11

Egypt. J. Soil. Sci. Vol. **61**, No. 2, pp. 161-173 (2021)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Is Nano-Biofortification the Right Approach for Malnutrition in the Era of COVID-19 and Climate change?

Hassan El-Ramady, Shimaa El-Mahdy, Aya Awad, Safa Nassar, Omima Osman, Eman Metwally, Eman Aly, Eman Fares and Ahmed El-Henawy*

Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh University, 33516 Kafr El-Sheikh, Egypt

Table of contents

HUMAN health may depend on the environment and its compartments, which may include climatic factors. These climatic factors and their changes might impact on human health particularly the outbreak of pandemics like COVID-19. The combined stress resulted from climate changes and COVID-19 could be noticed in several countries especially in the developing countries. Malnutrition is considered one of the most important problems in the developing countries in particular under the droughts, flooding, and other climatic events. Malnutrition was aggravated under COVID-19 outbreak in these countries due to the closure of borders between countries, the crisis of global trade, and the global food insecurity. The biofortification process is the sustainable solution to overcome malnutrition, which included very recently using nano-nutrients as called nano-biofortification. The approach of nano-biofortification is a promising tool in producing biofortified edible plants, otherwise this tool still needs more studies to answer the open questions like which nano-nutrients can be used in nano-biofortification? Which recommended doses and crops are considered suitable candidates?

Keywords: Human health; Nutrient deficiency; SARS-CoV-2; Biofortification; Biofortified crops.

*Corresponding author: aelhenawy@agr.kfs.edu.eg
Authors' Emails:hassan.elramady@agr.kfs.edu.eg; shimaaelmahdy@agr.kfs.edu.eg
aya.awaaadd@gmail.com; nasarsafa2@gmail.com;omimaadel10@gmail.com
emanosman655@gmail.com; emantamy900@gmail.com; fareseman41@gmail.com
DOI: 10.21608/ejss.2021.75653.1445
Received : 8/5/2021 ; Accepted: 17/6/2021

Introduction

It is well known that the humanity is linked to several environmental factors through a very complex web of relationships. Climate change and COVID-19 are considered the most important environmental issues all the over the world (Usman et al. 2021). COVID-19 as the greatest pandemic faced and still facing the humans in the modern history (Nicola et al. 2020), which has been caused disastrous impacts on the entire world (Shen et al. 2020). The novel coronavirus disease has been taking a devastating toll from all over the world. This pandemic and climate change already have been impacted on several sectors in our life such as tourism (Jiricka-Pürrer et al. 2020), agriculture and food security (Rasul, 2021), air travel restrictions (Kallbekken and Sælen, 2021), public health (Pascal et al. 2021), mental health (Marazziti et al. 2021), energy and its management (Chen et al. 2021), human behavior changes (Botzen et al. 2021 and Nakajima et al. 2021), waste respirator processing system (Zhao and You, 2021) and their different strategic management (Rahman et al. 2021). Therefore, a very strong relationship between both climate change and COVID-19 pandemic, and the global food security particularly in developing states (Hickey and Unwin, 2020).

In 2020, planet Earth faced a huge threats or challenges, including extreme snow disasters, floods and droughts, in Europe, North America, and Asia, unprecedented locust-attacks in Africa, and the global COVID-19 pandemic (Jiang et al. 2021). These challenges have had devastating impacts on food security, human health, and the environment (Littlejohn and Finlay, 2021). The human health needs essential nutrients and nutritional compounds and lack of them causes the malnutrition, which means "*nutrient deficiency including shortages of vitamins and minerals*" (Jiang et al. 2021). The malnutrition in the world has been impacted due to the COVID-19 pandemic, which influenced on the insecurity of both foods and its nutrition (Hickey and Unwin, 2020). Over the past few years, many approaches have been adapted to overcome the malnutrition mainly by agronomic biofortification (Silva et al. 2021), conventional breeding (Tiozon et al. 2021), and modern biotechnology (Zheng et al. 2020), which have made great contributions to develop different sustainable agricultural systems (Ashokkumar et al. 2020 and Steinwand & Ronald, 2020). However, "*at least one-third of the world's population suffers from malnutrition, and its eradication remains a tremendous challenge*" as reported by Jiang et al. (2021). Nano-biofortification is a new approach, which has used to produce biofortified crops rich in some micro-nutrients like nano-selenium (El-Ramady et al. 2020a), nano-iron (Guha et al. 2018, 2021), nano-zinc (Dimkpa et al. 2019 and Du et al. 2019), and nano-copper (Lopez-Vargas et al. 2018). Nano-biofortification could be performed by seed priming (De La Torre-Roche et al. 2020), foliar application (Knijnenburg et al. 2018; Shalaby et al. 2021) and soil application (Fakharzadeh et al. 2020).

Therefore, this review discussed the malnutrition and its impacts on human health with suggestion of nano-biofortification as a solution under the global crisis of both COVID-19 and climate change. This work also will focus on the links between COVID-19 and human health. What are the expected environmental impacts of climate change and COVID-19 on human health? Is there any possibility to handle the nano-biofortification as a new approach for malnutrition?

Human health under COVID-19 and climate change

There are several environmental issues that have linked to all our life including the pollution, climate change, electronic wastes, desertification, salinization, sustainability, soil-water-energy nexus, global immigration, wars (global disasters), hunger (malnutrition) and diseases and pandemics (especially COVID-19). It could notice that climate change and COVID-19 have a great concern on the global level as reported by several recent studies, which are linked to the environmental pollution and human health (Marazziti et al. 2021). It is reported that pollution, climate change, and COVID19 may increase the risk of mental disorders as presented in Fig. 1. This pollution is mainly resulted from urban-industrial and many human activities, which deteriorated the natural resources, and producing huge wastes.

Due to the potential of role of climate change and COVID-19 on the human health, many reports have been published to highlight and confirm these interrelationships. Some evidences indicated that strong relationships between pollution, climate change, and COVID-19 pandemic (Marazziti et al. 2021). The variables of climate may impact on the transmission rate of COVID-19 and its outbreak and this needs further investigations (Paraskevis et al. 2021). Both the COVID-19 pandemic and climate change are stock externalities with negative consequences for human health (Fuentes et al. 2020). The terrible impact of both climate change and COVID-19 pandemic on food security and

Fig. 1. Several activities of human could pollute the irrigation canals by throwing wastes, plastics, masks, whereas the not suitable land filling of wastes may cause and enhance the outbreak many diseases especially COVID-19 in Kafr El-Sheikh and Behera Governorates (Photos by the students)

the agriculture has been reported in many regions like in South Asia (Rasul, 2021). In their report, Perkins and his co-authors analyzed the global situation of COVID-19 pandemic under climate change and summarized the following lessons learned: "*the potentiality of reducing fossil fuel consumption and greenhouse gas emissions, the possibility of large-scale change, a case for strong sustainability, the significance of responding late, the limits of rugged individualism, and a (mis) trust in science"* (Perkins et al. 2021). Day by day, more studies are required on the relationship between both climate change and COVID-19 and the effects of this combined stress on the entire environment. Further studies also are urgent in this context such as what is the real impacts of COVID-19 on climate variables? Is COVID-19 an indirect mitigator for changing in climate? What is the expected effectiveness of climate change and COVID-19 pandemic on global food security particularly in developing countries? What are main problems of the combined stress resulted from COVID-19 and climate change on human health? To what extend the global troubles resulted from CIVID-19 will be continued? Is there any sustainable solution for this terrible pandemic in the nearest future?

