Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
key to the Researchers

Review Article
Volume 28 Issue 1 - November 2023
DOI: 10.19080/ARTOAJ.2023.28.556392

Agri Res & Tech: Open Access J

Research Progress on the Role of Cytokinin as a Nutrients Enhancer

Anindita Roy* and Rupak Chakraborty

South Dakota State University, USA

Submission: October 27, 2023; **Published:** November 07, 2023

***Corresponding author:** Anindita Roy, South Dakota State University, USA

Abstract

Wheat is considered as one of the most top cereal crops because it is extensively grown, ate as food crosswise the world, and recognized as the main food for approximately 35 per cent of the world population. But it is endangered by spot blotch disease triggering significant yield loss and present genotypes having deficiency of essential nutrients. Cytokinins are crucial phytohormones that not only control plant growth but also play a significant role during the interaction with other organisms including pathogens and in the nutrient metabolic pathway of plants. Lack of important nutrients like iron, zinc, and vitamin A reasons permanent damage to the body, compressing the need to raise the heap of these micronutrients in the eatable parts of the plant. Crop plants bio-fortification is one of the promising attempts by which the amounts of these essential nutrients could be boosted to a desirable amount. It is also discovered that it has an effect over Zn accretion in cereal crops plants.

Alteration of the cytokine dehydrogenase (CKX) enzyme that degrades cytokinin could affect important nutrients along with the yield and root growth. Several instances revealed that an increase in the contents of S, Zn, Mn, and Fe in the seeds of cereals is an image of growing the activity of CKX enzyme ensuing the enhancement of the root system which not only benefits in the absorption of water but is also helpful for sifting nutrients to the bottomless ends of the soil. Discovering micronutrients from the lithosphere via the root system supports the acceptance of the micronutrients and transferring them via the vascular system to the sink of the cereal crop plants. Thus, identification and combination of CKs/CKX linked genes into targeted cereal crop plants which discovering a bio-fortification method including CRISPR-Cas9 by conventional and molecular breeding methods and it could be the most principal job for developing the nutritional value of the wheat crops, which would be beneficial for humankind/society.

Keywords: Wheat; Spot blotch; Nutrients; Cytokinin; CKX; Biofortification

Introduction

Wheat (*Triticum aestivum* L.), does belong to the family Poaceae, and it is one of the most prominent cereal crops in the world [1,2]. Amongst the field cereal crops, wheat is considered as the most important cereal crop since it is broadly cultivated and consumed as food in the world. It is also recognized as the staple food for close to 35 percent of the world population and mandate for wheat is presumed to cultivate faster than the other main cereal crops [3]. It is being cultured in a wide limit of environmental conditions around the and it has many essential nutrition components and offers around 20% of protein in the human nutrition [4]. Most of the achievement was instigated by the amalgamation of high rates of speculation in crop research, organization, market progress, and proper policy provision that grabbed place in the first Green Revolution, however, still there is necessity to advance the crop production to achieve the demand of the quickly increasing population [4]. Wheat is being cultured at a huge scale and there is extreme demand in the world, therefore in response to food security in 21st century, structural alterations are desired to advance the crop production to achieve the mandate of deprived people [5]. Instead of being counted a main food, wheat is also a significant informant of nutrients for nearby 40% of the world [6]. Though, malnutrition is still a thoughtful problem now a days, henceforward, the growth of the promising wheat genotypes over crop bio-fortification which supports the predictable and developed breeding method is obligatory for nutritional security in the 21st century [7]. Almost 90%-95% of the wheat cultivated in the world is bread wheat containing 2n = 6x = 42 made of three sub genomes like A, B, and D diploid genomes which is a rich pool of genes deciding yield and its supporting traits [8]. But wheat crop is warned by spot blotch disease triggered by Bipolaris sorokiniana syn. Helminthosporium sativum syn. Cochliobolus sativus is researched one of the most overwhelming diseases in Eastern India and Southeast Asia [9,10].

