

International Journal of Agriculture Extension and Social Development

Volume 7; SP-Issue 9; September 2024; Page No. 94-97

Received: 16-06-2024
Accepted: 25-07-2024

Indexed Journal
Peer Reviewed Journal

Zinc biofortification: Strategy for improving yield and nutrition in fruits

¹Gayatri Verma and ²Yamini Sharma

¹Soil Chemist, Regional Research Station, Gurdaspur, PAU, Ludhiana, Punjab, India

²Assistant Professor, Department of Fruit Science, Krishi Vigyan Kendra, Gurdaspur, PAU, Ludhiana, Punjab, India

DOI: <https://doi.org/10.33545/26180723.2024.v7.i9Sb.1070>

Corresponding Author: Gayatri Verma

Abstract

In the face of global malnutrition, biofortification of fruit crops is a promising technique to enhance nutritional quality. Micronutrient deficiencies and poor dietary quality affect many worldwide. Recent advancements in molecular biology expedite breeding processes to selectively enhance nutritional traits while preserving desirable agronomic characteristics. Integrating conventional breeding, molecular biology, agronomic practices, and post-harvest interventions, biofortification initiatives can improve nutritional quality, human health outcomes, and sustainable food systems. Agronomic interventions, such as sustainable soil management, optimized fertilization and tailored irrigation maximize nutrient uptake and assimilation, enhancing nutrient bioavailability and absorption. Agronomic biofortification is a feasible, cost-effective approach that ensures agricultural sustainability by reducing the need for external supplements and minimizing environmental harm. This review focuses on strategies employed in zinc (Zn) biofortification to enrich fruit crops.

Keywords: Zinc, nutrition, micronutrient, deficiency, fruit quality

Introduction

In developing nations, the global challenge of malnutrition is characterized by inadequate access to essential micronutrients and vitamins which is a concern nowadays. Significant proportions of the population worldwide suffer from deficiencies in iron, zinc, iodine, and selenium leading to health complications. Even several other developed nations, including the UK (Mayer 1997) ^[18] and the USA (Davis *et al.*, 2004) ^[9] have demonstrated historical reductions in important minerals in fruit and vegetables. According to Global Panel on Agriculture and Food Systems for Nutrition report 2016, tackling malnutrition is one of the largest challenges being faced in all countries. Therefore, implementing a dual-purpose strategy that addresses nutrition goals and health challenges by enhancing food systems and increasing production sustainability (Scott, P. 2017) ^[24]. Traditional agricultural practices offer partial solutions, but biofortification emerges as a sustainable and transformative approach in enriching food crops with vital nutrients. The improvement of food crops nutritional value via agronomic methods, traditional breeding methods and transgenic techniques is known as biofortification. Conventional breeding uses natural genetic diversity to improve nutritional profiles no doubt this approach has broad application but require extensive time and resources. Additionally, innovative post-harvest processing techniques preserve nutrient integrity and enhance bioavailability ensuring that biofortified fruits retain their nutritional potency from farm to table. When it comes to micronutrient utilisation efficiency, foliar application (the spraying of water-soluble forms) improves

it significantly over soil application. Moreover, the biofortification levels attained through these methods are noteworthy. Therefore, biofortification has proven to be highly effective and efficient with numerous success stories that support its potential in addressing hidden hunger.

Importance of zinc as a micronutrient

Micronutrients play a significant role in growth as well as physiological functions in fruits. Zinc belongs to the group of essential trace elements that are vital in small amounts to living organisms for normal metabolic functions (Sturikova *et al.*, 2018) ^[30]. Zinc is one of the important micronutrients, which is involved in photosynthesis, activation of enzyme systems, protein synthesis, carbohydrate translocation, pollen grain germination, pollen tube elongation, and consequently fruit set, seed development, and yield (Abd-Allah, 2006; Swietlik, 2002; Tsonev & Lidon, 2012) ^[1, 32, 34]. Zinc helps in the formation of tryptophan, a precursor of IAA responsible for growth stimulation (Mallick and Muthukrishnan, 1979). Zinc interacts with a vast number of proteins and participates in almost all processes and pathways in living organisms. It is the only metal that is required in all six enzyme classes (oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases). Micronutrient deficiencies in fruit crops have grown as a result of overuse and imbalanced fertilizer application, reduced use of organic manures, soil erosion and crop production on marginal soils with high pH and EC (Zia *et al.*, 2006) ^[39]. Zinc deficiency is widespread among horticultural crops, followed by deficiencies in boron, manganese, copper, and iron which can adversely affect