Biofortification for human health

In general, human needs in his nutrition many mineral nutrients (e.g., Ca, Cu, N, P, K, Fe, Mg, Mn, Se, Zn) and a lot of vitamins such as vitamin A (retinol, retinal), B1 (thiamine), B2 (riboflavin), B3 (niacin, niacinamide), B5 (pantothenic acid), B6 (pyridoxine), B7 (biotin), B9 (folic acid), B 12 (cyanocobalamin), C (ascorbic acid), D (cholecalciferol), E (tocopherols), and K (phylloquinone). The global malnutrition is considered a real problem facing about half of the world's population due to a poor quality in their food intake, which could be overcome by biofortification techniques (Aziz et al. 2019). Biofortification is defined as the process, in which the bioavailable content of essential elements increases in edible portions of crop plants through agronomic fertilization, traditional breeding and genetic selection (Cheah et al. 2020) as well as the nano-biofortification (De La Torre-Roche et al. 2020). The main information about the biofortification process could be presented in Table 1.

The production of biofortified crops enriched in macro- or micro-nutrients has been applied several years ago such as Ca (Pessoa et al. 2021), Cu (Yusefi-Tanha et al. 2020a), I (Budke et al. 2020, 2021), Fe (Coelho et al. 2021; Okwuonu et al. 2021), Mg (Kumssa et al. 2020), Se (Lessa et al. 2020; Hossain et al. 2021; Trippe III and Pilon-Smits 2021), Zn (Okwuonu et al. 2021 and Silva et al. 2021). Using some vitamins (Fitzpatrick and Chapman 2020; Jiang et al. 2020; Tiozon et al. 2021) and other essential compounds like carotenoids (Watkins and Pogson 2020 and Zheng et al. 2020) and folate (Strobbe and Van Der Straeten 2017; De Lepeleire et al. 2018; Viscardi et al. 2020) for human health also have been applied in biofortification strategies. Biofortification has distinguished features as a promising approach including *effective process* in delivering micronutrients in an appreciative impact on human health, *stability* in enriching micronutrient levels, *high yield* which may guarantee high crop productivity, *efficacious* in increasing and improving status of micronutrients in people consuming them, *taste and cooking quality* of biofortified crop should be guaranteed and *accepted by consumers* as a major criteria for process of biofortification (Chandanshive et al. 2020).

Nano-Biofortification as a new approach

As a promising strategy, the biofortification process could improve the mineral nutrient contents in the staple food through the three methods (i.e., agronomic, breeding and genetic approaches). Nano-biofortification is considered one an innovative method, by which metal- or metal oxide-nanoparticles could be used for producing the biofortified crops for human health (Elemike et al. 2019 and Velazquez-Gamboa et al. 2021). The uptake of positive-charge metal-NPs was faster by the roots compared to negative-charge ones, whereas the latter were more efficiently translocated to the aerial parts (Perez de Luque, 2017). Due to their low toxicity, biocompatibility, and ecological nature, the biological or green synthesis of nanoparticles has been of great interest (Velazquez-Gamboa et al. 2021). Selenium is an essential nutrient for human nutrition due to its roles in regulating the metabolism of thyroid hormone, and cell growth as well as antioxidant defense and immune systems (Hu et al. 2021). For fighting against COVID-19, more concerns were paid for supplementary natural treatments (e.g., Se and Zn supplementation) to enhance the immune system and to reduce the viral load in the hosts to COVID-19 infected people (Schiavon et al. 2020; Zhang and Liu 2020). It is worthing to mention that the Zn-requirement of human body ranges from 40 to 50 mg kg^{-1} (Yang et al. 2021) and for selenium about 50-70 microgram Se per day (El-Ramady et al. 2020a). Se-application as nano-form (Se-NPs) as an alternative to conventional Se-fertilizers has been recommended for enriching many crops with organic-Se compounds (Babajani et al. 2019; Juárez-Maldonado et al. 2019) such as groundnut (*Arachis hypogaea* L.), tomato (*Solanum Lycopersicon* L.), pomegranate (*Punica granatum* L.), strawberry (*Fragaria* × *ananassa*), garlic (*Allium sativum* L.), and cucumber (*Cucumis sativus* L.), as reported by Hussein et al. (2019), Morales-Espinoza et al. (2019), Zahedi et al. (2019a, b), Li et al. (2020), Shalaby et al. (2021), respectively (Table 2).

The biosynthesis of Se-NPs and its biofortification remains a great task for scientists and need more investigations. Indeed, the effects of Se-nanoparticles on plants including different Se-NP concentrations and the application mode (like soil, foliar, and seed priming), also are strongly affected by the handling method for the NP-synthesis, which is further responsible for NP specific properties (i.e., the size, and the shape).

Challenges of nano-biofortification

The main challenges that face the nano-biofortification depend on the nano-nutrient and its properties beside its recommended applied dose as well as the essential nutrients for human immunity. In general, there are factors controlling this process related to consumer acceptance and regulatory policies, the palatability of biofortified crops, increasing awareness to the farmers and public *via* television, newspaper, consumer marketing and workshops.

