The Pharma Innovation Journal 2023; 12(6): 3184-3190

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 3184-3190

www.thepharmajournal.com
Received: 24-04-2023
Accepted: 28-05-2023

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Impact of brassinosteroids on salt stress tolerance in horticultural crops

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Abstract
Phytohormones are the most important chemicals these are produced in parts of the plant and transferred to the other plant parts, where they can regulate an indispensable role in responses to saltiness conditions. Brassinosteroids are a new plant hormone for promoting or enhancing the growth activities in plants. Salinity is the extensive abiotic stresses that disapprovingly disturb the cultivation of the crop. Reducing the consequence of saltiness enhances the implementation of important cultivar regulators which regulate the wide range of physiological and metabolic activity of plants. Plant steroid hormones Brassinosteroids are pertinent for controlling the cellular divisions, cell distinction, and cell elongation of the number of cell types in its life cycle. 24-epibrassinolide and 28-homobrassinolide are applied to plants and it will increase the growth and protect the plant from adverse environmental stresses. That article includes the major aspects of the hormone stresses. That article includes the major aspects of the hormone involved in horticultural crops for maintaining the biotic factors and gave concentrates on various hormones at molecular and biochemical levels for getting the desirable stress response.

Keywords: Brassinolides, horticultural crops, 24-epibrassinolide, 28-homobrassinolide, salt stress

1. Introduction

Brassinosteroids are new plant growth hormones with several plant growth-promoting activities. Brassinosteroids were founded on the rapeseed pollen, *Brassica napus* L. It can regulate the plant processes for plant development and plant growth, plant cell proliferation, elongation, reproduction phase, photomorphogenesis, fruit ripening, cell division, flowering development, cell senescence, root initiation and resistance to the eco-physiological and biota stresses are cold, pesticides, heat, and drought. Brassinosteroid occurrence has been identified in almost all parts of the plant, such as leaves, stems, flower buds, fruits, roots, shoots, seeds, vascular cambium, and pollen. In order to increase the development, productivity, and fruit quality of agri-horticulture plants, brassinosteroids are a natural, safe, non-genotoxic, phytohormone that may be employed (Ghosh *et al*., 2022) [24]. The loss in global crop production is mostly caused by soil salinity and drought, in particular (Boscaiu & Fita, 2020) [7]. Various physiologic and metabolic functions, involving growth, gaseous exchange, relative moisture content, cell permeability, and the presence of pigments involved in photosynthesis activities, are adversely impacted by high salt values in plants (Azarmi *et al*., 2010) [2]. Nacl stress can lower overall chlorophyll concentrations by degrading chlorophyll contents, and such degradation has been connected to Na+ toxicity (Shahzad *et al*., 2019) [53]. As a result of salt, plants respond by restricting their growth, limiting the formation of lateral shoots, decreasing the size of their leaves and fruits, and decreasing the content of both their fresh and dry components (Sinha *et al*., 2022) [44]. By interfering with the evapotranspiration mechanism, salinity in water lowers the rate at which plants transpire, hence lowering agricultural output (Habib *et al*., 2016) [27]. Salt stress considerably decreased the N, P, and K concentrations in the leaves when it was present in irrigation water (Alam *et al*., 2020) [5]. Brassinosteroids are steroid phytohormones found in plants that assist in a number of physiological processes, including gas exchange; stalk elongation, and cell multiplication and expansion, which enhances the ability of plants to respond to salt stress (Gupta *et al*., 2017) [22]. Plant efficiency can be enhanced by rhizosphere microorganisms, especially helpful bacteria and fungus (Mondal & Kaur, 2017) [40]. The Brassinosteroids associated with the phytohormones including the polyamines for regulating the different developmental and plant physiological processes (Saini *et al*., 2015) [57]. The fruit flavour is significantly influenced by acidity, which may be significantly reduced by exogenous administration of 24-epibrassinolide, while retaining fruit quality (Wang *et al*., 2020) [67].

24- Epibrassinolides promotes the genetic and physiological changes in pepper varieties under salt stress condition. BRs affect root and flower development, cell division, photomorphogenesis, tissue vascular matrix, proton pumps, membrane polarization, and stress modulation (Clouse, 2011) [10]. Water and salt shock adversely impact plants by impeding osmotic processes, nutrient uptake, and the reduction of photosynthetic activity (Stepien & Klobus, 2006) [52]. Brassinosteroids promote the exertion of catalyzing and decrease the action of peroxides and ascorbic acid oxide undergoing salinity conditions (Sadeghi & Shekafandeh, 2014) [56] and also regulates the secondary metabolites (Rao *et al*., 2002) [47]. By enhancing proline synthesis in harsh environmental circumstances, Homobrassinolide confers stress tolerance. It also induces flowering and boosts fruit set and development (Wang *et al*., 2019) [66]. Additionally, BRs control the activity of defense-related enzymes, allowing for the development of robust defenses against various pathogens (Pavani *et al*., 2020) [46]. In cultivars susceptible to salinity, phytohormones preserved the physiological viability of the seeds and the development traits of the seedlings, reducing the negative impacts of salt on horticultural crops (Junior *et al*., 2021) [30].