Worldwide it is seen as the most important disease, principally in warm and humid zones of South Asia and South America [11]. As per encounters, labors have been made and many resistance genotypes have been discovered but accessibility of immune plants is missing [11,12]. This disease was stated in the initiating of 19th century but increased further importance after the Green Revolution [13]. Complex cultivars of barley and wheat are under unadorned outbreak from pathogens principally at the time of late milking, stage, dough or during flowering which seriously interrupts the grain filling and finally results to lessening the profit of barley [14] and wheat crops [15]. The application of fungicide can totally decrease the spot blotch disease harshness [16], but frequent application of these fungicides not only rise the price of farming but also poisons the atmosphere and is related with appearance of fungicidal resistance in the objective pathogen [17].

Therefore, advancement of resistance cultivars by joining the predictable and developed molecular breeding method is an actual and economical-effective approach for contesting the spot blotch disease. The accessibility of genetic evidence on spot blotch resistance genetics is inadequate as uncovered by obtainable literature and restricted genotypes have had their confrontation level recognized. Also, this disease, wheat crop also undergoes from lacking the essential nutrients for the human body. While the body does not acquire sufficient nutrients, it starts many difficulties including digestion, dizziness, fatigue, weight loss, and malnutrition which can reason mental or physical incapacity. Previous studies specified that micronutrients are vital for physiological roles, and their absence reasons severe health illnesses, and it (Zn) is active in reproduction and neurotransmission, especially the immune system [18].

Another study informed that lack of micronutrients triggers deficiencies to physical growth, learning and reproductive health, reduce in immune resistance, and arise in the rate of infection [19]. Even if the country has reached entire food grain production around at 296.65 million tons during 2019-20, this production is upper by 26.87 million tones than the usual production of the previous 5 years. Also, wheat production is likely at 107.59 million tons during 2019-20 (Anonymous). This profuse grain production is mostly recognized to the manufacture of high yielding genotypes. But, in the production of high resilient varieties, sufficient care has not been given to important nutrients; as a result, such improved genotypes are high yielding but have minimal concentrations of vital nutrients so the standard urged level. Thus, discovering the genetic data and detecting latent genotypes which discuss a good cause for resistance, are rich in vital nutrients, and can connect the cytokinin related genes would be a great method for developing crop production and other necessary traits using predictable and molecular breeding methods including multidisciplinary methods. Considering producing the high resilient wheat genotypes along with those rich in beleaguered nutrients and necessary for other agronomically characters, attaching the cytokinin Phytohormones are one of the developing methods for the scientists under the varying climate.

The altering climate consequences in an enhance of the greenhouse gases which cause the drop of crop production and as result, nutritional lacking in humans [20,21] affirmed that enhancing drought is because of changing the climatic and it decreases the accessibility of vital micronutrients, specifically Fe and Zn. Due to supply the mandate of the fast growing population, growing the harvest of crop plants is the main goal of plant breeders in the 21st century for producing sufficient food, growing the vital nutrients level in the eatable parts of crop plants, over either bio-fortification means growing crops that have higher amount of nutrition in their eatable parts or improving the larger genotypes along with amusing in nutrients over current breeding methods is the present necessity. Meanwhile malnutrition is a thought-provoking matter at a global level, efforts have been made under the leadership of the Consultative Group on International Agricultural Research (CGIAR) and accordingly huge bio-fortified genotypes of different crop plants have been developed across the globe. In addition, bio-fortified wheat genotypes with those better for other necessary traits have been advanced and unrestricted [22]. Production of wheat or battered cereal crop plants including other necessary traits can also be improved by two key approaches, the first one is improving the high resilient genotypes as well as those improved for resistance and rich in vital nutrients by combining all associated gene(s)/QTLs into a single cultivar, and the second one is saving the production loss of genotypes happened by biotic or abiotic factors.

Overviewing the role of Cytokinin for improving nutrients along with other required traits

For reviving the challenge, the developed wheat genotypes consisted pleasing yield and establish improvement in the other attributes but in some way be deficient in having the necessary nutrients for body. For this reason, in very currently, 28 bio-fortified wheat genotypes (Figure 1) have been established by some agricultural institutions by which country those have sufficient vital nutrients and development in other necessary traits [22]. Also, many other findings have been carried out concerning the transportation of micronutrients and the way to increase their substance in cereal crops for example [4,23,24,25 ,26 ,27].