TABLE 1. The main information about the biofortification process

Item and its details	References
Definition	
Biofortification is a process or a food-based strategy that enhances or increases the bioavailability and/or level of nutrients or vitamins in crops to improve human health	Jiang et al. (2020), Tiozon et al. (2021)
Different approaches	
Agronomic biofortification or fertilization	Silva et al. (2021)
Conventional or traditional breeding	Tiozon et al. (2021)
Modern biotechnology or transgenic and gene editing	Zheng et al. (2020)
Nano-biofortification	Guo et al. (2018), De La Torre-Roche et al. (2020)
Targeted crops	
Staple crops	
Wheat (*Triticum aestivum* L.)	Islam et al. (2020); Delaqua et al. (2021)
Rice (*Oryza sativa* L.)	Tiozon et al. (2021)
Maize (*Zea mays* L.)	Cheah et al. (2020)
Cassava (*Manihot esculenta* L.)	Okwuonu et al. (2021)
Sweet potato (*Ipomoea batatas* L.)	Nkhata et al. (2020)
Beans or legumes	Ngigi et al. (2019), Kumar and Pandey (2020)
Common bean (*Phaseolus vulgaris* L.)	Basavaraja et al. (2021)
Cowpea (*Vigna unguiculata* L.)	Coelho et al. (2021), Silva et al. (2021)
Chickpea (*Cicer arietinum* L.)	Pal et al. (2019)
Lentil (*Lens culinaris* Medik)	Rasheed et al. (2020)
Soybean (*Glycine max* L.)	Knijnenburg et al. (2018), Sharma et al. (2019)
Vegetable crops	Buturi et al. (2021)
Carrot (*Daucus carota* L.)	Smoleń et al. (2019)
Garlic (*Allium sativum* L.)	Sohrabi et al. (2020)
Lettuce (*Lactuca sativa* L.)	Puccinelli et al. (2021)
Spinach (*Spinacia oleracea* L.)	Watanabe et al. (2017),
Sweet basil (*Ocimum basilicum* L.)	Puccinelli et al. (2021)
Tomato (*Solanum lycopersicum* L.)	Sabatino et al. (2021)
Fruit crops	
Apple (*Malus domestica* L.)	Budke et al. (2021)
Strawberry (*Fragaria* x *ananassa* L.)	Budke et al. (2020)
Common methods	
Soil application	Fakharzadeh et al. (2020)
Foliar application	Knijnenburg et al. (2018), Shalaby et al. (2021)
Seed or tuber priming	De La Torre-Roche et al. (2020)
Hydroponic systems	Puccinelli et al. (2021)
In vitro system	Hu et al. (2020)
Micro-farm system	El-Ramady et al. (2016)
Targeted nutrients	
Calcium (Ca)	Pessoa et al. (2021)
Copper (Cu)	Yusefi-Tanha et al. (2020a)
Iodine (I)	Budke et al. (2020, 2021)
Iron (Fe)	Coelho et al. (2021), Okwuonu et al. (2021)
Magnesium (Mg)	Kumssa et al. (2020)
Selenium (Se)	Lessa et al. (2020), Hossain et al. (2021)
Zinc (Zn)	Okwuonu et al. (2021), Silva et al. (2021)
Targeted vitamins or carotenoids or folate	
Many vitamins like A, B12, etc.	Jiang et al. (2020), Tiozon et al. (2021)
Carotenoids (tetraterpenoids)	Watkins and Pogson (2020), Zheng et al. (2020)
Folate	De Lepeleire et al. (2018), Viscardi et al. (2020)

TABLE 2. List of some published studies on applied Se-based-NPs biofortification

Targeted plant (scientific name)	Applied nano-dose	Se-forms and preparing method	Growth media, applied method and the country	Reference
Chicory (*Cichorium intybus* L.)	Nano-Se at 4 and 40 mg l^{-1}	Chemical applied Se-NPs (10–45 nm)	Pots contained peat and perlite (1:1) in Iran	Abedi et al. (2021)
Wheat (*Triticum aestivum* L.) cv. Masr1	Se-NPs (50, 75, and 100 mg/m)	Chemical and biological nano-Se (20-80 nm)	Greenhouse, pot experiments, soaked grains in nano-solution in Egypt	El-Saadony et al. (2021)
Bell pepper (*Capsicum annuum* L.), variety Kitrino	Se-NPs at 10 and 50 mg L^{-1}	Chemical applied Se-NPs (2–20 nm)	Greenhouse, gags contained mixture peat and perlite in (1:1) in the USA	González-García et al. (2021)
Coffee (*Coffea arabica* L.) red Itucaí cultivar	Nano-Se at 5000 mg l^{-1}	Selenate 10-160 mg l^{-1}, microbial nano-Se and nano-Se	Foliar application for field experiments in Brazil	Mateus et al. (2021)
Cucumber (*Cucumis sativus* L.)	Nano-Se at 25 mg L^{-1}	Biological applied nano-Se	Foliar application for protected cultivation in Egypt	Shalaby et al. (2021)
Paddy rice (*Oryza sativa* L.)	Se NPs at 25-100 µmol l^{-1} (75 nm)	Chemical applied nano-Se	Foliar application for pot experiment in China	Wang et al. (2021)
Bitter melon (*Momordica charantia* L.)	From 1 to 50 mg L^{-1}	Na_2SeO_4 and chemical Se-NPs (10-45 nm)	*In vitro* experiment in Iran	Rajaee Behbahani et al. (2020)
Strawberry (*Fragaria×ananassa* Duch.)	Se-NPs and Se /SiO_2-NPs (50 and 100 mg l^{-1})	Chemical Se-NPs (25 mg L^{-1}, 60 nm)	Greenhouse, pots filled with mixture of ratio (1:1:2) sand: animal manure: topsoil in Iran	Zahedi et al. (2020)
Tomato (*S. lycopersicum* L.), saladette "El Cid F1	Se-NPs from 10 to 20 mg L^{-1}	Chemical Se-NPs (2 – 20 nm)	Greenhouse, bags filled with peat moss and perlite (1:1) in Mexico	Hernández-Hernández et al. (2019)
Tomato (*S. lycopersicum* L.), saladette El Cid F1	Se-NPs from 10 to 20 mg L^{-1}	Chemical Se-NPs (2 – 20 nm)	Greenhouse, bags filled with peat moss and perlite (1:1) in Mexico	Quiterio-Gutiérrez et al. (2019)
Groundnut (*Arachis hypogaea* L.)	Se-NPs at 20 and 40 mg l^{-1}	Chemical Se-NPs (10 – 30 nm)	Foliar application on pot experiment in Egypt	Hussein et al. (2019)
Tomato (*S. lycopersicum* L.), saladette El Cid F1	Se-NPs from 5 to 20 mg L^{-1}	Chemical Se-NPs (2 – 20 nm)	Greenhouse, bags filled with peat moss and perlite (1:1) in Mexico	Morales-Espinoza et al. (2019)
Pomegranate: *Punica granatum* L. cv. Malase Saveh	Se-NPs using 5 L per tree at 1 or 2 µM	Na_2SeO_4 and chemical Se-NPs (10–45 nm)	Orchard experiment, foliar field trial in Iran	Zahedi et al. (2019a)
Strawberry (*Fragaria ananassa* Duch.) cv. Kurdistan	Se-NPs at 10 and 20 mg L^{-1}	Chemical Se-NPs (10–45 nm)	Pots filled with perlite, coco peat and sand (5:7:23) as foliar applied in Iran	Zahedi et al. (2019b)

Using the nano-biofortification needs to be very clear concerning the optimum doses of used nano-nutrients, which may become emerging pollutants under over-dose. Therefore, there are an urgent need for studying the release of nano-nutrients and their fate in the environment, which will be applied in the biofortification program especially their impacts on their potential toxicity and public safety (Schiavon et al. 2020). Hence, further studies should be systematically addressed the risk assessment and its management of nano-nutrients when applied to agricultural purposes to avoid any unpredictable health hazard from their occurrence in the environment. It should be also stressed on the nano-nutrients, which could be involved in our struggle against COVID-19 through promoting the human immunity like Se and Zn. This approach could be achieved by two ways the first through biofortified crops using nano-nutrients or through using these nano-nutrients in pharmaceutical applications to increase the bioavailability of these nutrients in drugs or targeting therapeutic agents to specific organs.

