DOI: 10.5586/aa.1777

Publication history
Received: 2019-06-28
Accepted: 2019-07-01
Published: 2019-07-01

Handling editor
Bożena Denisow, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin, Poland

Authors' contributions
BHN and MW equally contributed to writing the text; MH: critical review

Funding
This work did not involve any funds.

Competing interests
BHN and MW are members of the editorial team of *Acta Agrobotanica*; MH served as guest editor of the issue

Citation
Hawrylak-Nowak B, Hasanuzzaman M, Wójcik M. Biostimulation and biofortification of crop plants – new challenges for modern agriculture. Acta Agrobot. 2019;72(2):1777. https://doi.org/10.5586/aa.1777

EDITORIAL

Biostimulation and biofortification of crop plants – new challenges for modern agriculture

Barbara Hawrylak-Nowak[1], Mirza Hasanuzzaman[2], Małgorzata Wójcik[3]*

[1] Department of Botany and Plant Physiology, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland
[2] Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka 1207, Bangladesh
[3] Department of Plant Physiology, Faculty of Biology and Biotechnology, Maria Curie-Skłodowska University in Lublin, Akademicka 19, 20-033 Lublin, Poland

* Corresponding author. Email: mwojcik@poczta.umcs.lublin.pl

In the era of climate change and the rapid increase in food demand for the ever-growing population estimated to exceed 11 billion by the end of the twenty-first century, there is a real problem with provision of the so-called food safety. The extreme climate phenomena and increased anthropopressure exert a negative impact on food production manifested in progressing losses of agricultural land and a decrease in crop yield and quality. As a result, approximately 3 billion people on the globe are affected by malnutrition caused by either an insufficient food supply (acute hunger) or deficit of vitamins and elements in their diet (hidden hunger) [1]. Unfortunately, no universal solution for effective elimination of these problems has been found so far. There are many approaches to manage the adverse effects of climate change and the increasing environmental pollution/degradation in order to ensure sustainable food security. One of them is the so-called "climate-smart agriculture", which involves adjustment of agricultural practices in a way to make agricultural production more resistant to the consequences of climate change and at the same time to reduce the negative impact of agriculture on the environment, including the climate [2].

Plants are the basis of the human diet and feed for livestock. As sessile organisms, plants are exposed to a variety of abiotic and biotic stress factors, resulting, among others, in reduced yield potential, which causes large economic losses and food shortages. Therefore, increasing the tolerance of crop plants to stressful conditions is a prerequisite of satisfying the food demand of the human population. The mechanisms of tolerance to stress factors in plants are highly complex and multifaceted, which impedes development of effective methods for mitigation of the negative stress effects on plant production [3]. Therefore, increasing the resistance of crops to adverse environmental conditions is one of the most important challenges to sustain or enhance crop productivity in currently used agricultural areas and to settle crop vegetation in many regions where cultivation has been very difficult or even impossible so far. This task can be accomplished, e.g., by application of biostimulants and/or various mineral plant nutrition schemes, including nutrition with trace elements that are especially insufficient in the human diet [4].

A biostimulant is defined as any exogenous substance or microorganism, other than a fertilizer, which applied to plants or to the rhizosphere stimulates natural processes to improve plant nutritional efficiency, abiotic/biotic stress tolerance, and/or crop yield and quality [5,6]. There are several categories of biostimulants, including natural substances (e.g., seaweed extracts, humic and fulvic acids, protein hydrolysates, chitosan and other biopolymers, vitamins), synthetic compounds (e.g., synthetic growth regulators, chelating ligands like ethylenediaminetetraacetic acid – EDTA), inorganic compounds (e.g., nonessential but beneficial elements such as Si, Se, Al, Co, Na), and beneficial fungi and plant growth promoting (rhizo)bacteria [5,7]. The effect of application of some of these compounds on plant performance in stressful conditions and on food quality is discussed in this issue of *Acta Agrobotanica*. Many commercial products containing mixtures of such substances and/or microorganisms are available on the market. On the other hand, some biostimulants can simultaneously serve as biofortification factors, improving the bioavailability and uptake of minerals by plants. Biofortification in turn is defined as a process of enriching the nutritional quality of staple crops through (***i***) agronomic practices, such as foliar and soil application of fertilizers, (***ii***) using the best traditional and molecular breeding practices, and (***iii***) modern biotechnology, including genetic modification [8]. The generation of biofortified food crops aims mainly at enhancement of the content of microelements (Fe, Zn, Se, I, Ca, F) and vitamins (vitamin A, C, E, B) that are often deficient in the human diet, particularly in developing countries, causing serious health problems [4,8]. This process requires that agricultural research should make direct linkages with the human health and nutrition sectors. The serious challenge is to get producers and consumers to accept biofortified crop plants and to increase the intake of the target nutrients.