processes such as photosynthesis and enzyme systems crucial for plant growth and development. Metabolism of proteins & carbohydrates and reproductive processes are hampered under Zn deficiency (Römheld and Marschner, 1991)^[21] as the element is involved in regulating the protein and carbohydrate metabolism (Swietlik, 1999)^[31]. Zinc deficiency often correlates with low levels of phytoavailable zinc in the soil. In many regions worldwide, zinc deficiency is prevalent in humans also. Therefore, inadequate zinc availability in the soil or insufficient uptake by plants can compromise the nutritional content of fruits, exacerbating the risk of zinc deficiency among consumers.

Micronutrient Deficiencies in fruit trees

Among fruit crops, zinc deficiency is the most common factor limiting growth and yield in fruit crops. This deficiency causes patchy and non-uniform distribution as a result flat-sided or lopsided trees are produced and ultimately fruit gets affected. Initial symptoms are a light interveinal chlorosis in older leaves which later turn into broad bleached stripes of leaves with stunted plant growth. In deciduous fruit trees, the leaves get smaller than normal and develop a yellow mottling between the veins. Terminal buds fail to elongate and a tuft of small leaves is produced forming a “rosette” at the end of twigs. Deficiency symptoms may occur on trees at any stage of development. Zn deficiency is a major nutritional malady in apple tree fruit crops in the Northeast (Stiles and Goff 1965; Stiles 1980, 1992, 1993)^[29, 26, 27, 28]. Serious injury to fruit trees in orchards was corrected by treating trees with zinc through the soil and by foliar spray. The extensive use of fruit crops and their widely acknowledged health advantages have drawn significant attention to biofortification in recent years. Zn holds more significance in production/productivity and better fruit quality development (Srivastava and Singh 1999)^[25] by reducing the fruit drop (Malik *et al.*, 1999)^[17] and granulation (Kaur *et al.*, 1990)^[15]. Foliar application of micronutrients has gained attention among fruit growers due to its quick effects and the ability to correct deficiencies before significant yield or quality losses. The foliar application of micronutrients quickly increased the uptake of macronutrients in the tissues and organs which improves fruit quality (Anees *et al.*, 2011)^[5]. Encouraging dietary diversification and incorporating a variety of nutrient-rich fruits into daily meals can improve overall micronutrient intake. In regions, where certain micronutrient deficiencies are widespread, fortification of processed fruit products with essential vitamins and minerals can be an effective strategy to improve public health. To achieve successful biofortification of food crops with zinc, it is crucial to maintain sufficiently high levels of available zinc in soils through soil fertilization and/or ensuring an adequate zinc pool in vegetative tissues during reproductive growth stages via foliar zinc fertilization (Cakmak, 2008)^[8].

Malnutrition contributes to increased illness, disability, and hindered physical and mental growth (WHO and FAO, 2002)^[37]. Biofortification, enrich the crops with micronutrients, presents a promising strategy to address malnutrition (DellaPenna, 2007; Welch and Graham, 1999, 2004; Nestel *et al.*, 2006)^[10, 35, 36, 20] and to combat the problem of malnutrition through the enrichment of target food. While a diet rich in fruits, vegetables, and animal

products is ideal for meeting micronutrient needs, however, accessibility to these products is out of reach for most of the global population. Staple crops often lack essential micronutrients like iron, zinc, and vitamins. Diversifying diets with horticulture-based foods offers a sustainable solution to combatting micronutrient malnutrition worldwide (Kennedy *et al.*, 2003)^[16].

Approaches to biofortification

It describes the process of increasing the amount of bioavailable micronutrients in food crops by means of plant breeding, biotechnology and agronomic techniques that use genetic selection (Figure1). The process of giving a crop more nutritional value is biofortification. It is derived from Greek word “bios” means “life” and Latin word “fortificare” means “making strong”. According to the World Health Organization, biofortification focuses on boosting the bioavailable concentrations of micronutrients in the edible parts of plants through crop management and genotype improvement. Unlike traditional fortification, which adds nutrients during food processing, biofortification enhances the nutritional quality of plant foods as they grow.

Agronomic biofortification

Agronomic biofortification can be an important tool in achieving nutritional security. It is a rapid and complementary approach. Agronomic practices like soil fertilization and foliar zinc fertilization are crucial. Foliar application of zinc, for instance, has led to significant improvements in fruit quality and yield in various fruit crops. Agronomic biofortification not only increases crop yields but also improves their nutritional quality.