Conclusions

The main results of COVID-19 pandemic have been involved several restrictions in transport or travel or trade, the physical distance lockdown, terrible global closure in borders, food stalls, food processing industries, and borders. The changing in climate may include rising in temperatures, changing in precipitation patterns, extreme weather events, flooding, droughts, extreme heat stress, and sea level rise. Based on the suffering of the world from climate change and COVID-19, it is well mentioned that "*COVID-19 pandemic has also indicated the importance of focusing on another global crisis, i.e., climate change. What can one natural crisis teach us about another crisis? The surprising COVID-19 epidemic has demonstrated how the problems of the human race are linked with each other*". Due to the massive destruction of COVID-19 in human health terms, the WHO already has declared medical emergencies around the globe. The relationship between climate change and COVID-19 has gain great concerns by scientists to clarify this combined stress from both perspectives, i.e., the impact of COVID-19 on climate change and vice versa. The malnutrition may be caused a serious problem in human immunity, which its turn lead to the infection by COVID-19. To overcome the malnutrition problem, different approaches of biofortifications have been applied recently particularly nano-biofortification. The using of nano-nutrients in enriching cultivated crops has a promising progress like nano-Se, nano-Cu, nano-Fe and others. This new approach has still many open questions such as to which extend can we depend on nano-nutrients in nano-biofortification process? Is nano-biofortification is available method for all desirable crops for human nutrition? Which limitations should be considered for nano-biofortification? When the nano-biofortification is considered a global strategy for fighting the malnutrition?

Ethics approval and consent to participate:

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

All authors declare their consent for publication.

Contribution of authors

This study was designed and implemented by authors, where all authors contributed in writing the manuscript, interpreting information presented and have read and agreed to the version of the manuscript.

Funding

This research received no external funding.

Conflicts of Interest

The author declares no conflict of interest.

Acknowledgements

This work was achieved during the Graduation Project for the fourth level, Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh University during the 2020/2021.

References

Abedi S, Iranbakhsh A, Ardebili ZO, Ebadi M (2021) Nitric oxide and selenium nanoparticles confer changes in growth, metabolism, antioxidant machinery, gene expression, and flowering in chicory (*Cichorium intybus* L.): potential benefits and risk assessment. *Environmental Science and Pollution Research* **28**, 3136–3148. https://doi.org/10.1007/s11356-020-10706-2 .

Ashokkumar K, Govindaraj M, Karthikeyan A, Shobhana VG, Warkentin TD (2020) Genomics-integrated breeding for carotenoids and folates in staple cereal grains to reduce malnutrition. *Front Genet.* **11**, 414.

Aziz MZ, Yaseen M, Abbas T, Naveed M, Mustafa A, Hamid Y, Saeed Q, Ming-Gang X (2019) Foliar application of micronutrients enhances crop stand, yield and the biofortification essential for human health of different wheat cultivars. J*ournal of Integrative Agriculture* 2019, **18**(6), 1369-1378. doi: 10.1016/S2095-3119(18)62095-7.

Bărbieru OG, Dimitriu L, Călin M, Raut I, Constantinescu Aruxandei D, Oancea F (2019) Plant biostimulants based on selenium nanoparticles biosynthesized by Trichoderma strains. Proceedings **29**(1), 95. https://doi.org/10.3390 /proceedings2019029095.

Basavaraja T, Satheesh Naik SJ, Rahul Chandora, Mohar Singh, and NP Singh (2021) Breeding for Enhanced Nutrition in Common Bean. In: D. S. Gupta et al. (eds.), Breeding for Enhanced Nutrition and Bio-Active Compounds in Food Legumes, https://doi.org/10.1007/978-3-030-59215-8_8, pp: 181-209. Springer Nature Switzerland AG.

Botzen W, Duijndam S, van Beukering P (2021) Lessons for climate policy from behavioral biases towards COVID-19 and climate change risks. World Development **137**, 105214. https://doi.org/10.1016/j.worlddev.2020.105214.

Budke C, Dierend W, Schön H-G, Hora K, Mühling KH, Daum D (2021) Iodine Biofortification of Apples and Pears in an Orchard Using Foliar Sprays of Different Composition. Front. *Plant Sci.* 12:638671. doi: 10.3389/fpls.2021.638671.

Budke C, Straten ST, Mühling KH, Broll G, Daum D (2020) Iodine biofortification of field-grown strawberries – Approaches and their limitations. Scientia Horticulturae **269**, 109317. https://doi.org/10.1016/j.scienta.2020.109317.

Buturi CV, Mauro RP, Fogliano V, Leonardi C, Giuffrida F (2021) Mineral Biofortification of Vegetables as a Tool to Improve Human Diet. *Foods*, **10**, 223. https://doi.org/10.3390/foods10020223.

Chandanshive S, Shaikh Y, Raturi G, Sathe AP, Sanand S, Nadaf A (2020) Biofortification for Nutrient Content and Aroma Enrichment in Rice (*Oryza sativa* L.). In: T. R. Sharma et al. (eds.), Advances in Agri-Food Biotechnology, https://doi.org/10.1007/978-981-15-2874-3_3, pp: 57- 84. Springer Nature Singapore Pte Ltd.

Cheah ZX, O'Hare TJ, Harper SM, Kochanek J, Bell MJ (2020) Zinc biofortification of immature maize and sweetcorn (*Zea mays* L.) kernels for human health. Scientia Horticulturae 272, 109559. https://doi.org/10.1016/j.scienta.2020.109559.

Chen C, Nelson H, Xu X, Bonilla G, Jones N (2021) Beyond technology adoption: Examining home energy management systems, energy burdens and climate change perceptions during COVID-19 pandemic. *Renewable and Sustainable Energy Reviews* **145**, 111066. https://doi.org/10.1016/j.rser.2021.111066.

Coelho RC, Barsotti RCF, Maltez HF, Júnior CAL, Barbosa HS (2021) Expanding information on the bioaccessibility and bioavailability of iron and zinc in biofortified cowpea seeds. *Food Chemistry* **347**, 129027. https://doi.org/10.1016/j.foodchem.2021.129027.

De La Torre-Roche R, Cantu J, Tamez C, Zuverza-Mena N, Hamdi H, Adisa IO, Elmer W, Gardea-Torresdey J, White JC (2020) Seed Biofortification by Engineered Nanomaterials: A Pathway to Alleviate Malnutrition? *J. Agric. Food Chem.* **68**, 12189-12202.

De Lepeleire J, Strobbe S, Verstraete J, Blancquaert D, Ambach L, Visser RGF, Stove C, Van Der Straeten D (2018) Folate Biofortification of Potato by Tuber-Specific Expression of Four Folate Biosynthesis Genes. *Molecular Plant* **11**, 175-188.

Delaqua D, Carnier R, Berton RS, Corbi FCA, Coscione AR (2021) Increase of selenium concentration in wheat grains through foliar application of sodium selenate. *Journal of Food Composition and Analysis* **99**, 103886. https://doi.org/10.1016/j.jfca.2021.103886.

Dimkpa CO, Singh U, Bindraban PS, Elmer WH, Gardea-Torresdey JL, White JC (2019) Zinc oxide nanoparticles alleviate drought-induced alterations in sorghum performance, *nutrient acquisition, and grain fortification. Sci. Total Environ.* **688**, 926-934.

Du W, Yang J, Peng Q, Liang X, Mao H (2019) Comparison study of zinc nanoparticles and zinc sulphate on wheat growth: From toxicity and zinc biofortification. *Chemosphere* **227**, 109e116. https://doi.org/10.1016/j.chemosphere.2019.03.168.

