayat S. 2009. Effect of brassinosteroids on the plant responses to environmental stresses. *Plant Physiology and Biochemistry*, 47(1): 1–8.

Balbaa KL. 2007. Response of two fenugreek *Trigonella foenugracium* L. cultivars to foliar application with Brassinosteroids. *Alexandria Science Exchange Journal*, 28(4): 204-215.

Braun P and Wild A. 1984. The influence of Brassinosteroids on growth and parameters of photosynthesis of wheat and mustard plants. *Journal of Plant Physiology*, 166: 189-196.

Burbulis N, Jonytiene V, Kupriene R and Blinstrubiene A. 2011. Changes in proline and soluble sugars content during cold acclimation of winter rapeseed shoots in vitro. *Journal of Food Agriculture and Environment*, 99(22): 371-374.

Cao YY and Zhao H. 2008. Protective roles of brassinolide on rice seedlings under high temperature stress. *Rice Science*, 15(1): 63-68.

Chon NM, Koseki NN, Takeuchi Y and Abe H. 2008. Role of ethylene in abnormal growth induced by high concentration of brassinolide in rice seedlings. *Journal of Pesticide Science*, 33(1): 67-72.

Davies PJ. 2010. Plant hormones biosynthesis, signal transduction, action! 3rd ed. Springer, Dordercht Netherlands, 802 P.

Divi UK, Rahman T and Krishna P. 2015. Gene expression and functional analyses in brassinosteroid-mediated stress tolerance. *Plant Biotechnology Journal*, 14(1): 419-432.

Fariduddin Q, Yusuf M, Chalkoo S, Hayat S and Ahmad A. 2011. 28-homo-brassinolide improves growth and photosynthesis in *Cucumis sativus* L. through an enhanced antiox 390 abiotic and biotic stress in plants - recent advances and future perspectives idant system in the presence of chilling stress. *Photosynthetica*, 49(1): 55–64.

Fariduddin Q, Mir BA, Yusuf M and Ahmad A.

2014. 24-epibrassinolide and/or putrescine trigger physiological and biochemical responses for the salt stress mitigation in *Cucumis sativus* L. *Photosynthetica*, 52(3): 464–74.

Fujii S and Saka H. 2001. The promotive effect of brassinolide on lamina joint-cell elongation, germination and seedlings growth under low temperature stress in rice (*Oriza sativa* L.). *Plant Production Science*, 4(3): 210-214.

Grove M, Spencer GF, Rohwedder WK, Mandava N, Worley JF, Warthen JD, Steffens GL, Anderson JL and Cook JC. 1979. Brassinolid, a plant growth-promoting steroid isolated from *Brassica napus* pollen. *Nature*, 281: 216-217.

Hathout T. 1996. Salinity stress and its counter action by the growth regulator "Brassinolide" in wheat plants (*Triticum aestivum* L. cultivar Giza 157). *Egyptian Journal of physiology*, 20(112): 127-152.

Hayat S and Ahmad A. 2011. Brassinosteroids: a class of plant hormone. Springer Netherlands, London UK, 462 P.

Hayat S, Ali B, Hasan SA and Ahmad A. 2007. Brassinosteroid enhanced the level of antioxidants under cadmium stress in *Brassica juncea* (L.). *Environmental and Experimental Botany*, 60(1): 33–41.

Hedden P and Thomws SG. 2006. Plant hormone Signaling. Blackwell Publishing Ltd, Harpenden, UK, 19 P.

Hirai K, Fujii S and Honjo K. 1991. Plant growth regulating action of Brassinolide : I. the effect of brassinolide on ripening of rice plants under low temperature condition. Japan Journal of Crop Science, 60(1): 29–35.

Hu WH, Wu Y, Zeng JZ, He L and Zeng QM. 2010. Chill-induced inhibition of photosynthesis was alleviated by 24-epibrassinolide pretreatment in cucumber during chilling and subsequent recovery. *Photosynthetica*, 48(4): 537-544.

Hussein TAH. 2018. Effect of growth regulators on growth and leaves mineral and hormonal content of juvenile olive trees (*Olea europaea* L.). M.Sc. Thesis. Sudan university of Science and Technology- College of Graduate studies, 66 P.

Kerrit AAK. 2005. Effect of some growth regulators on maize plants growth and productivity under salt stress in Gaza strip. PhD. Thesis, Women's college, Ain Shams University.

Khripach V, Zhabinskii V and De Groot A. 2000. Twenty years of brassinosteroids: steroidal plant hormones warrant better crops for the XXI century. *Annals of Botany*, 86(3): 441-447.

Khripach V, Zhabinskii VN and Lakhvich FA. 1996. Prospects for practical use of brassinosteroids a new class of phytohormones. *Seliskokhozyaistvennaya Biologia*, 1: 3-11.

Kim H, Park PJ, Hwang HJ, Lee SY, Oh MH and Kim SG. 2006. Brassinosteroid signal control expression of the AXR3/IAA17 gene in the cross-talk point with auxin in root development. *Bioscience, Biotechnology and Biochemistry*, 70(4):768–773.

Kim KS and Sa JG. 1989. Effects of plant growth regulator, brassinolide, on seedling growth in rice (*Oryza sativa* L). *The Research Reports of Rural Developement Administration*, 31(1):49–53.

Krishna P. 2003. Brassinosteroid-mediated stress responses. *Journal of Plant Growth Regulation*, 22(4): 289-297.

Liu Y, Zhao Z, Si J, Di C, Han J and An L. 2009. Brassinosteroids alleviate chilling-induced oxidative damage by enhancing antioxidant defense system in suspension-cultured cells of *Chorispora bungeana*. Plant Growth Regulation, 59(3): 207-214.