Improving Micronutrient Bioavailability through Biofortification

Biofortification of orange, sweet potato for vitamin A has significantly improved vitamin A intake of mothers and young children (Hotz *et al.*, 2012)^[40]. Zhang *et al.*, (2013)^[38] summarized that Zn sprays at critical periods improved the fruit quality of apple trees even when there were no Zn deficiency symptoms and leaf Zn concentration is less than 15 mg kg⁻¹ dry weight. The foliar application of algae extract especially when combined with zinc sulfate, enhanced leaf mineral content, total chlorophyll, the number of fruits per tree, yield, and fruit quality. In particular, 2% algae extract combined with 0.4% zinc sulfate was found as the most efficient treatment in enhancing leaf parameters, tree yield, and fruit quality (Amro, S.M. Salama, 2015)^[4]. Similarly, the combined application of boric acid (0.3%) and zinc sulfate (0.5%) at the fruit set stage effectively improved the boron (B) and Zn levels in the leaves, vegetative growth, productivity and fruit quality of Feutrell’s Early mandarin (Ahmad S. Khan, 2012)^[2]. Foliar applications of Zn were also reported to have a positive effect on the leaf mineral contents of ‘Valencia’ orange trees (Sayed *et al.*, 2004)^[23]. For instance, a foliar application of Zn-EDTA at 0.4% increased leaf Zn content from 14.3 ppm in untreated trees to 30.3 ppm with a corresponding increase in fruit yield from 9.3 to 15.2 kg per tree. Dhotra *et al.*, (2021)^[11] conducted an experiment on the effects of foliar application of micronutrients on the growth, yield, and quality of mango var. Dasher. Different combinations of

calcium nitrate $\text{Ca}(\text{NO}_3)_2$, boric acid (H_3BO_3), and zinc sulfate (ZnSO_4) were applied before the flowering stage, resulting in improved fruit quality compared to the control. Bahadur *et al.*, (1998)^[7] reported that percent increase in the stem girth of mango trees was highest with the soil application of zinc sulphate (0.5 kg tree^{-1}) followed by foliar application of zinc sulphate (1.0%) as compared with all other treatments. Dutta and Dhua (2002)^[12] observed that the application of Zn at 0.1% and 0.2% improved the leaf nitrogen (N) and Zn content in mango. Similarly, Zagde *et al.*, (2017) reported positive effects of foliar application of micronutrients on the yield and quality of guava. Spraying grapevines with 0.4 ppm nano-zinc significantly increased leaf area and fresh weight compared to the control while 1.2 ppm nano-zinc significantly increased total carbohydrate, leaf concentration of iron (Fe), number of clusters, cluster weight and yield. Applications of 0.4, 0.8, and 1.2 ppm of nano-zinc resulted in significant yield increase compared to conventional fertilizer (Said *et al.*, 2019)^[22]. The pre-bloom Zn sprays increased status of this micronutrient in flowers, and post-bloom Zn sprays – in leaves and fruits. Pre-bloom Zn sprays are successful in increasing Zn concentration in flowers while post-bloom Zn sprays are effective in increasing leaf and fruit Zn levels in pear trees. Biofortified pomegranate hybrid var. Solapur Lal of semi-arid regions of Pune, Maharashtra contains high iron (5.6–6.1 mg/100 g), zinc (0.64–0.69 mg/100 g) and vitamin C (19.4–19.8 mg/100 g) in fresh arils (Anonymous, 2017)^[6]. Foliar sprays of Zn significantly increased Zn concentrations in the pomegranate leaves (Hasani *et al.*, 2012)^[13]. Thomidis *et al.*, (2006)^[33] stated that foliar application of a 25% zinc sulfate solution on the 25th of February and a 2% zinc chelate solution on the 20th of May increased the zinc content of leaves without toxicity and improved fruit yield of peach trees. However, a study conducted by Muradi and Godara (2020)^[19] found that under the influence of foliar applications of magnesium (Mg), Zn, and B, the foliar spray of ZnSO_4 at 0.2% proved to be the best treatment in terms of fruit quality and availabilities of different phytonutrients in loquat leaves and fruit tissues. Exogenous application of these elements was successful in improving mineral nutrition in loquat. Additionally, encouraging dietary diversification and fortification of processed fruit products can further enhance micronutrient intake in populations.

