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REVIEW PAPER

Practical aspects of brassinosteroids in drought stress protection and its usage in agriculture

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Summary

Brassinosteroids (BRs) represents a new group of phytohormones. They contribute to regulation of plants growth and development, act as regulators of plant processes as seed germination, elongation growth, photomorphogenesis and photosynthesis. They are critical in response to environmental and biotic stresses like: heat, salinity, heavy metal pollution or pathogenic microorganisms. Drought stress occurs during deficiency of water in the plant environment. Lack of water in plant medium highly affects the plant development. It comes to plant processes disorders and abnormal development of plants. Long-term drought stress may cause the death of plant. Drought stress occurs in agriculture. Hence, there is a need to protect plants against its effect. Numerous reports indicate that BRs are beneficial to plants during stress, including drought. In the following research, the role of BRs in plants and usefulness of these growth regulators during stresses, especially drought, was explained. Additionally, the previous use in agriculture was described.

Key words: abiotic stress, agriculture, plant hormones, yield

Słowa kluczowe: stres abiotyczny, rolnictwo, hormony roślinne, plon

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INTRODUCTION

Plant hormones regulate various range of aspects of plant growth, development, and environmental response. It occurs through a diverse array of signal transduction pathways that modulate the expression of abundance of different genes needed for elongation, division and differentiation [1]. BRs are a class of polylactone steroids. Their structure is parallel to animal and insect steroid hormones controlling a broad range of responses in plants like cell division and expansion, xylem differentiation, seed germination apical dominance and vegetative growth [2, 3]. Since the first isolation of BRs in oilseed rape, the group of these growth regulators includes nearly 70 compounds. BRs have been detected or isolated from over 100 plant species, exposing their widespread distribution in the plant kingdom [4]. Discovery of BRs was described as a new perspective on agronomy and horticulture [5, 6]. They are crucial plant hormones that act as wide spectrum of vegetative and generative development, including pollen germination, sex expression, flowering, fruit development, and seed growth, enhancing the yield of plenty of cereals, legumes and plants of horticultural importance. BRs are not long-distance signals, because they are not able to be transported over distances within root and shoot or from an organ to different one in a shoot [7]. They contribute to physiological, biochemical and molecular responses in plants. Hence, they participate in processes like seed germination, vascular differentiation, photosynthesis, enzyme activation and senescence. BRs also protect plants against various range of abiotic and biotic stress factors [8].

Activity of brassinosteroids in plants

BRs profoundly influence cellular dynamics known as plant hormones with a broad spectrum of activities starting with germination and seed development [9, 10]. There are crucial factors of generative development, such as inflorescence and different aspects of plant reproduction, including floral transition to male fertility [11]. BRs and GA are two most important growth regulators that determine plant height by regulating elongation [12]. Light-regulated processes, such as photosynthesis and photomorphogenesis are also controlled by BRs. Apparently, BRs affect the net photosynthetic rate by amending the activity of rubisco and of carbonic anhydrase. Moreover, BRs positively affect photosynthesis during plant stress [7]. Physiological functions of BRs and ABA are known as antagonistic [1]. However, it was also proved that BRs can affect stomatal closure in the same manner as in ABA [13]. Using BRs or their analogues can also affect the yield of crops. Application of BRs analogue (Biobras-16) increased the yield of pepper without any negative effects on their nutritive and organoleptic features [14, 15].

BRs usage as anti-stress defense in plants

It was proved that BRs provide protection against a number of abiotic and biotic types of stress [16], like low and high temperature [17, 18], salinity [19], heavy metal pollution [20], water stresses [21], and pathogens [8]. Dhaubhadel et al. [22] demonstrated that treatment with EBL increased thermostolerance of rapeseed and tomato seedlings. EBL affected the ROS balance by launching the antioxidant enzymes activities, decreased the content of H$_2$O$_2$ and the level of reduced glutathione in tobacco [23]. Janeczko et al. in 2007 reported that treatment with EBL increased carotenoids content in rape [24].