2. Structure

Brassinosteroids are identified as C28, C27 & C29 based on different substitutions of the alkyl sequence of the side bonds. The trans-ring system merged with some two –OH (hydroxyl radical) at ring-A and 7-oxa-6-ketone system at B-ring for BR. The total number BRs is 49, out of the 25 are related to 6-oxo, 5 to 7-oxalactone, 17 relate to 6-dexoand 2 relate to given (Table-1).

Table 1: Brassinosteroids structure

Carbon	B-ring	A-ring (substituent)	Characteristics (s)	References
C28	7-Oxalactone	C(2α,3α)-OH	24-epiBL, BL, DL	(Schmidt *et al*., 1996) [50]
		C(2α,3β)-OH	3-epiBL	(Konstantinova *et al*., 2001) [36]
		C(2β,3α)-OH	2-epi-23-dehydroBL	(Watanabe *et al*., 2000) [64]
		C(2β,3β)-OH	2,3-diepi-23-dehydroBL	
		C3α-OH	7-oxTY	(Katsumata *et al*., 2008) [32]
		C3β-OH	7-oxTE	
	6-Oxo	C(2α,3α)-OH	24-epiCS, CS	(Schmidt *et al*., 1995) [49]
		C(2α,3β)-OH	3,24-diepiCS,3-epiCS	(Kim *et al*., 1987) [33]
		C(2β,3α)-OH	2-epiCS	(Kim *et al*., 1987) [33]
		C(2β,3β)-OH	2,3-diepiCS	
	6-Deoxo	C3β-OH	6-deoxoCT	
		C3α-OH	3-epi-6-deoxoCT	(Yokota *et al*., 1990) [68]
C27	6-Oxo	C3α-OH	28-norTY	(Katsumata *et al*., 2008) [32]
		C(2α,3α)-OH	28-norCS	(Gamoh *et al*., 1990) [21]
	6-Deoxo	C3β-OH	6-deoxo-28-norCT	(Bancos *et al*., 2002) [6]
		C3α-OH	3-epi-6-deoxo-28-norCT	
C29	6-Oxo	C(3α,2α)-OH	28-homoDS	(Yokota *et al*., 1983) [69]
		C3β-OH	3-epi-2-deoxy-25-MeDS	(Park *et al*., 2000)
	6-Deoxo	C(3α,2α)-OH	6-deoxo-25-MeDS	
	7-Oxalactone	C(3α,2α)-OH	28-homoDL,28-homoBL	(Yokota *et al*., 1984) [70]

3. Effect of brassinosteroids on cell physiology

The plant expansion is inhibited along with salt in rhizoid water for two purposes. First, it impairs the plant's proficiency to imbibe water, succeeding in unperceptive expansion. The water and osmotic-deficit effect actualization is saline. Secondly, this might infiltrate the denitrification stream and harm cells in an emerging leaflet, slowing even supplementary, that is the ion-excess or alkali-specific impact of salinity. Because of osmotic fragility generate by elevated salt aggregation in plants and soil, the hydrophilic magnitude of root systems decreases, and dehydration from leaflets speeds up in the preliminary of salt stress, which is also dubbed hyper osmotic stress (Munns, 2005) [38]. The presence of salinity solution inhibits leaves and to a mild extent, rootage (Munns, 1993) [39]. The salt taken by the plant concentration in old leaves, the long-term transfer into transpiring leaves leads to the leaves dying because of extremely high Na+ and Cl- concentrations. The injury is most likely caused by a salt load that exceeds the cells' ability to digest salinity in the vacuoles. Salinity then swiftly accumulates in protoplasm, inhibiting the synthesized action. Otherwise, it could accumulate in the plasma membrane and cause damage and that cell is dehydrated. BRs cause conversion in enzyme campaign, RNA, membrane potential, DNA and protein production, photosynthesis, and the stability of other androgenic plant hormones, among other physiological reactions (Mandava, 1988). Under salt stress, BRs also restored chlorophyll levels and boosted the nitrate dehydrogenate activity. The leaflets of salinity plants have nitrate reductase activity. Because nitrate transfer to the roots is impeded by salt, this is a consequence of nitrate intake hindrance loading of the xylem (Anuradha & Rao, 2003) [4]. The application of 28-homoBL to the leaves or the delivery of 28-homoBL through the roots of plants grown from NaCl-soaked seeds improved growth, seed yield, ethylene content, and nucleic acid content (Hayat *et al*., 2006, Hayat *et al*., 2007) [24, 25].