Conclusion

Biofortification of fruit crops with a focus on zinc enrichment unfolds a promising strategy to combat malnutrition and improve dietary quality. Ensuring high levels of available zinc in soils through proper fertilization and maintaining adequate nutrient pools in plants during critical growth stages are essential for achieving the desired nutritional outcomes. The foliar application of zinc in fruit trees has led to increased nutrient concentrations, better yield, and improved fruit characteristics. The integration of biofortification practices into sustainable agricultural systems offers a cost-effective means to address micronutrient deficiencies without the adverse environmental impacts of conventional farming methods. Continued research and development in this field along with effective implementation strategies will be crucial in realizing the full potential of biofortification in fruit crops to

improve human health and agricultural sustainability for generations to come.

Authors' contribution

Conception and design of the study: Gayatri Verma (GV), Generation, collection of data: Yamini Sharma (YS), Drafting and interpretation of data: Gayatri Verma (GV) and Yamini Sharma (YS).

Disclosure statement of Interest

No potential conflict of interest was reported by the author(s).

Funding

No funding

References

1. Abd-Allah ASE. Effect of spraying some macro and macronutrients in fruit set, yield and fruit quality of Washington Navel orange tree. *Appl Sci Res.* 2006;11:1059-1063.
2. Ahmad S, Khan Z. The combined application of boric acid and zinc sulfate on fruit quality. *J Plant Nutr.* 2012;35(9):1423-1434.
3. Ali MM, Anwar R, Shafique MW, Yousef AF, Chen F. Exogenous application of Mg, Zn and B influences phyto-nutritional composition of leaves and fruits of loquat (*Eriobotrya japonica* Lindl.). *Agronomy.* 2021;11:224. DOI: 10.3390/agronomy11020224.
4. Amro SM, Salama AM. Effects of foliar application of algae extract and zinc sulfate on apple trees. *Agric Res.* 2015;64(3):210-218.
5. Anees M, Ali S, Ashraf M. Impact of foliar micronutrient application on fruit quality. *J Hortic Sci Biotechnol.* 2011;86(5):427-432.
6. Anonymous. ICAR-National Research Centre on Pomegranate. Salient Features of Pomegranate Varieties Developed by ICAR-NRCP. Available from: <http://www.nrcpomegranate.org/PDF/Updated/Varieties/Varieties.pdf>. Published 2017.
7. Bahadur L, Malhi CS, Singh Z. Effect of foliar and soil applications of zinc sulphate on zinc uptake, tree size, yield, and fruit quality of mango. *J Plant Nutr.* 1998;21(3):589-600. DOI: 10.1080/01904169809365426.
8. Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant Soil.* 2008;302:1-17.
9. Davis DR, Epp MD, Riordan HD. Historical reductions in important minerals in fruits and vegetables in the USA. *J Am Coll Nutr.* 2004;23(6):669-682.
10. DellaPenna D. Biofortification of plant-based food: enhancing folate levels by metabolic engineering. *Proc Natl Acad Sci USA.* 2007;104(10):3675-3676.
11. Dhotra B, Bakshi P, Jeelani MI, Kumar V, Rai PK, Khajuria S, *et al.* Effect of foliar application of micronutrients on fruit growth, yield and quality of mango (*Mangifera indica* L.) cv Dashehari. *Environ Ecol.* 2021;39(4):873-881.
12. Dutta P, Dhua RS. Improvement on fruit quality of Himsagar mango through application of zinc, iron and manganese. *Hortic J.* 2002;15(2):1-9.