Impact on water stress reduction

Drought is significant factor limiting agricultural productivity and has an adverse effect on global food security [25]. It is defined as condition in which water availability to plants is low and unfavourable for the growth of plants [26]. Drought stress occurs in the environment by various range of factors such as low relative humidity and light intensity by lack of rainfall. Due to no water in soil plants can no longer uptake nutrients and water from the soil [25]. Drought stress affects quality and quantity of yield and may result in the death of plants. It leads to numerous range of physiological and biochemical changes in plants affecting its life cycle and production of reactive oxygen species like: O$_2^\bullet$, OH$^\bullet$, and H$_2$O$_2$. However, it was found that endogenous application of BRs may mitigate water stress effects in plants. Kagale et al. 2007 [3] reported that seedlings of A. thaliana and B. napus treated with EBL survived drought stress in larger number than in untreated ones (tab. 1). EBL affected the expression of drought-responsive genes in both species. EBL treatment in tomato resulted in higher shoot fresh and dry mass, reduced content of MDA and H$_2$O$_2$ and higher proline content. Hence, application of EBL affected the increase of antioxidant enzymes activity [27]. Similarly, EBL treatment alleviated drought stress in tomatoes by number of flower clusters, relative water content and SOD increasing, and hence decreasing of H$_2$O$_2$ [28]. Foliar application of BRs affected significantly plant growth parameters, Ca, P, K and H$_2$O$_2$ content.
in wheat-affected drought stress. Additionally, beneficial effect of combination BRs and BC on higher content of photosynthetic pigments was observed (tab. 1). Application of EBL or EBL + JA reduced water stress, improving photosynthetic and transpiration rate, stomatal conductance and antioxidative defense. Moreover, BR significantly alleviated the drought stress, compared to JA [29]. Soaking seeds in solution of BS mitigated stress consequences in groundnuts [30].

**Brassinosteroids usefulness in agriculture**

BRs are described as environmentally friendly compounds [15, 32]. Thus, they might be used as substitutes of pesticides and fungicides [8]. They are commonly used to promote growth and development of plants and at the same time to decrease plant stress effects. BRs can improve the usage of plant's own detoxification mechanisms to decrease remnants of carbamate, organophosphorus and organochlorine pesticides by 30–70% [15]. However, they demonstrate low stability in field conditions, therefore, its large-scale application is possible only by using more stable and cost-effective BRs analogues [33]. There are over 130 structural and functional analogues which are more stable than BRs, although simultaneously show similar plant growth activities [32, 34]. They are frequently used in enhancing the productivity of a wide range of agricultural and horticultural crops. Nevertheless, Barket (2017) [8] reported that the studies are insufficient, due the breadth of issue and are poorly known so far. There is a large unused potential in BRs utility in crop production. For agricultural purposes, the BR compound (EBL) has been registered since 1992 in Belarus and Russia, and used in commercial production of cereals and crops [35]. Additionally, the economical and practical relevance of BRs was proved in Japan, China and Russia [36].

**Abbreviations:**


**Table 1.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Compound</th>
<th>Dose</th>
<th>Application method</th>
<th>Effect</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Arabidopsis thaliana</em></td>
<td>EBL</td>
<td>1 µM</td>
<td>in vitro</td>
<td>Increasing plant survival (80 and 28% – <em>A. thaliana</em>, 90 and 60% – <em>B. napus</em></td>
<td>[3]</td>
</tr>
<tr>
<td><em>Brassica napus</em></td>
<td>EBL</td>
<td>1 µM</td>
<td>foliar application</td>
<td>Reducing of MDA, H$_2$O$_2$ content, antioxidant enzyme launching</td>
<td>[27]</td>
</tr>
<tr>
<td><em>Lycopersicon esculentum</em> L.</td>
<td>EBL</td>
<td>1 µM</td>
<td>foliar application</td>
<td>Reducing of H$_2$O$_2$ content</td>
<td>[28]</td>
</tr>
<tr>
<td><em>Triticum aestivum</em> L.</td>
<td>EBL</td>
<td>1 and 3 µM</td>
<td>foliar application</td>
<td>Increasing Ca, P and K content, reducing oxidative stress indicators</td>
<td>[31]</td>
</tr>
<tr>
<td><em>Brassica rapa</em></td>
<td>EBL + JA</td>
<td>0.01 µM EBL; 10 µM JA</td>
<td>foliar application</td>
<td>Elevation of oxidative enzymes activity</td>
<td>[29]</td>
</tr>
<tr>
<td><em>Arachis hypogaea</em></td>
<td>BS</td>
<td>1 ppm</td>
<td>seed soaking</td>
<td>Increased activity of oxidative enzymes</td>
<td>[30]</td>
</tr>
<tr>
<td><em>Brassica juncea</em> L.</td>
<td>HBL</td>
<td>0.01 µM</td>
<td>foliar application</td>
<td>Increased growth parameters, photosynthetic rate, activity of oxidative enzymes</td>
<td>[21]</td>
</tr>
</tbody>
</table>

**Ethical approval:** The conducted research is not related to either human or animal use.

**Conflict of interest:** Author declares no conflict of interest.

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