Table 2: Effect of brassinosteroids on cell physiology

S. No.	Cell physiology characteristics	Reference
1.	Increasing flowers	Yokota *et al*. (1984) [70]
2.	Increasing fruit set	Kamuro and Takatsuto (1999) [34]
3.	Reducing fruit drop	Suzuki *et al*. (1990) [48]
4.	Reducing fruit cracking	Peng *et al*. (2004) [45]
5.	Influence fruit ripening	Chai *et al*. (2013) [11]

4. Induction of thermal tolerance in plants

One of the active substances synthesized during BL biosynthesis is 24-epibrassinolide (EBL), which can enhance a variety of metabolic functions in plants, including the uptake of carbon dioxide, nucleic acid synthesis, and ROS metabolism, and light absorption (Tanveer *et al*., 2018) [61]. Since numerous preceding research suggested that EBL may be useful in reducing various abiotic stressors, high-temperature sensitivity can be achieved by exogenous administration of EBL (Shahzad *et al*., 2018) [53]. EBL strengthens a variety of morphological and physiological characteristics to stimulate plant growth and production under High-temperature stress. Eggplant growth and yield were considerably reduced while exposed to HT stress, however, with the application of EBL, the plant increased in stature by 26%, stem girth by 42%, and root and shoot volume by 43 and 55%, respectively. It is feasible that EBL can stimulate the carbon incorporation process, which will accelerate plant expansion under HT stress. HT stress primarily inhibits plant blossoming and fruit set, which subsequently diminishes agricultural production. A larger number of tomatoes per plant and increased pollen germination, pollen tube development with less pollen bursting, and EBL-induced tomato output enhancement were all linked to HT stress (Singh *et al*., 2005) [51]. By improving antioxidant activity, diminishing lipid peroxidation in rice seedlings, and accumulating heat shock protein, EBL promotes thermal tolerance (Cao and Hua, 2008) [9]. Under both stress and non-stress situations, BLs are also involved in influencing the structure, plasticity, and transparency of cell membranes (Siddiqui *et al*., 2018) [54]. EBL treatment enhances the carbon absorption process and shields it against HT-induced oxidative damage, which in turn boosts plant growth and productivity.

5. Effectiveness of foliar nutrition additives on Horticultural Crops

Recent hostile climatic and edaphic situations have increased the incidence of reproductive abnormalities in horticultural crops, comprising intense air volatility, dehydration shock and desiccation, excessive illumination stress, subsurface salinity and alkalinity, and nutrient deficiency (Kallsen, 2017) [37]. The accessibility of micronutrients for plant incorporation is diminished by soil acidification in addition to surface salinity owing to the generation of recalcitrant aggregates or adversarial effects. Foliar micronutrients should be delivered in this situation when fertilizer demand is at its peak, in theory, because soil availability and root absorption may not be ample to meet expectations even with a suitable amount of soil-applied fertilizer. Supplemental aerial nourishment with zinc, potassium, nitrogen, calcium, and boron might be efficacious in alleviating the consequences of environmental stressors, perhaps immediately direct synthesis, phloem loading and conveyance of photo-assimilates, and allocation appropriate to sink need, or vicariously by safeguarding plants from ROS damage (Wimmer *et al*., 2013) [65]. Plant growth regulators (PGRs) may strengthen crop quality aspects such as nutrient effectiveness and susceptibility to abiotic stress (Colla and Rouphael, 2015) [12]. Brassinosteroids (BRS) participate in a diversity of physiological activities, such as respiration control, antioxidant systems, and other associated areas, which promote the overall effectiveness of plants (Fariduddin *et al*., 2013) [15]. Under challenging atmospheric conditions, brassinosteroids (BRS) influence a comprehensive spectrum of biological processes like blossoming and fruit development (Nolan *et al*. 2020) [43]. PGRs have been shown to improve the efficiency of nutrient exporters in cell membranes and augment nutrition activity, each of which has been associated with enhanced plant nutrient efficiency (De Pascale *et al*., 2017) [14].