Therefore, for developing wheat genotypes for having enough nutrients and for developing other desirable traits containing resistance for biotic and abiotic stresses. Also, these genotypes can be selected as the contributor parents in the breeding programs. Moreover, many other studies identify that some of their genotypes consist of exceptional genetic make-up and for having this exceptional genetic make-up if a chemical foliar sprayer fertilizer is offered, afterwards, they can produce sufficient nutrients into the cereal crops. Therefore, genotypes can be explored by this advanced breeding to realize genetics of these desirable traits with a goal to establish great genotypes. Likewise, involvement of phenotypic traits including having the

How to cite this article: Anindita R, Rupak C. Research Progress on the Role of Cytokinin as a Nutrients Enhancer. Agri Res& Tech: Open Access J. 2019; 28(1): 556362. DOI:10.19080/ARTOAJ.2023.28.556362

resistance to spot blotch in wheat such as leaf tip necrosis [28], and stay green trait [29] have been suggested for breeding to develop these desirable genotypes because these morphological traits are greatly related for having resistance against spot blotch disease. Stay-green is a significant trait of wheat that is unable to increase the production of wheat crops for the reason of having efficiency in photosynthesis. However, it is also capable to support for resistance to spot blotch and other abiotic/biotic stresses. Also, this distinctive trait can be applied as a phenotypical marker for choosing the spot blotch disease resistant wheat plant and develop the breeding of favorable genotypes by hybridization. Cytokinins are recognized as the most effective controller for the senescence and stay-green trait of plants. Earlier study informed expression of cytokinins can improve seed production, seed size and grain number of the cereal crops including wheat [30]. Also, it has an important role against biotic and abiotic stressors [31].

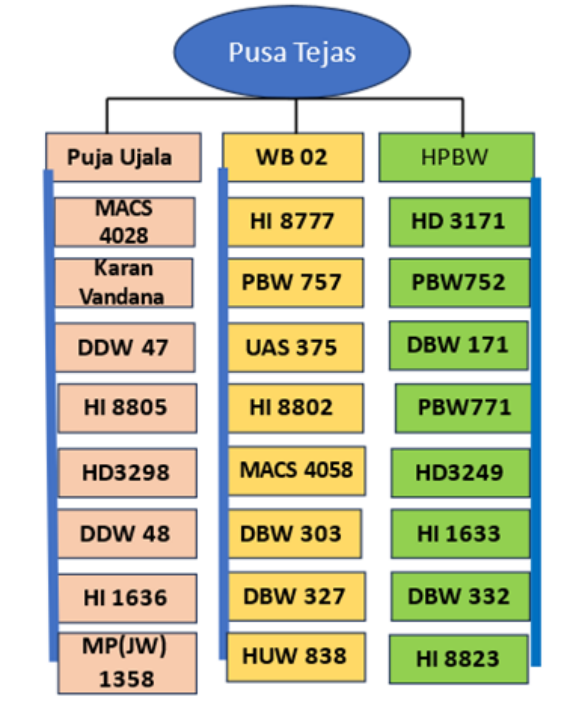

Figure 1: Schematic diagram of 28 Bo-fortified wheat varities developed by research institutes in India.

The investigations of cytokinin amount in the presence of different conditions discloses that cytokinin metabolism is highly controlledin the response to environmental stresses [32]. For having its recognized influences on encouraging seed number and seed size and having the effect under environmental stressed surroundings and producing vital nutrients, the cytokinins may be the hormone which can support the second "Green Revolution" [33,34] sums up the aimed breeding for the micronutrients that is perceived by Harvest Plus which is a biofortified breeding program including micronutrient phenotyping, genomic selection, and speed breeding to develop the biofortified genotypes by biofortification iron (Fe), zinc (Zn), and provitamin A (PVA) which are three important micronutrients, and these are essential for human health. In the 21st century, these three important micronutrients have gotten momentum. The plan of Harvest Plus can drastically enhance the amount of Fe, Zn, and PVA in bio-fortified wheat classes with gigantic potential. These bio-fortified genotypes can be utilized as the donors in the upcoming breeding platforms for crop development. The major center ofCGIAR viz., CIMMYT have an excellent function to improve desirable wheat genotypes which consist sufficient zinc and other desirable nutrients [35,36]. Along with this, Cytokinin also plays a significant role in achieving another desirable traits for cereal crop plants. Phytohormones are created by plants, whereas plant growth controllers are applied by humans for specific reasons. Phytohormones are necessary components, and they regulate the overall plant growth [37].