Elemike EE, Uzoh IM, Onwudiwe DC, Babalola OO (2019) The role of nanotechnology in the fortification of plant nutrients and improvement of crop production. *Applied Sciences* **9** (3), 499.

El-Ramady H, Alshaal T, Abdalla N, Prokisch J, Sztrik A, Fári M, Domokos-Szabolcsy É (2016) Selenium and nano-selenium biofortified sprouts using micro-farm systems. Global Advances in Selenium Research from Theory to Application – Bañuelos et al (Eds.). Taylor & Francis Group, DOI: 10.13140/RG.2.1.1065.9925.

El-Ramady H, Brevik EC, Amer M, Elsakhawy T, Omara AE-D, Elbasiouny H, Elbehiry F, Mosa AA, El-Ghamry AM, Bayoumi Y, Shalaby TA (2020c). Soil and Air Pollution in the Era of COVID-19: A Global Issue. *Egypt. J. Soil. Sci.* **60** (4), 437 – 448. DOI: 10.21608/ejss.2020.49996.1411.

El-Ramady H, Eid Y, Brevik EC (2020b) New Pollution Challenges in Groundwater and Wastewater Due to COVID-19. *J. Sus. Agric. Sci.* **46** (4), 61 – 73. DOI: 10.21608/jsas.2020.51353.1257.

El-Ramady H, Faizy SE-D, Abdalla N, Taha H, Domokos-Szabolcsy É, Fari M, Elsakhawy T, Omara AE-D, Shalaby T, Bayoumi Y, Shehata S, Geilfus C-M, Brevik EC (2020a) Selenium and Nano-Selenium Biofortification for Human Health: Opportunities and Challenges. *Soil Syst.,* **4**, 57. doi:10.3390/soilsystems 4030057.

El-Ramady H, Singh A, Rajput VD, Amer M, Omara AE-D, Elsakhawy T, Elbehiry F, Elbasiouny H, Abdalla N (2021) Environment, Biodiversity and Soil Security: A New Dimension in the Era of COVID-19. *Env. Biodiv. Soil Security,* 5, 1-14. DOI: 10.21608/jenvbs. 2021.55669.1125.

El-Saadony MT, Saad AM, Najjar AA, Alzahrani SO, Alkhatib FM, Shafi ME, Selem E, Desoky EM, Fouda SEE, El-Tahan AM, Hassan MAA (2021) The use of biological selenium nanoparticles to suppress *Triticum aestivum* L. crown and root rot diseases induced by Fusarium species and improve yield under drought and heat stress.

Fakharzadeh S, Hafizi M, Baghaei MA, Etesami M, Khayamzadeh M, Kalanaky S, Akbari ME, Nazaran MH (2020) Using Nanochelating Technology for Biofortification and Yield Increase in Rice. *Sci Rep.* 2020, 10: 4351. doi: 10.1038/s41598-020-60189-x.

Fitzpatrick TB, Chapman LM (2020) The importance of thiamine (vitamin B1) in plant health: From crop yield to biofortification. *J. Biol. Chem.* **295** (34), 12002–12013. DOI 10.1074/jbc.REV120.010918.

Fuentes R, Galeotti M, Lanza A, Manzano B (2020) COVID-19 and Climate Change: A Tale of Two Global Problems. *Sustainability,* **12**, 8560,doi:10.3390/su12208560.

González-García Y, Cárdenas-Álvarez C, Cadenas-Pliego G, Benavides-Mendoza A, Cabrera-de-la-Fuente M, Sandoval-Rangel A, Valdés-Reyna J, Juárez-Maldonado A (2021) Effect of Three Nanoparticles (Se, Si and Cu) on the Bioactive Compounds of Bell Pepper Fruits under Saline Stress. *Plants (Basel)* **10** (2), 217. doi: 10.3390/plants10020217.

Guha T, Mukherjee A, Kundu R (2021) NanoScale Zero Valent Iron (nZVI) Priming Enhances Yield, Alters Mineral Distribution and Grain Nutrient Content of *Oryza sativa* L. cv. Gobindobhog: A Field Study. *Journal of Plant Growth Regulation,* https://doi.org/10.1007/s00344-021-10335-0.

Guha T, Ravikumar KV, Mukherjee A, Kundu R (2018) Nanopriming with zero valent iron (nZVI) enhances germination and growth in aromatic rice cultivar (*Oryza sativa* cv. Gobindabhog L.). *Plant Physiol Biochem.* 127:403-413. https://doi.org/10.1016/j.plaph y.2018.04.014.

Guo H, White JC, Wang Z, Xing B (2018) Nano-enabled fertilizers to control the release and use efficiency of nutrients. *Current Opinion in Environmental Science & Health*, **6**:77-83. https://doi.org/10.1016/j.coesh.2018.07.009.

He L, Zhao J, Wang L, Liu Q, Fand Y, Li B, Yu Y-L, Chen C, Li Y-F (2021) Using nano-selenium to combat Coronavirus Disease 2019 (COVID-19)? *Nano Today* **36**, 101037. https://doi.org/10.1016/j.nantod.2020.101037.

Hernández-Hernández H, Quiterio-Gutiérrez T, Cadenas-Pliego G, Ortega-Ortiz H, Hernández-Fuentes AD, de la Fuente MC, Valdés-Reyna J, Juárez-Maldonado A (2019) Impact of selenium and copper nanoparticles on yield, antioxidant system, and fruit quality of tomato plants. *Plants,* **8**, 355.

Hickey GM, Unwin N (2020) Addressing the triple burden of malnutrition in the time of COVID-19 and climate change in Small Island Developing States: what role for improved local food production? *Food Security* 12, 831-835. https://doi.org/10.1007/s12571-020-01066-3.

Hossain A, Skalicky M, Brestic M, Maitra S, Sarkar S, Ahmad Z, Vemuri H, Garai S, Mondal M, Bhatt R, Kumar P, Banerjee P, Saha S, Islam T, Laing AM (2021) Selenium Biofortification: Roles, Mechanisms, *Responses and Prospects. Molecules.* **26** (4), 881. doi: 10.3390/molecules26040881.

Hu T, Hui G, Li H, Guo Y (2020) Selenium biofortification in *Hericium erinaceus* (Lion's Mane mushroom) and its in vitro bioaccessibility. *Food Chemistry* **331**, 127287. https://doi.org/10.1016/j.foodchem.2020.127287.

Hu T, Li H, Zhao G, Guo Y (2021) Selenium enriched *Hypsizygus marmoreus*, a potential food supplement with improved Se bioavailability. LWT **140**, 110819. https://doi.org/10.1016/j.lwt.2020.110819

Hussein HA, Darwesh OM, Mekki BB, El-Hallouty SM (2019) *Evaluation of cytotoxicity*, biochemical profile and yield components of groundnut plants treated with nano-selenium. *Biotech Rep* **24**, e00377. https://doi.org/10.1016/j.btre.2019.e00377.

Islam MZ, Park B-J, Kang H-M, Lee Y-T (2020) Influence of selenium biofortification on the bioactive compounds and antioxidant activity of wheat microgreen extract. *Food Chemistry* **309**, 125763. https://doi.org/10.1016/j.foodchem. 2019. 125763.