6. Brassinosteroids' effect on salt tolerance

BRs have a wide range of protective and stimulatory effects on plant yield and quality (Khripach *et al*., 2000) [35]. Different developing portions of originating seeds, including the epicotyls, peduncles, and epicotyls in coleoptiles, mesocosms, and dicot seeds in monocotyledon seeds, were all elongated when brassinosteroids were applied at very low concentration (Clouse *et al*., 1996) [8]. Crop yield augmentation, differentiation, cell division and cell elongation, senescence, the biology of reproduction (flowering), and ethylene induction are all physiological processes that are impacted by BRs (Houimli *et al*., 2008) [26]. The destructive effects of insufficient salinity on crop maturation may be linked to hydrodynamic stress, apoptosis brought on by an excess of sodium (Na+) and chloride (Cl), nutritional imbalances, diminished turgor, and modifications in the anatomical structure of the leaves (Farouk & Al-Huqail., 2022) [20]. Reactive oxygen species (ROS) which are hazardous and may destabilize cellular processes and drastically impact enzymatic processes were produced in excess as a result of excess Na+. ROS accumulation often compromises with antioxidant homeostasis, causing photosynthetic productivity to deteriorate (Farhangi & Torabian, 2017) [18] reducing nutritional absorption, influencing the incorporation of nitrogen and osmolytes, influencing the profile of phytohormones, and regulating the expression of genes. In addition to transforming the plasma membrane and stimulating metabolic activities in a demanding environment, BRs also promoted ion absorption, promoted the transport of chlorophyll to the sink, and modified the plasma membrane (Ali *et al*., 2008) [1]. Salt shock also facilitates the delineation of the hydrodynamic and ionic components, albeit with significant discrepancies. The plants should contend with a substantial discrepancy in osmotic pressure when they are confronted with a salt shock that contributes to plasmolysis and the evacuation of the nourishing solution from the apoplast. Roots cells efficiently activate genes connected to osmotic responses. Salt is promptly carried through the ground to the branches during this phase because the plants are unwilling to restrict the passage of the solutes (Franzoni *et al*., 2019) [19].

Table 3: Effect of brassinosteroids on salt tolerance

S. No.	Name of fruit	Type of brassinosteroids	Tolerance attribute	Reference
1.	Orange	BL	Decreased fruit drop	Kuraishi *et al.* (1991) [31]
2.	Grapes	EBL	Promoted ripening	Symons *et al.* (2006)
3.	Watermelon	EBL	Increased yield (20%)	Wang *et al.* (1994) [63]
4.	Litchi	BL	Reduced fruit cracking	Peng *et al.* (2004) [45]
5.	Jujube (Ber)	BS	Reduced postharvest losses	Zhu *et al.* (2010) [71]
6.	Cucumber	BS	Early fruit Development	Fu *et al.* (2008) [17]
7.	Papaya	BS	Quick ripening	Fabi *et al.* (2007) [16]
8.	Apple	BL	Increased protein level	Sharma *et al.* (2021) [60]

7. Effects of Brassinosteroids on numerous horticultural crops under salt stress conditions

In orange trees, the application of brassinolides at the time of flowering will increase the fruit set. When the brassinolides are applied at the fruit growth stage the physiological drop will be decreased and the aggregate yield of fruits plant^{-1} will be increased. (Kuraishi *et al.*, 1991) [31] was found that in citrus (*Citrus unshiu*) the acidity/Brix ratio and juice production will also be increased.

In grapes (*Vitis vinifera* L.) trees the application of BSs. Application is done with the number of seedless vines grape cultivars, it can utilize the numbers of BRs solutions concentration (0.1 mg L^{-1}, 0.5 mg L^{-1}, and 1 mg L^{-1}) on twelve years old grapevine crops. As a result, the length, cluster weight, and width will be increased considerably by the application of 0.5 and 1 mg L^{-1} BL. Fruit firmness, TSS content, and Total Phenolics content will be increased when we applied 0.5 mgL^{-1} (Champa *et al*., 2015) [13].

In watermelon, the foliar application of 24-epibrassinolides increased the yield by 20% by 0.01 mg L^{-1} (Ikekawa and Nagai, 1987) [28]. The application of EBL will increase the fruit set, delay in senescence, and the number of flowers.

BS improves the fruit ripening, its quality as well as fruit yield. However, when spraying the solution of brassinolides on litchi before the blossom on the leaves increased the pectin methyl esterase activities and water-soluble content of pectin, calcium, and protopectin in the pericarp of the fruits, and the rate of fruit cracking will be reduced, providing an essential role through the increment in litchi's commercial worth fruit (Peng *et al*., 2004) [45]. As shown, (Zhu *et al*., 2010) [71] also found that brassinosteroids use will reduce the postharvest decay at a concentration of 5M found by Penicillium expansum on ber and also delayed the maturation by prohibiting the rate of ethylene production and the respiration rate, by that lifespan of the fruits will also be increased. Jujube fruit trees have more potential to resist salinity conditions as compared to other fruits. The two wild varieties of Indian jujube (*Ziziphus nummularia* and *Ziziphus rotundifolia*) were found to be more resistant under saline conditions due to higher CO_2 assimilation, stomata conductance high, higher hormonal regulation, and better translocation of nutrients by the accumulation of the higher amount of Na+ in roots by the restricted translocation and higher ratio of K+/Na+ to keep the ions balance in leaves (Mohammadkhani, 2018) [41].