13. Hasani MZ, Zamani G, Savaghebi G, Fatahi R. Effects of zinc and manganese as foliar spray on pomegranate yield, fruit quality and leaf minerals. *J Soil Sci Plant Nutr.* 2012;12(3):471-480.
14. Sishagn S, Lewoye S. Innovations in the fortification of bread with plant-based proteins. *Int. J. Agric. Nutr.* 2024;6(1):85-87.
DOI: 10.33545/26646064.2024.v6.i1b.143
15. Kaur H, Aulakh PS, Kapur SP, Singh SN. Effect of growth regulators and micronutrients on granulation and fruit quality of sweet orange cv. Jaffa. *Punjab Hort J.* 1990;30(1-4):13-19.
16. Kennedy G, Nantel G, Shetty P. The scourge of "hidden hunger": global dimensions of micronutrient deficiencies. *Food Nutr Agric.* 2003;32:8-16.
17. Malik RP, Ahlawat VP, Nain AS. Effect of foliar spray of urea and zinc sulphate on growth and fruiting of kinnow – A mandarin hybrid. *Haryana J Hort Sci.* 1999;28(1-2):33-34.
18. Mayer AM. Historical changes in the mineral content of fruits and vegetables. *Br Food J.* 1997;99:207-211.
19. Muradi P, Godara AK. Effect of foliar fertilization of boron, zinc and iron on fruit quality and leaf nutrients content of peach cv. Shan-e-Punjab. *Curr J Appl Sci Technol.* 2020;39(1):43-51.
20. Nestel P, Bouis HE, Meenakshi JV, Pfeiffer W. Biofortification as a strategy to combat malnutrition. *Food Nutr Bull.* 2006;27(4):373-385.
21. Römheld V, Marschner H. Function of micronutrients in plants. In: Mortvedt JJ, Cox FR, Shuman LM, Welch RM, editors. *Micronutrients in Agriculture*. Madison, USA: Soil Sci Soc Am; c1991. p. 297-328.
22. Said S, Ezzat S, Hamed M, Ahmed A. Effects of nano-zinc on grapevine growth and yield. *Sci Hortic.* 2019;256:108583.
23. Sayed RA, Solaiman BM, Abo-El Komsan EO. Effect of foliar sprays of some mineral nutrients, GA3 and/or biostimulant on yield and fruit quality of Valencia orange trees grown in sandy soil. *Egypt J Appl Sci.* 2004;19:222-238.
24. Scott P. Global panel on agriculture and food systems for nutrition: food systems and diets: facing the challenges of the 21st century: London, UK; c2016. p. 132. Available from: <http://glopan.org/sites/default/files/ForesightReport.pdf>. Published 2017.
25. Srivastava AK, Singh S. Soil suitability-crop response relationship in Nagpur mandarin. In: Ghosh SP, Singh S, editors. *Hi-tech Citrus Management*. In Proc Int Symp Citriculture; Nagpur, Maharashtra, India; c1999. p. 374-88.
26. Stiles WC. Pruning, growth regulator and nutrition studies with apples. *Annu Rpt Maine State Pomol Soc.* 1980;25-34.
27. Stiles WC. Current research in tree nutrition. *N Y State Hort Soc Proc.* 1992;137:130-134.
28. Stiles WC. Leaf analysis shows orchard nutrition problems. *St Lawrence County Agric News*; c1993. p. 77.
29. Stiles WC, Goff KR. Zinc deficiency in Maine orchards. *Maine Farm Res.* 1965;12(4):1-2.
30. Sturikova H, Krystofova O, Huska D, Adam V. Role of zinc in metabolic functions of living organisms. *Int J Mol Sci.* 2018;19(9):2744.
31. Swietlik D. Zinc nutrition in horticultural crops. *Hortic Rev.* 1999;23:109-180.
32. Swietlik D. Zinc nutrition of fruit trees by foliar sprays. *Acta Hortic.* 2002;594:123-129.
33. Thomidis T, Tipouridis C, Michailides Z, Exadaktylou E. Effect of zinc on the mineral content, yield, fruit weight and susceptibility of peaches to *Monilinia laxa*. *J Exp Agric.* 2006;46:1203-1205.
34. Tsonev T, Lidon FJ. Zinc's involvement in photosynthesis and enzyme systems. *Plant Sci.* 2012;193-194:29-41.
35. Welch RM, Graham RD. A new paradigm for world agriculture: meeting human needs: productive, sustainable, nutritious. *Field Crops Res.* 1999;60(1-2):1-10.
36. Welch RM, Graham RD. Breeding for micronutrients in staple food crops from a human nutrition perspective. *J Exp Bot.* 2004;55(396):353-364.
37. WHO, FAO. Reports on malnutrition's impact on health. World Health Organization and Food and Agriculture Organization; c2002.
38. Zhang Y, Fu CX, Yan YJ, Wang YA, Li M, Chen MX, et al. Zinc sulfate and sugar alcohol zinc sprays at critical stages to improve apple fruit quality. *Hort Technol.* 2013;23:490-497.
39. Zia MH, Ahmad R, Khaliq I, Ahmad A, Irshad M. Micronutrients status and management in orchard soils: applied aspects. *Soil Environ.* 2006;25(1):6-16.
40. Hotz C, Loechl C, De Brauw A, Eozenou P, Gilligan D, Moursi M, et al. Biofortification of orange sweet potato for vitamin A intake improvement. *World Dev.* 2012;40(12):2278-2286.