Jiang L, Strobbe S, Van Der Straeten D, Zhang C (2021) Regulation of Plant Vitamin Metabolism: Backbone of Biofortification for the Alleviation of Hidden Hunger. *Mol. Plant,* 14, 40-60. https://doi.org/10.1016/j.molp.2020.11.019.

Jiricka-Pürrer A, Brandenburg C, Probstl-Haider U (2020) City tourism pre- and post-covid-19 pandemic – Messages to take home for climate change adaptation and mitigation? *Journal of Outdoor Recreation and Tourism* **31**, 100329. https://doi.org/10.1016/j.jort.2020.100329.

Juárez-Maldonado A, Ortega-Ortíz H, Morales-Díaz AB, González-Morales S, Morelos-Moreno Á, Cabrera-De la Fuente M, Sandoval-Rangel A, Cadenas-Pliego G, Benavides-Mendoza A (2019) Nanoparticles and nanomaterials as plant biostimulants. *Int J Mol Sci.* **20** (1), 162. https://doi.org/10.3390/ijms20010162.

Kallbekken S, Sælen H (2021) Public support for air travel restrictions to address COVID-19 or climate change. Transportation Research Part D 93, 102767. https://doi.org/10.1016/j.trd.2021.102767.

Khanna K, Kohli SK, Kaur R, Bhardwaj A, Bhardwaj V, Ohri P, Sharma A, Ahmad A, Bhardwaj A, Ahmad P (2020) Herbal immune-boosters: Substantial warriors of pandemic Covid-19 battle. *Phytomedicine*, https://doi.org/10.1016/j.phymed.2020.153361.

Knijnenburg JTN, Hilty FM, Oelofse J, Buitendag R, Zimmermann MB, Cakmak I, Grobler AF (2018) Nano- and Pheroid technologies for development of foliar iron fertilizers and iron biofortification of soybean grown in South Africa. *Chem. Biol. Technol. Agric.* **5**, 26 https://doi.org/10.1186/s40538-018-0138-8.

Kumar S, Pandey G (2020) Biofortification of pulses and legumes to enhance nutrition. Heliyon 6 (2020) e03682.https://doi.org/10.1016/j.heliyon.2020.e03682.

Kumssa DB, Lovatt JA, Graham NS, Palmer S, Hayden R, Wilson L, Young SD, Lark RM, Penrose B, Ander EL, Thompson R, Jiang L-X, Broadley MR (2020) Magnesium biofortification of Italian ryegrass (*Lolium multiflorum* L.) via agronomy and breeding as a potential way to reduce grass tetany in grazing ruminants. *Plant Soil,* 457, 25-41. https://doi.org/10.1007/s11104-019-04337-x.

Landa P (2021) Positive effects of metallic nanoparticles on plants: Overview of involved mechanisms. *Plant Physiology and Biochemistry,* **161**, 12–24. https://doi.org/10.1016/j.plaphy.2021.01.039.

Lessa JHL, Raymundo JF, Corguinha APB, Martins FAD, Araujo AM, Santiago FEM, de Carvalho HWP, Guilherme LRG, Lopes G (2020) Strategies for applying selenium for biofortification of rice in tropical soils and their effect on element accumulation and distribution in grains. *Journal of Cereal Science,* **96**, 103125. https://doi.org/10.1016/j.jcs.2020.103125.

Li Y, Zhu N, Liang X, Zheng L, Zhang C, Li YF, Zhang Z, Gao Y, Zhao J (2020) A comparative study on the accumulation, translocation and transformation of selenite, selenate, and SeNPs in a hydroponic-plant system. *Ecotoxicol Environ Saf.* **189**, 109955. https://doi.org/10.1016/j. ecoenv.2019.109955.

Littlejohn P, Finlay BB (2021) When a pandemic and an epidemic collide: COVID-19, gut microbiota, and the double burden of malnutrition. BMC *Medicine* **19**, 31. https://doi.org/10.1186/s12916-021-01910-z.

Lopez-Vargas ER, Ortega-ortiz H, Cadenas-pliego G, De-Alba-Romenus K, Cabrera-De-La-Fuente M, Benavides-Mendoza A, Juarez-Maldonado A (2018). Foliar Application of Copper Nanoparticles Increases the Fruit Quality and the Content of Bioactive Compounds in Tomatoes. *Appl. Sci.* **8**, 20.

Marazziti D, Cianconi P, Mucci F, Foresi L, Chiarantini I, Vecchia AD (2021) Climate change, environment pollution, COVID-19 pandemic and mental health. *Science of the Total Environment* **773**, 145182. https://doi.org/10.1016/j.scitotenv. 2021.145182.

Mateus MPB, Tavanti RFR, Tavanti TR, Santos EF, Jalal A, dos Reis AR (2021) Selenium biofortification enhances ROS scavenge system increasing yield of coffee plants. *Ecotoxicology and Environmental Safety* **209**, 111772. https://doi.org/10.1016/j.ecoenv.2020.111772.

Morales-Espinoza MC, Cadenas-Pliego G, Pérez-Alvarez M, Hernández-Fuentes AD, Cabrera de la

Fuente M, Benavides-Mendoza A, Valdés-Reyna J, Juárez-Maldonado A (2019) Se nanoparticles induce changes in the growth, antioxidant responses, and fruit quality of tomato developed under NaCl Stress. *Molecules,* **24** (17). https://doi.org/10.3390 /molecules24173030.

Nakajima K, Takane Y, Kikegawa Y, Furuta Y, Takamatsu H (2021) Human behavior change and its impact on urban climate: Restrictions with the G20 Osaka Summit and COVID-19 outbreak. *Urban Climate,* **35**, 100728. https://doi.org/10.1016/j.uclim.2020.100728.

Ngigi PB, Lachat C, Masinde PW, Laing GD (2019) Agronomic biofortification of maize and beans in Kenya through selenium fertilization. *Environ Geochem Health* **41**, 2577–2591. https://doi.org/10.1007/s10653-019-00309-3(0123456789().,-volV).

Nicola M, Alsafi Z, Sohrabi C, Kerwan A, Al-Jabir A, Iosifidis C et al (2020) The socio-economic implications of the coronavirus pandemic (COVID-19): a review. *International Journal of Surgery* (London, England) **78**, 185. https://doi.org/10.1016/j.ijsu.2020.04.018.

Nkhata SG, Chilungo S, Memba A, Mponela P (2020) Biofortification of maize and sweetpotatoes with provitamin A carotenoids and implication on eradicating vitamin A deficiency in developing countries. *Journal of Agriculture and Food Research,* **2**, 100068. https://doi.org/10.1016/j.jafr.2020.100068.

Okwuonu IC, Narayanan NN, Egesi CN, Taylor NJ (2021) Opportunities and challenges for biofortification of cassava to address iron and zinc deficiency in Nigeria. *Global Food Security,* **28**, 100478. https://doi.org/10.1016/j.gfs.2020.100478.

Pal V, Singh G, Dhaliwal SS (2019) Agronomic biofortification of chickpea with zinc and iron through application of zinc and urea. *Communications in Soil Science and Plant Analysis,* **50**, 15, 1864-1877. DOI: 10.1080/00103624.2019.1648490.