24-epiBL enhanced the genetic as well as a physiological alternate in the diversity of pepper underneath the salinity. However, they keep reducing the deleterious effect of salt stress in pea (*Psidium Sativa*) and increasing its growth rate. Treated the bean (*Phaseolus vulgaris*) with 5uM epiBL the stress has to be detoxified and brought out by improving the rate of growth and sodium chloride, the intensity of pods protein, and pod quantity in beans. Further found that the utilization of brassinolides (24-EpiBL) will reduce these biochemical and physiological effects of salt stress conditions in cucumber. 28-homoBL can enhance the cucumber growth, leaf chlorophyll, and antioxidant enzymes level by applying 1umol L^{-1} (Ahmad *et al*., 2019) [3] reported that the NaCl will reduce the root and shoot growth, and its dry and wet weight is also reduced by the salt stress. The application of Homobrassinolide with AMF (arbuscular mycorrhizal fungi) will result in increasingly dry and wet weight and the root and shoot length.

In papaya, the application of BRs on a specific leaf area as well as on the whole canopy could promote the degradation of chlorophyll and plant development, as well as the abscission and leaf senescence. The height increment was determined for every plant by calculating the difference between the present height and the height recorded after the first day of measurements.

In the stress conditions, the plants are stressed in different manners: oxidative damage, and ionic and osmotic stress (Su *et al*., 2020) [59]. Apple trees are highly affected by the serious salt stress, arising from the loss in quality and production of apples. Attenuate the effect of salt stress conditions. Brassinolides (BLs) were applied which the anti-oxidative activities, ion homeostasis, and osmotic balance will influence. This will find that the enhancement in the application and inspection of brassinolides physiologic effect under the salt stress conditions. Treat the seeds with different components of nutrients solution to examine the desired results. Seed were drenched along 0.05 mg L^{-1}, 0.1 mg L^{-1} and 0.2 mg L^{-1} of BLs.

Homobrassinolide implementation can stimulate the campaign of peroxides, catalase, and membrane catabolism decreased in groundnut (Verma *et al*., 2012) [62]. And by this foundation, the lipid peroxidation is decreased, which seems to reduce reactive oxygen species (ROS) and it can remove stressful situations by the use of antioxidant that is activated by the BR hormone. Germination of spinach was enhanced up to 54% to 72% by soaking the seeds in brassinolides aqueous solutions (Kim *et al*., 1987) [33].

8. Conclusion

Stresses can significantly decrease the yield potential and the cultivation area will shift for important commercially grown fruit crops by the change in the climate. They have also increased the quantity and the quality of horticultural plants such as apple, papaya, pea, bean, cucumber, orange, litchi, watermelon, grapes, etc. BS also protected the plants from different biotic stresses such as pathogens attack. 28-homobrassinolide overcame the salt stress effect on the cucumber plants and enhanced the growth attributes, antioxidants enzymes, and leaf chlorophyll.