This special issue of *Acta Agrobotanica* is focused on the possibility to combat the problem of deficiencies of various micronutrients in the human diet and to enhance sustainable crop production by biofortification and biostimulation of crop plants as complementary health-beneficial and cost-effective approaches. This fits very well in the challenges posed by "climate-smart agriculture". The results reported here are provided by authors from Australia, Bangladesh, Bulgaria, the Czech Republic, India, Japan, Poland, Ukraine, and the USA representing a range of expertise, including biologists, plant physiologists, agronomists, and horticulturists. The issue contains 13 articles, original research papers and reviews, addressing the following topics: (***i***) enhancement of plant growth and plant stress resistance by biostimulants, (***ii***) biofortification of crop plants with some micronutrients to produce functional food, and (***iii***) improvement of the quality of crops using biofortification and biostimulation.

Studies by Hasanuzzaman et al. from Bangladesh and Al Mahmud et al. from Japan have shown that exogenously applied salicylic acid (SA) and EDTA can increase resistance to Pb and Cd in plants from the Brassicaceae family by enhancement of their antioxidant defense and metal chelation capacity. Moreover, Moumita et al. have shown that exogenously applied gibberellic acid (GA) stimulated the plant antioxidant system thus mitigating the negative impact of drought stress in spring wheat.

Suboptimal temperatures at an early stage of plant development can significantly reduce plant growth and development. Application of biostimulants on seeds before sowing or on young plant seedlings can help to combat this problem. Klimek-Kopyra et al. from Poland tested three different commercially available biostimulants in terms of their effect on germination and seedling growth of seven different cultivars of winter pea (*Pisum sativum* L.) in low temperature (4°C) conditions. The efficiency of the tested biostimulants was rather low; however, some cultivars appeared to be more chilling resistant than others. On the other hand, the Bulgarian research presented by Cholakova-Bimbalova et al. has shown that the use of protein hydrolyzates increased the performance of young maize plants exposed to chilling stress contributing positively to leaf gas exchange, photosynthetic pigment concentration, and some parameters of chlorophyll fluorescence. Although this biostimulant did not affect the plant growth, the authors suggested that, in subsequent optimal thermal conditions, the protein hydrolyzate-treated plants would recover more quickly from the chilling stress than the non-treated plants.

The review article by Malinowski and Belesky from the USA highlights the importance of microorganisms for plant performance in stressful conditions. Special attention has been paid to the association of many cool-season grass species with fungal endophytes from the genus *Epichloë* (Clavicipitaceae). It was demonstrated that the presence of these endophytes crucially increased grass resistance to a plethora of abiotic (drought, mineral imbalance) and biotic (pathogens, nematodes, herbivory, plant competition) stress factors. The latter can be explained by the production of a variety of secondary compounds, for instance ergot and lolitrem alkaloids, which are highly toxic to animals, including humans. Recently, epichloid endophyte strains with no or only limited production of these alkaloids have been selected and introduced into several grass cultivars in order to enhance the host resistance to environmental stresses without hindering grazing livestock. The mechanisms behind the increased stress resistance of such associations as well as the consequences of endophyte infection for the ecosystem are discussed.

Another interesting contribution came from Poland. In her article presenting a switch from crop to ornamental plants, Monder reports on application of biostimulants for improvement of the propagation of two old rose cultivars 'Harison's Yellow' and 'Poppius', which are generally considered difficult to propagate. Two eco-friendly preparations, i.e., plant-based Root Juice and Tytanit, appeared to be quite efficient in rooting of the rhizome/root cuttings. In another paper, Švécarová et al. from the Czech Republic have shown the potential of oryzalin for improvement of chemical flavor components in the commercial hop crop (*Humulus lupulus* L.).

Two review articles provided by authors from Bangladesh deal with a problem of malnutrition and a challenge to reduce it using biofortified staple foodstuff. In Bangladesh and the neighboring countries in South Asia, like India or Pakistan, millions and millions of people experience micronutrient malnutrition. This has been recognized as the major cause of the slowed down progress in human development and the extremely high rate of infant mortality [9]. Therefore, huge effort is devoted there to enhancement of the nutritional quantity and quality. The paper by Das et al. emphasizes various breeding and agronomic approaches to the biofortification of wheat (*Triticum aestivum* L.) grains with Zn. As a result of a conventional breeding program, a new promising Zn-biofortified wheat variety 'BARI Gom 33' was developed by the Bangladesh Wheat and Maize Research Institute with the technical support from the International Maize and Wheat Improvement Centre in Mexico. This wheat variety is especially interesting as it combines a few desirable traits – it not only provides Zn-biofortified grains and 5–8% higher yields than the check wheat varieties in Bangladesh but also exhibits resistance to the deadly wheat blast disease caused by the fungus *Magnaporthe oryzae* pathotype *triticum* (MoT). In a review paper by Hossain et al., the status of malnutrition in Bangladesh is discussed along with the possible health and economic gain from rapid dissemination of the 'BARI Gom 33' wheat variety in this country.