Paraskevis D, Kostaki EG, Alygizakis N, Thomaidis NS, Cartalis C, Tsiodras S, Dimopoulos MA (2021) A review of the impact of weather and climate variables to COVID-19: In the absence of public health measures high temperatures cannot probably mitigate outbreaks. S*cience of the Total Environment* **768**, 144578. https://doi.org/10.1016/j.scitotenv.2020.144578.

Pascal M, Lagarrigue R, Laaidi K, Boulanger G, Denys S. (2021) Have health inequities, the COVID-19 pandemic and climate change led to the deadliest heatwave in France since 2003? *Public Health* **194**, 143-145. https://doi.org/10.1016/j.puhe.2021.02.012.

Perez de Luque A (2017) Interaction of nanomaterials with plants: What do we need for real applications in agriculture? *Frontiers in Environmental Science,* 5: 12.

Perkins KM, Munguia N, Ellenbecker M, Moure-Eraso R, Velazquez L (2021) COVID-19 pandemic lessons to facilitate future engagement in the global climate crisis. *Journal of Cleaner Production,* **290**, 125178. https://doi.org/10.1016/j.jclepro.2020.125178.

Pessoa CC, Lidon FC, Coelho ARF, Caleiro JC, Marques AC, Luís IC, Kullberg JC, Legoinha P, Brito MG, Ramalho JC, Guerra MAM, et al. (2021) Calcium biofortification of Rocha pears, tissues accumulation and physicochemical implications in fresh and heat-treated fruits. *Scientia Horticulturae* **277**, 109834. https://doi.org/10.1016/j. scienta. 2020. 109834

Puccinelli M, Landi M, Maggini R, Pardossi A, Incrocci L. (2021) Iodine biofortification of sweet basil and lettuce grown in two hydroponic systems. *Scientia Horticulturae* **276**, 109783. https://doi.org/10.1016/j.scienta.2020.109783.

Quiterio-Gutiérrez T, Ortega-Ortiz H, Cadenas-Pliego G, Hernández-Fuentes AD, Sandoval-Rangel A, Benavides-Mendoza A, la Fuente M, Juárez-Maldonado A (2019) The application of selenium and copper nanoparticles modifies the biochemical responses of tomato plants under stress by *Alternaria solani*. *Int. J. Mol. Sci.* **20**, 1950.

Rahman MM, Bodrud-Doza M, Shammi M, Islam ARMT, Khan ASM (2021) COVID-19 pandemic, dengue epidemic, and climate change vulnerability in Bangladesh: Scenario assessment for strategic management and policy implications. *Environmental Research,* **192**, 110303. https://doi.org/10.1016/j.envres.2020.110303.

Rajaee Behbahani S, Iranbakhsh A, Ebadi M, Majd A, Ardebili ZO (2020) Red elemental selenium nanoparticles mediated substantial variations in growth, tissue differentiation, metabolism, gene transcription, epigenetic cytosine DNA methylation, and callogenesis in bitter melon (*Momordica charantia*); an *in vitro* experiment. *PLoS ONE* **15** (7), e0235556. https://doi.org/10.1371/journal.pone.0235556.

Rasheed N, Maqsood MA, Aziz T, Jabbar A (2020) Characterizing Lentil Germplasm for Zinc

Biofortification and High Grain Output. *Journal of Soil Science and Plant Nutrition,* **20**, 1336–1349. https://doi.org/10.1007/s42729-020-00216-y .

Rasul G (2021) Twin challenges of COVID-19 pandemic and climate change for agriculture and food security in South Asia. E*nvironmental Challenges,* **2,** 100027. https://doi.org/10.1016/j.envc.2021.100027.

Sabatino L, La Bella S, Ntatsi G, Iapichino G, D'Anna F, De Pasquale C, Consentino BBC, Rouphael Y (2021) Selenium biofortification and grafting modulate plant performance and functional features of cherry tomato grown in a soilless system. *Scientia Horticulturae* **285**, 110095. https://doi.org/10.1016/j.scienta. 2021.110095.

Schiavon M, Nardi S, dalla Vecchia F, Ertani A (2020) Selenium biofortification in the 21st century: status and challenges for healthy human nutrition. *Plant Soil*, **453**, 245-270. https://doi.org/10.1007/s11104-020-04635-9.

Shalaby TA, Abd-Alkarim E, El-Aidy F, Hamed E, Sharaf-Eldin M, Taha N, El-Ramady H, Bayoumi Y, dos Reis AR (2021) Nano-selenium, silicon and H_2O_2 boost growth and productivity of cucumber under combined salinity and heat stress. *Ecotoxicology and Environmental Safety,* **212**, 111962. https://doi.org/10.1016/j.ecoenv.2021.111962.

Sharma S, Malhotra H, Borah P, Meena MK, Bindraban P, Chandra S, Pande V, Pandey R (2019) Foliar application of organic and inorganic iron formulation induces differential detoxification response to improve growth and biofortification in soybean. *Plant Physiol. Rep.* **24** (1), 119-128. https://doi.org/10.1007/s40502-018-0412-6.

Shen W, Yang C, Gao L (2020) Address business crisis caused by COVID-19 with collaborative intelligent manufacturing technologies. IET Collaborative Intelligent Manufacturing **2**(2), 96–99. https://doi.org/10.1049/iet-cim.2020.0041.

Silva VM, Nardeli AJ, Mendes NA, Rocha MM, Wilson L, Young SD, Broadley MR, White PJ, dos Reis AR (2021) Agronomic biofortification of cowpea with zinc: Variation in primary metabolism responses and grain nutritional quality among 29 diverse genotypes. *Plant Physiology and Biochemistry,* **162**, 378-387. https://doi.org/10.1016/j. plaphy. 2021.02.020.

Smole□ S, Baranski R, Ledwo□yw-Smoleń I, Skoczylas Ł, Sady W (2019) Combined biofortification of carrot with iodine and selenium. *Food Chemistry* 300, 125202. https://doi.org/10.1016/j.

foodche.125202.

Sohrabi M, Mehrjerdi MZ, Karimi S, Tavallali V (2020) Using gypsum and selenium foliar application for mineral biofortification and improving the bioactive compounds of garlic ecotypes. *Industrial Crops & Products* **154**, 112742. https://doi.org/10.1016/j.indcrop.2020.112742.

Steinwand MA, Ronald PC (2020) Crop biotechnology and the future of food. *Nat. Food,* 1, 273-283.

Strobbe S, Van Der Straeten D (2017) Folate biofortification in food crops. *Current Opinion in Biotechnology*, **44**, 202-211.

Tiozon RN, Fernie AR, Sreenivasulu N (2021) Meeting human dietary vitamin requirements in the staple rice via strategies of biofortification and post-harvest fortification. *Trends in Food Science & Technology,* **109**, 65-82. https://doi.org/10.1016/j.tifs.2021.01.023.

Trippe III RC, Pilon-Smits EAH (2021) Selenium transport and metabolism in plants: Phytoremediation and biofortification implications. *Journal of Hazardous Materials,* **404**, 124178. https://doi.org/10.1016/j.jhazmat.2020.124178.