9. References

1. Ali B, Hayat S, Fariduddin Q, Ahmad A. 24-Epibrassinolide protects against the stress generated by salinity and nickel in Brassica juncea. Chemosphere. 2008 Jul 1;72(9):1387-1392.
2. Azarmi R, Taleshmikail RD, Gikloo A. Effects of salinity on morphological and physiological changes and yield of tomato in hydroponics system. Journal of Food, Agriculture & Environment. 2010;8(2):573-576.
3. Ahmad H, Hayat S, Ali M, Liu H, Chen X, Li J, *et al*. The Protective Role of 28-Homobrassinolide and *Glomus versiforme* in Cucumber to Withstand Saline Stress. Plants (Basel, Switzerland). 2019;9(1):42. DOI https://doi.org/10.3390/plants9010042
4. Anuradha S, Ram Rao SS. 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. 2003 May;40:29-32. DOI https://doi.org/10.1023/A:1023080720374
5. Alam A, Ullah H, Attia A, Datta A. Effects of salinity stress on growth, mineral nutrient accumulation and biochemical parameters of seedlings of three citrus rootstocks. International Journal of Fruit Science. 2020 Oct 1;20(4):786-804.
6. Bancosİ S, Nomura T, Sato T, Molnár G, Bishop GJ, Koncz C, *et al*. Regulation of transcript levels of the Arabidopsis cytochrome P450 genes involved in brassinosteroid biosynthesis. Plant physiology. 2002 Sep;130(1):504-513. DOI https://doi.org/10.1104/pp.005439
7. Boscaiu M, Fita A. Physiological and molecular characterization of crop resistance to abiotic stresses. Agronomy. 2020 Sep 2;10(9):1308.
8. Clouse SD, Langford M, McMorris TC. A brassinosteroid-insensitive mutant in Arabidopsis thaliana exhibits multiple defects in growth and development. Plant physiology. 1996 Jul 1;111(3):671-678.
9. Cao YY, Hua ZH. Protective roles of brassinolide on rice seedlings under high temperature stress. Rice Science. 2008 Mar 1;15(1):63-68.
10. Clouse SD. Brassinosteroid signal transduction: from receptor kinase activation to transcriptional networks regulating plant development. The Plant Cell. 2011 Apr;23(4):1219-1230.
11. Chai J, Liu JN, Ngai EW. Application of decision-making techniques in supplier selection: A systematic review of literature. Expert systems with applications. 2013 Aug 1;40(10):3872-3885.
12. Colla G, Rouphael Y. Biostimulants in horticulture. Scientia Horticulturae. 2015;196:1-134.
13. Champa WH, Gill MI, Mahajan BV, Aror NK, Bedi S. Brassinosteroids improve quality of table grapes (*Vitis vinifera* L.) cv. flame seedless. Tropical Agricultural Research. 2015 Nov 20;26(2):368-379.
14. De Pascale S, Rouphael Y, Colla G. Plant biostimulants: Innovative tool for enhancing plant nutrition in organic farming. Eur. J. Hortic. Sci. 2017 Dec 1;82(6):277-285.
15. Fariduddin Q, Mir BA, Yusuf M, Ahmad A. Comparative roles of brassinosteroids and polyamines in salt stress tolerance. Acta physiologiae plantarum. 2013 Jul;35:2037-2053.
16. Fabi JP, Cordenunsi BR, de Mattos Barreto GP, Mercadante AZ, Lajolo FM, Oliveira do Nascimento JR. Papaya fruit ripening: response to ethylene and 1-methylcyclopropene (1-MCP). Journal of agricultural and food chemistry. 2007 Jul 25;55(15):6118-6123.
17. Fu FQ, Mao WH, Shi K, Zhou YH, Asami T, Yu JQ. A role of brassinosteroids in early fruit development in cucumber. Journal of Experimental Botany. 2008 Jun 1;59(9):2299-2308.
18. Farhangi-Abriz S, Torabian S. Antioxidant enzyme and osmotic adjustment changes in bean seedlings as affected by biochar under salt stress. Ecotoxicology and environmental safety. 2017 Mar 1;137:64-70.
19. Franzoni G, Cocetta G, Trivellini A, Ferrante A. Transcriptional regulation in rocket leaves as affected by salinity. Plants. 2019 Dec 23;9(1):20.
20. Farouk S, Al-Huqail AA. Sustainable biochar and/or melatonin improve salinity tolerance in borage plants by modulating osmotic adjustment, antioxidants, and ion homeostasis. Plants. 2022 Mar 13;11(6):765.
21. Gamoh K, Okamoto N, Takatsuto S, Tejima I. Determination of traces of natural brassinosteroids as dansylaminophenylboronates by liquid chromatography with fluorimetric detection. Analytica chimica acta. 1990 Jan 1;228:101-105. DOI https://doi.org/10.1016/S0003-2670(00)80484-5
22. Gupta P, Srivastava S, Seth CS. 24-Epibrassinolide and sodium nitroprusside alleviate the salinity stress in Brassica juncea L. cv. Varuna through cross talk among proline, nitrogen metabolism and abscisic acid. Plant and Soil. 2017 Feb;411(1):483-498.
23. Ghosh T, Panja P, Sau S, Datta P. Role of brassinolide in fruit growth, development, quality and cracking of litchi cv. bombai grown in new alluvial zone of West Bengal. International Journal of Bio-resource and Stress Management. 2022;13(5):507-512.
24. Hayat S, Ali B, Ahmad A. Response of Brassica juncea to 28-homobrassinolide grown from the seeds exposed to salt stress. Journal of Plant Biology. 2006 Apr;33(1&2):169-174.
25. Hayat S, Ali B, Hasan SA, Ahmad A. Effect of 28-homobrassinolide on salinity-induced changes in Brassica juncea. Turkish Journal of Biology. 2007;31(3):141-146.
26. Houimli SIM, Denden M, El Hadj SB. Induction of salt tolerance in pepper (*Capsicum annuum*) by 24-epibrassinolide. Eur Asian Journal of Bio Sciences. 2008;2(1):83-90.
27. Habib SH, Kausar H, Saud HM. Plant growth-promoting rhizobacteria enhance salinity stress tolerance in okra through ROS-scavenging enzymes. BioMed Research International, 2016, (10).
28. Ikekawa N, Nagai T. Brassinosteroids fruiting hormones for melons. Jpn. Kokai Tokkyo Koho. JP. 1987;63(88,243):0201.
29. Jiroutova P, Oklestkova J, Strnad M. Crosstalk between brassinosteroids and ethylene during plant growth and under abiotic stress conditions. International journal of molecular sciences. 2018 Oct 22;19(10):3283.
30. Júnior SD, de Andrade JR, de Lima RF, Guimarães RF, de Souza AR, do Nascimento R. Effects of 24-epibrassinolide on germination and growth of tomato seedlings under salt stress. Revista de Agricultura