Liu Y, Jiang H, Zhao Z and An L. 2011. Abscisic acid is involved in brassinosteroids-induced chilling tolerance in the suspension-cultured cells from *Chorispora bungeana*. *Journal of Plant Physiology*, 168(9): 853-862.

Mahesh B, Parshavaneni B, Ramakrishna B and Rao SSR. 2013. Effect of brassinosteroids on germination and seedling growth of radish (*Raphanus sativus* L.) under PEG-6000 induced water stress. *American Journal of Plant Sciences*, 4(12): 23052313.

Marakli S and Gozukirmizi N. 2016. Abiotic stress alleviation with brassinosteroids in plant roots. Intech, Chapter 16: 374-394. DOI: 10.5772/61336.

Marakli S, Temel A and Gozukirmizi N. 2014. Salt stress and homobrassinosteroid interactions during germination in barley roots. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 42(2): 446-452.

Mohamed HE. 2005. Physiological studies on the effect of brassinolide on *Nigella sativa* L. M.Sc. Thesis, Faculty of Education, Ain Shams University.

Mona EE, Samera OB and Ibrahim SA. 2011. Influence of Brassinosteroids on wheat plant (*Triticum aestivum* L.) production under salinity stress conditions I-growth parameters and photosynthetic pigments. *Australian Journal of Basic and Applied Sciences*, 5(5): 58-65.

Mouchel CF, Osmont KS and Hardtke CS. 2006. BRX mediates feedback between brassinosteroid levels and auxin signalling in root growth. *Nature*, 443(7110): 458-461.

Mussig C, Shin GH and Altmann T. 2003. Brassinosteroids promote root growth in arabidopsis. *Plant Physiology,* 133(3): 1261-1271.

Nomura T, Kushiro T, Yokota T, Kamiya Y, Bishop GJ and Yamaguchi S. 2005. The last reaction producing brassinolide is catalyzed by cytochrome P- 4505, CYP85A3 in tomato and CYP85A2 in arabidopsis. *The Journal of Biological Chemistry*, 280(18): 17873-17879.

Ramraj VM, Vyas BN, Godrej NB and Mistry KB, Swami BN and Singh N. 1997. Effects of 28-homobrassinolide on yields of wheat, rice, groundnut, mustard, potato and cotton. *The Journal of Agricultural Science*, 128(4): 405-413.

Rao SSR, Varian B, Vidya SE and Anuradha S. 2002. Brassinosteroids - a new class of phytohormones. Current Science. 82(10): 1239-1245. Reproductive yield of chickpea. *Journal of Plant Nutrition*, 32:703–11.

Romani G, Marre MT and Bonetti A. 1983. Effects of a brassinosteroid on growth and electrogenic proton extrusion in maize root segments. *Physiologia Plantarum*, 59(4): 528–532.

Ryu H, Kim K, Cho H, Park J, Choe S and Hwang I. 2007. Nucleocytoplasmic shutting of BZRI Mediated by phosphorylation is essential in arabidopsis Brassinosteroid signaling. *The Plant Cell*, 19(9): 2749-2762.

Sairam RK. 1994. Effect of homo-brassinolide application on metabolic activity and grain yield of wheat under normal and water-stress condition. *Journal of Agronomy and Crop Science*, 173(1): 11-16.

Sasse J. 2002. Physiological actions of brassinosteroids: an update. *Journal of Plant Growth Regulation*, 22(4): 276-288.

Sasse JM, Smith R and Hudson I. 1995. Effect of 24 epibrassinolide on germination of seeds of Eucalyptus camaldulensis in saline conditions. *Process Plant Growth Regulation Society American*, 22: 136-141.

Talaat NB and Shawky BT. 2013. 24-Epibrassinolide alleviates salt-induced inhibition of productivity by increasing nutrients and compatible solutes accumulation and enhancing antioxidant system in wheat (*Triticum aestivum* L.). *Acta Physiologiae Plantarum*, 35(3): 729-740.

Upreti KK and Murti GSR. 2004. Effects of brassinosteroids on growth, nodulation, phytohormone content and nitrogenase activity in French bean under water stress. *Biologia Plantarum*, 48(3): 407-411.

Vardhini BS and Rao SSR. 1999. Effect of brassinosteroids on nodulation and nitrogenase activity in groundnut (*Arachis hypogaea* L.). *Plant Growth Regulation*, 28(3): 165-167.

Wang B and Zeng G. 1993. Effect of epibrassinolide on the resistance of rice seedlings to chilling injury. *Journal of Plant Physiology and Molecular Biology*, 19 (1): 38-42.

Wang Q, Ding T, Gao L, Pang J and Yang N. 2012. Effect of brassinolide on chilling injury of green bell pepper in storage. *Scientia Horticulturae*, 144: 195–200.

Wu X, Yao X, Chen J, Zhu Z, Zhang H and Zha D. 2014. Brassinosteroids protect photosynthesis and antioxidant system of eggplant seedlings from high-temperature stress. *Acta Physiologiae Plantarum*, 36(2): 251-261.

Xu HL. 2007. Effect of exogenous epibrassinolide and abscisic acid on grain yield of sorghum plants growing under soil water deficit. In dryland crop production: technology break through and study cases. HL. Xu, (Eds.) (Trivandrum, India: Research Signpost). 195-202.

Yokota T and Takahashi N. 1985. Chemistry, physiology and agricultural application of brassinolide and Related steroids. In: BOPP M. (Eds.) plant growth substances, Berlin, Springer-Verlag, 129-138 P.

Zandi M. 2012. The role of corticosteroids in today's oral and maxillofacial surgery. Intech. Chapter 21: 539-556. DOI: 10.5772/48655.