Plant phytohormones control the shoot growth, tillering, flowering, ageing, root growth, distortion, color development of fruit, deterrence of leaf fall, etc. Cytokinin, auxin, gibberellin (GA), ethylene, and abscisic acid (ABA) are five main plant-growth-regulators. Researcher identified that, cytokinin shows a very important role for the cell division and control the overall plant growth among these five hormones [38]. It increases cell division and other morphological developments including seed

How to cite this article: Anindita R, Rupak C. Research Progress on the Role of Cytokinin as a Nutrients Enhancer. Agri Res& Tech: Open Access J. 2019; 28(1): 556362. DOI:10.19080/ARTOAJ.2023.28.556362

germination, flowering, and leaf aging, etc. as also has been indicated in Figure 2. Cytokinin has an important effect on the maintenance of photosynthesis process during stress and have a helpful effect on drought tolerance [39] Research investigates that cytokinins can improve the destruction to plants produced by different abiotic stresses [40,41]. Therefore, hormones have been developed for crop development for having desirable trait [42,43]. Cytokinin has been observed in both plants and animals and they are the main controller of plant development, and it is required for metabolic processes in cereal crop plants) as it is also indicated in Figure 2. Cytokinins are N6-substituted purine byproducts chemically. Zeatin (Z), Isopentenyladenine (iP), and dihydrozeatin (DZ) are known as the prime cytokinins which are in higher plants. Climate change causes decreasing agricultural applies and restricting the crop yield. The hoards in discovering the essential genes of cytokinin phytoharmone for improving the crop yield are required to confirm the accessibility of food with essential nutrition security [44].