Neotropical. 2021 Feb 12;8(1):e4842-.
31. Kuraishi S, Sakurai N, Eun JS, Sugiyama K. Effect of brassinolide on levels of indoleacetic acid and abscisic acid in squash hypocotyls: possible application for preventing fruit abortion. ACS Symposium Series. 1991;28:312-319.
32. Katsumata T, Hasegawa A, Fujiwara T, Komatsu T, Notomi M, Abe H, *et al*. Arabidopsis CYP85A2 catalyzes lactonization reactions in the biosynthesis of 2-deoxy-7-oxalactone brassinosteroids. Bioscience, biotechnology, and biochemistry. 2008 Aug 23;72(8):2110-217.
DOI https://doi.org/10.1271/bbb.80192
33. Kim SK, Yokota T, Takahashi N. 25-Methyldolichosterone, a new brassinosteroid with a tertiary butyl group from immature seed of Phaseolus vulgaris. Agricultural and biological chemistry. 1987 Aug 1;51(8):2303-5.
DOI https://doi.org/10.1080/00021369.1987.10868344
34. Kamuro Y, Takatsuto S. Brassinosteroids: steroidal plant hormones. Practical Application of Brassinosteroids in Agricultural Fields. Springer-Verlag, Tokyo, 1999, 223-241.
35. Khripach V, Zhabinskii V, de Groot A. Twenty years of brassinosteroids: steroidal plant hormones warrant better crops for the XXI century. Annals of botany. 2000;86(3):441-447.
36. Konstantinova OV, Antonchick AP, Oldham NJ, Zhabinskii VN, Khripach VA, Schneider B. Analysis of underivatized brassinosteroids by HPLC/APCI-MS. Occurrence of 3-epibrassinolide in Arabidopsis thaliana. Collection of Czechoslovak Chemical Communications. 2001;66(12):1729-7234.
DOI https://doi.org/10.1135/cccc20011729
37. Kallsen CE. Temperature-related variables associated with yield of 'Kerman'pistachio in the San Joaquin Valley of California. American Society for Horticultural. 2017;52(4):598-605.
Doi https://doi.org/10.21273/HORTSCI11775-17
38. Munns R. Genes and salt tolerance: bringing them together. New phytologist. 2005;167(3):645-663.
39. Munns R. Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses. Plant, Cell & Environment. 1993 Jan;16(1):15-24.
40. Mondal HK, Kaur H. Effect of salt stress on medicinal plants and its amelioration by plant growth promoting microbes. International Journal of Bio-resource and Stress Management. 2017;8(3):477-487.
41. Mohammadkhani N, Servati M. Effects of Alhagi maurorum and Cardaria draba weeds on mineral nutrients absorption in wheat. Journal of Iranian Plant Ecophysiological Research. 2018 Jun 21;13(49):82-90.
42. Munns R, Hare RA, James RA, Rebetzke GJ. Genetic variation for improving the salt tolerance of durum wheat. Australian Journal of Agricultural Research. 2000;51(1):69-74.
43. Nolan TM, Vukašinović N, Liu D, Russinova E, Yin Y. Brassinosteroids: multidimensional regulators of plant growth, development, and stress responses. The Plant Cell. 2020 Feb;32(2):295-318.
44. Sinha N, Chaudhary SK, Rani R, Karuna K, Ahmad MF. Impact of Salt Stress on Fruits and Its Mitigation Strategies. Plant Sciences. 2022;11(1):4692-4704.
45. Peng J, Tang X, Feng H. Effects of brassinolides on the physiological properties of litchi pericarp (*Litchi chinensis* cv. nuomoci). Scientia horticulture. 2004;101(4):407-416.
46. Pavani K, Jena C, Vaka DV. Article on influence of bio-regulators on guava (*Psidium guajava* L.) cv. L-49 along with crop regulation by branch bending and shoot pruning under South-East conditions of Odisha. Journal of Pharmacognosy and Phytochemistry. 2020;9(2):1564-1566.
47. Rao SSR, Vardhini BV, Sujatha E, Anuradha S. Brassinosteroids–a new class of phytohormones. Current Science; c2002. p. 1239-1245.
48. Suzuki A, Murakami Y, Maotani T. Physiological studies on physiological fruit drop of persimmon, Diospyros kaki Thunb. 4: Effect of fruit growth on physiological fruit drop of persimmon. Bulletin of the Fruit Tree Research Station. Series A. (Japan). 1990;15:41-49.
49. Schmidt J, Himmelreich U, Adam G. Brassinosteroids, sterols and lup-20 (29)-en-2α, 3β, 28-triol from Rheum rhabarbarum. Phytochemistry. 1995 Sep 1;40(2):527-531.
50. Schmidt J, Böhme F, Adam G. 24-Epibrassinolide from Gypsophila perfoliata. Zeitschrift für Naturforschung C. 1996 Dec 1;51(11-12):897-899.
51. Singh I, Shono M. Physiological and molecular effects of 24-epibrassinolide, a brassinosteroid on thermotolerance of tomato. Plant Growth Regulation. 2005 Nov;47(2):111-119.
52. Stępień P, Kłbus G. Water relations and photosynthesis in Cucumis sativus L. leaves under salt stress. Biologia Plantarum. 2006 Dec;50:610-616.
53. Shahzad B, Tanveer M, Che Z, Rehman A, Cheema SA, Sharma A, Song H, ur Rehman S, Zhaorong D. Role of 24-epibrassinolide (EBL) in mediating heavy metal and pesticide induced oxidative stress in plants: a review. Ecotoxicology and environmental safety. 2018 Jan 1;147:935-944.
54. Siddiqui H, Hayat S, Bajguz A. Regulation of photosynthesis by brassinosteroids in plants. Acta Physiologiae Plantarum. 2018;40(3):1-15.
55. Takatsuto S, Abe H, Yokota T, Shimada K, Gamoh K. Identification of castasterone and teasterone in seeds of *Cannabis sativa* L. Journal of Japan Oil Chemists' Society. 1996 Sep 20;45(9):871-3.
56. Sadeghi F, Shekafandeh A. Effect of 24-epibrassinolide on salinity-induced changes in loquat (*Eriobotrya japonica* Lindl). J Appl Bot Food Qual. 2014 Jan 1;87:182-189.
57. Saini S, Sharma I, Pati PK. Versatile roles of brassinosteroid in plants in the context of its homoeostasis, signaling and crosstalks. Frontiers in plant science. 2015 Nov 4;6:950. DOI http://doi. 10.3389/fpls.2015.00950
58. Shahzad B, Fahad S, Tanveer M, Saud S, Khan IA. Plant responses and tolerance to salt stress. In Approaches for enhancing abiotic stress tolerance in plants; c2019. p. 61-78.
59. Su Q, Zheng X, Tian Y, Wang C. Exogenous brassinosteroids alleviates salt stress in apple by regulating the transcription of NHX-Type Na+ (K+)/H+ antiporters: Frontiers in Plant Science. 2020;10:33-89.
60. Sharma KS. Brassinosteroids application responses in fruit crops. *International* Journal of Agricultural