Usman M, Husnain M, Riaz A, Riaz A, Ali Y (2021) Climate change during the COVID-19 outbreak: scoping future perspectives. *Environmental Science and Pollution Research,* https://doi.org/10.1007/s11356-021-14088-x.

Vahedifard F, Chakravarthy K (2021) Nanomedicine for COVID-19: the role of nanotechnology in the treatment and diagnosis of COVID-19. Emergent Mater. 1-25. doi: 10.1007/s42247-021-00168-8.

Velazquez-Gamboa MC, Rodrıguez-Hernandez L, Abud-Archila M, Gutierrez-Miceli FA, Gonzalez-Mendoza D, Valdez-Salas B, GonzalezTerreros E, Lujan-Hidalgo MC (2021) Agronomic Biofortification of *Stevia rebaudiana* with Zinc Oxide (ZnO) Phytonanoparticles and Antioxidant Compounds. *Sugar Tech.* **23** (2), 453-460. https://doi.org/10.1007/s12355-020-00897-w.

Viscardi S, Marileo L, Barra PV, Paola Duran P, Inostroza-Blancheteau C (2020) From farm to fork: it could be the case of Lactic Acid Bacteria in the stimulation of folates biofortification in food crops. *Current Opinion in Food Science,* 2020, **34**, 1–8. https://doi.org/10.1016/j.cofs.2020.08.002.

Wang C, Cheng T, Liu H, Zhou F, Zhang J, Zhang M, Liu X, Shi W, Cao T (2021) Nano-selenium controlled cadmium accumulation and improved photosynthesis in indica rice cultivated in lead and cadmium combined paddy soils. *Journal of Environmental Sciences* **103**, 336–346. https://doi.org/10.1016/j.jes.2020.11.005.

Wang C, Rong H, Zhang X, Shi W, Hong X, Liu W, Cao T, Yu X, Yu Q (2020) Effects and mechanisms of foliar application of silicon and selenium composite sols on diminishing cadmium and lead translocation and affiliated physiological and biochemical responses in hybrid rice (*Oryza sativa* L.) exposed to cadmium and lead. *Chemosphere,* **251**, 126347. https://doi.org/10.1016/j.chemosphere.2020.126347.

Watanabe S, Ohtani Y, Tatsukami Y, Aoki W, Amemiya T, Sukekiyo Y, Kubokawa S, Ueda M (2017) Folate Biofortification in Hydroponically Cultivated Spinach by the Addition of Phenylalanine. *Journal of Agricultural and Food Chemistry,* 2017 **65** (23), 4605-4610. DOI: 10.1021/acs.jafc.7b01375.

Watkins JL and Pogson BJ (2020) Prospects for Carotenoid Biofortification Targeting Retention and Catabolism. *Trends in Plant Science,* **25** (5), 501-512. https://doi.org/10.1016/j.tplants. 2019.12.021.

Yang G, Yuan H, Ji H, Liu H, Zhang Y, Wang G, Chen L, Guo Z (2021) Effect of ZnO nanoparticles on the productivity, Zn biofortification, and nutritional quality of rice in a life cycle study. *Plant Physiology and Biochemistry* **163**, 87-94. https://doi.org/10.1016/j.plaphy.2021.03.053.

Yang X, Alidoust D, Wang C (2020) Effects of iron oxide nanoparticles on the mineral composition and growth of soybean (*Glycine max* L.) plants. *Acta Physiologiae Plantarum,* **42**, 128. https://doi.org/10.1007/s11738-020-03104-1.

Yusefi-Tanha E, Fallah S, Rostamnejadi A, Pokhre LR (2020a) Root System Architecture, Copper Uptake and Tissue Distribution in Soybean (*Glycine max* (L.) Merr.) Grown in Copper Oxide Nanoparticle (CuONP)-Amended Soil and Implications for Human Nutrition. *Plants,* **9**, 1326; doi:10.3390/plants9101326.

Yusefi-Tanha E, Fallaha S, Rostamnejadi A, Pokhrel LR (2020b) Zinc oxide nanoparticles (ZnONPs) as a novel nanofertilizer: Influence on seed yield and antioxidant defense system in soil grown soybean (*Glycine max* cv. Kowsar). *Science of the Total Environment,* **738**, 140240. https://doi.org/10.1016/j.scitotenv.2020.140240.

Zahedi SM, Abdelrahman M, Hosseini MS, Hoveizeh NF, Tran LP (2019b) Alleviation of the effect of salinity on growth and yield of strawberry by foliar spray of selenium-nanoparticles. *Environ. Pollut.* **253**, 246-258.

Zahedi SM, Hosseini MS, Meybodi NDH, da Silva JAT (2019a) Foliar application of selenium and nano-selenium affects pomegranate (*Punica granatum* cv. Malase Saveh) fruit yield and quality. *South African Journal of Botany,* **124,** 350–358. https://doi.org/10.1016/j.sajb.2019.05.019.

Zahedi SM, Moharrami F, Sarikhani S, Padervand M (2020) Selenium and silica nanostructure-based recovery of strawberry plants subjected to drought stress. *Sci Rep.,* 10, 17672. doi: 10.1038/s41598-020-74273-9.

Zamarchi F, Vieira IC (2021) Determination of paracetamol using a sensor based on green synthesis of silver nanoparticles in plant extract. *Journal of Pharmaceutical and Biomedical Analysis,* **196**, 113912. https://doi.org/10.1016/j.jpba.2021.113912.

Zhang L, Liu Y (2020) Potential interventions for novel coronavirus in China: A systematic review. *J. Med Vir.* **92**, 479-490. https://doi.org/10.1002/jmv.25707.

Zhang S, Shen T, Yang Y, Ma X, Gao B, Li YC, Wang P (2021) Novel environment-friendly superhydrophobic bio-based polymer derived from liquefied corncob for controlled-released fertilizer. *Progress in Organic Coatings,* 151, 106018. https://doi.org/10.1016/j.porgcoat.2020.106018.

Zhang W-H, Sun R-B, Xu L, Liang J-N, Wu T-Y, Zhou J (2019) Effects of micro-/nano-hydroxyapatite and phytoremediation on fungal community structure in copper contaminated soil. *Ecotoxicology and Environmental Safety,* **174**, 100–109. https://doi.org/10.1016/j.ecoenv.2019.02.048.

Zhao X, You F (2021) Waste respirator processing system for public health protection and climate change mitigation under COVID-19 pandemic: Novel process design and energy, environmental, and techno-economic perspectives. *Applied Energy,* **283**, 116129. https://doi.org/10.1016/j.apenergy. 2020.116129.

Zheng X, Kuijer HNJ, Al-Babili S (2020) Carotenoid Biofortification of Crops in the CRISPR Era. *Trends in Biotechnology,* https://doi.org/10.1016/j.tibtech.2020.12.003.

Zulfiqar F, Ashraf M (2021) Nanoparticles potentially mediate salt stress tolerance in plants. *Plant Physiology and Biochemistry,* **160**, 257-268. https://doi.org/10.1016/j.plaphy.2021.01.028.