Two other articles show a possibility to enhance the I and Se content in crop plants through application of different forms of these elements on leaves or into growth media. The review article by Krzepiłko et al. describes the effect of various forms of I fertilizers and different ways of application thereof (fertigation, foliar and soil treatment, hydroponics) on I accumulation in plants. It has been concluded that such an approach can increase the concentration of this element to levels corresponding to human nutritional requirements; however, the mode of cultivation and fertilization as well as the chemical form of I should be adapted to a specific species to ensure successful I biofortification. On the other hand, Woch and Hawrylak-Nowak compared Se accumulation and some antioxidative parameters in sprouts of alfalfa (*Medicago sativa* L.), radish (*Raphanus sativus* L. var. *sativus*), and white mustard (*Sinapis alba* L.) treated with different concentrations of selenite (Se^{4+}) or selenate (Se^{6+}). Se supplied as selenite was accumulated more efficiently than selenate and the application of both Se forms resulted in increased accumulation of anthocyanins but had no significant influence on the L-ascorbic acid concentration and free radical scavenging activity.

Finally, the results provided by Mehebub et al. from Bangladesh/the USA have revealed that application of biostimulants is not always connected with improvement of plant growth but may have a positive effect on food quality; thus, the biostimulant can play a role in biofortification. More precisely, the authors sprayed a natural compound chitosan, usually used to prevent postharvest pathogenic diseases, on early fruits and foliage of litchi. Although such treatment did not result in increased the fruit size, the nutritional value of litchi fruit significantly improved due to the augmented concentration of phenolics, flavonoids, and ascorbic acid, which contribute to enhanced antioxidant activity.

In conclusion, it is well established that biostimulation and biofortification are promising, cost-effective, and environmentally friendly strategies for improving the nutritional status of malnourished populations throughout the world. We believe that the papers published in this special issue of *Acta Agrobotanica* substantially contribute to our better understanding of the effects of biostimulants on plant growth and resistance to stress factors as well as the effect of biofortification with some elements essential in the human diet on plant yield and quality. We hope the articles will bring this subject to the attention of a wide range of readers, not just to experts. We take the

opportunity to thank all the authors for their contribution to this special issue. We are also grateful to all the reviewers for their valuable comments and suggestions, which helped to improve the submitted manuscripts.

The guest editor of the issue is Professor Mirza Hasanuzzaman, Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Bangladesh.

References

1. FAO, IFAD, WFP. The state of food insecurity in the world [Internet]. Rome: FAO; 2015 [cited 2019 Jun 28]. Avaliable from: http://www.fao.org/3/a-i4646e.pdf
2. Campbell BM, Thornton P, Zougmoré R, van Asten P, Lipper L. Sustainable intensification: what is its role in climate smart agriculture? Curr Opin Environ Sustain. 2014;8:39–43. https://doi.org/10.1016/j.cosust.2014.07.002
3. Mou B. Improvement of horticultural crops for abiotic stress tolerance: an introduction. HortScience, 2011;46(8):1068–1069. https://doi.org/10.21273/HORTSCI.46.8.1068
4. White PJ, Broadley MR. Biofortification of crops with seven mineral elements often lacking in human diets – iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytol. 2009;182:49–84. https://doi.org/10.1111/j.1469-8137.2008.02738.x
5. du Jardin P. Plant biostimulants: definition, concept, main categories and regulation. Sci Hortic (Amsterdam). 2015;196:3–14. https://doi.org/10.1016/j.scienta.2015.09.021
6. Yakhin OI, Lubyanov AA, Yakhin IA, Brown PH. Biostimulants in plant science: a global perspective. Front Plant Sci. 2017;7:2049. https://doi.org/10.3389/fpls.2016.02049
7. Soppelsa S, Kelderer MC, Casera C, Bassi M, Robatscher P, Andreotti C. Use of biostimulants for organic apple production: effects on tree growth, yield, and fruit quality at harvest and during storage. Front Plant Sci. 2018;9:1342. https://doi.org/10.3389/fpls.2018.01342
8. Nestel P, Bouis HE, Meenakshi JV, Pfeiffer W. Biofortification of staple food crops. J Nutr. 2006;136:1064–1067. https://doi.org/10.1093/jn/136.4.1064
9. Dixit S, Shukla R, Sharma YK. Biofortification of plant nutrients: present scenario. In: Hasanuzzaman M, Fujita M, Oku H, Nahar K, Hawrylak-Nowak B, editors. Plant nutrients and abiotic stress tolerance. Singapore: Springer Nature; 2018. p. 119–136. https://doi.org/10.1007/978-981-10-9044-8_4