Environment and Biotechnology. 2021;14:123-140.
61. Tanveer M, Shahzadi B, Sharma A, Khan EA. 24-epibrassinolide application in plants: improving drought stress tolerance in plants. Plant Physiology of Chemistry. 2018;10:1016.
62. Verma A, Malik CP, Gupta VK. *In vitro* effects of brassinosteroids on the growth and antioxidant enzyme activities in groundnut. International Scholarly Research Network. 2012;2000(1):18-19.
63. Wang T, Luo Y, Small GM. The POX1 gene encoding peroxisomal acyl-CoA oxidase in Saccharomyces cerevisiae is under the control of multiple regulatory elements. Journal of Biological Chemistry. 1994 Sep 30;269(39):24480-24485.
64. Watanabe T, Yokota T, Shibata K, Nomura T, Seto H, Takatsuto S. Cryptolide, a new brassinolide catabolite with a 23-oxo group from Japanese cedar pollen/anther and its synthesis. Journal of Chemical Research. 2000 Jan;2000(1):18-19.
65. Wimmer MA, Eichert T. Mechanisms for boron deficiency-mediated changes in plant water relations. Plant science. 2013 Apr 1;203:25-32.
66. Wang S, Liu J, Zhao T, Du C, Nie S, Zhang Y, *et al*. Modification of Threonine-1050 of SlBRI1 regulates BR Signalling and increases fruit yield of tomato. BMC plant biology. 2019 Dec;19(1):1-3.
67. Wang M, Cai C, Lin J, Tao H, Zeng W, Zhang F, *et al*. Combined treatment of epi-brassinolide and NaCl enhances the main phytochemicals in Chinese kale sprouts. Food chemistry. 2020 Jun 15;315:126275.
68. Yokota T, Ogino Y, Takahashi N, Saimoto H, Fujioka S, Sakurai A. Brassinolide is biosynthesized from castasterone in Catharanthus roseus crown gall cells. Agricultural and Biological Chemistry. 1990 Apr 1;54(4):1107-1108.
69. Yokota T, Baba J, Takahashi N. Brassinolide-related Bioactive Sterols in Dolichos lablab: Brassinolide, Castasterone and a NewAnalog, Homodolicholide. Agricultural and Biological Chemistry. 1983;47(6):1409-1411.
70. Yokota T, Baba J, Koba S, Takahashi N. Purification and separation of eight steroidal plant-growth regulators from Dolichos lablab seed. Agricultural and biological chemistry. 1984 Oct 1;48(10):2529-2534.
71. Zhu Z, Zhang Z, Qin G, Tian S. Effects of brassinosteroids on postharvest disease and senescence of jujube fruit in storage. Postharvest Biology and Technology. 2010 Apr 1;56(1):50-55.