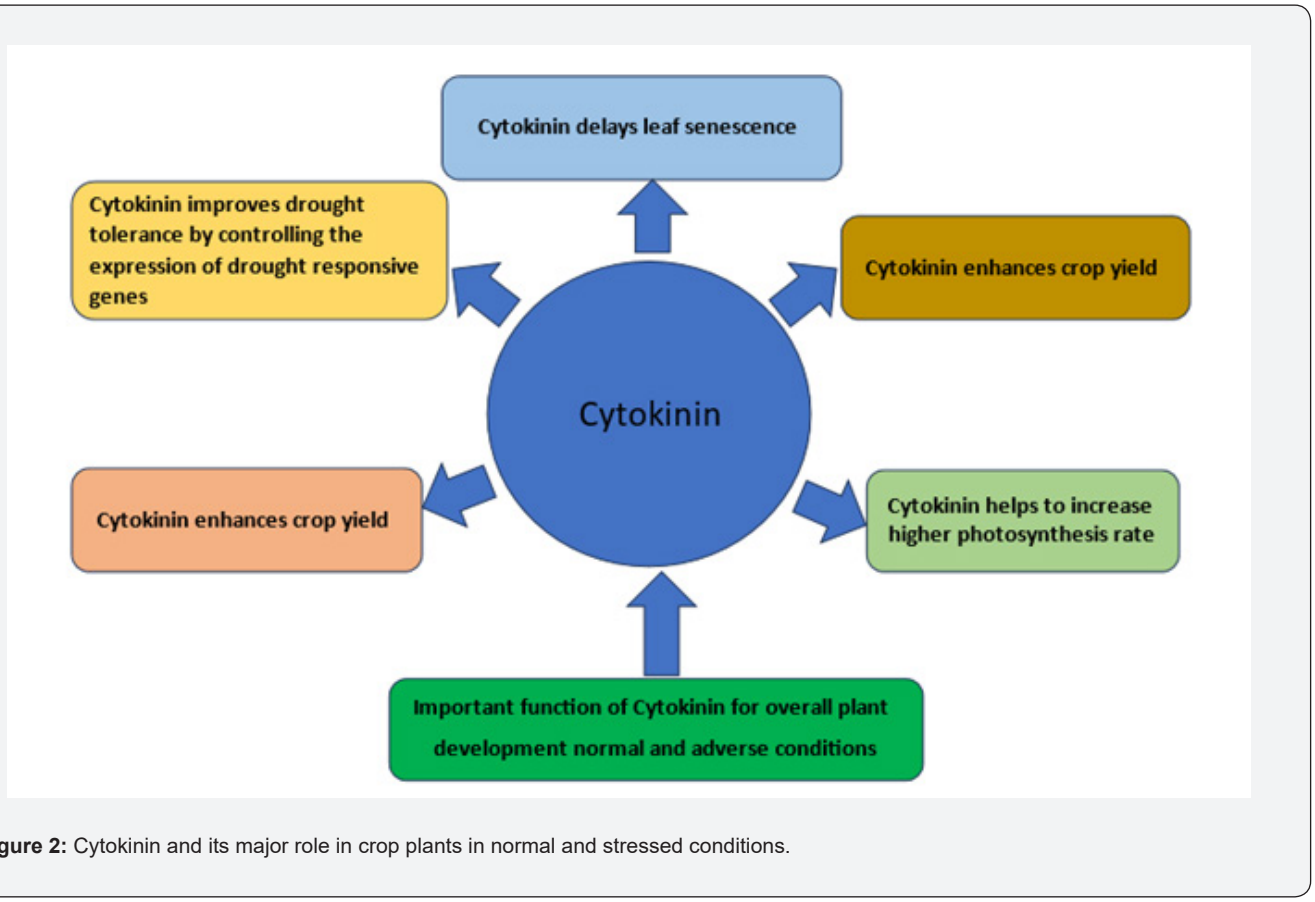

Figure 2: Cytokinin and its major role in crop plants in normal and stressed conditions.

Utilization of Modern Technology for Crop Bio-Fortification

Articles show around 820 million people are starving in the world and around two billion people are experiencing from micronutrient shortcomings [45-47]. Many cereal crops can gather essential micronutrients. But few major plants deficit the satisfactory volumes of such essential micronutrients viz., Fe and Zn in the eatable chunks [48], for example, essential crop plants such as wheat, rice and maize have very little amounts of Fe and Zn [49]. In modern investigation, it is powerfully testified that micronutrient absences raise vulnerability to many infective diseases, such as Covid-19 [50]. So, extra concentration needs to be made to increase these significant micronutrients in the crop plants by bio-fortification, which is a modern approach to contest against micronutrient absence. Diverse beneficial methods of bio-fortification are utilized to advance the nutritional worth of plants, to overawed nutritional the difficulties existing in Figure 3, and discussed by previous research group with a statement that bio-fortification is a cost-effective and supportable agricultural approach for growing the bio-accessibility of vital micronutrients in the eatable chunks of plants and dropping malnutrition [51].

Furthermore, they have identified that inherited bio-fortification based on genetic engineering for growing or operating the expression of genes that distress the regulation of metal homeostasis and transporter proteins that help to rise the micronutrient and larger yield by CRISPR-Cas9 (bacterial

How to cite this article: Anindita R, Rupak C. Research Progress on the Role of Cytokinin as a Nutrients Enhancer. Agri Res& Tech: Open Access J. 2019; 28(1): 556362. DOI:10.19080/ARTOAJ.2023.28.556362

Clustered Regularly Interspaced Short Palindromic Repeats) method can be used as a hopeful high-potential approach and very advanced GM method to solve out the micronutrient lacking problem. This procedure was used in a previous study [52] Through adjusting the germ line cells, Crispr-cas method has the promising effect to advance transgenics without affecting tissue culture [53]. In previous studies, advanced genetic alteration methods are utilized in applied and basic investigation [54]. Similarly, classic hereditarily modified method an extensive range of genetic alternation method are being advanced for the genetic alteration of different organisms, for instance, plants for research determinations or for the progress of cereal crop plants for agricultural. These methods are also indicated to as "new breeding methods" for developing desirable traits [55].

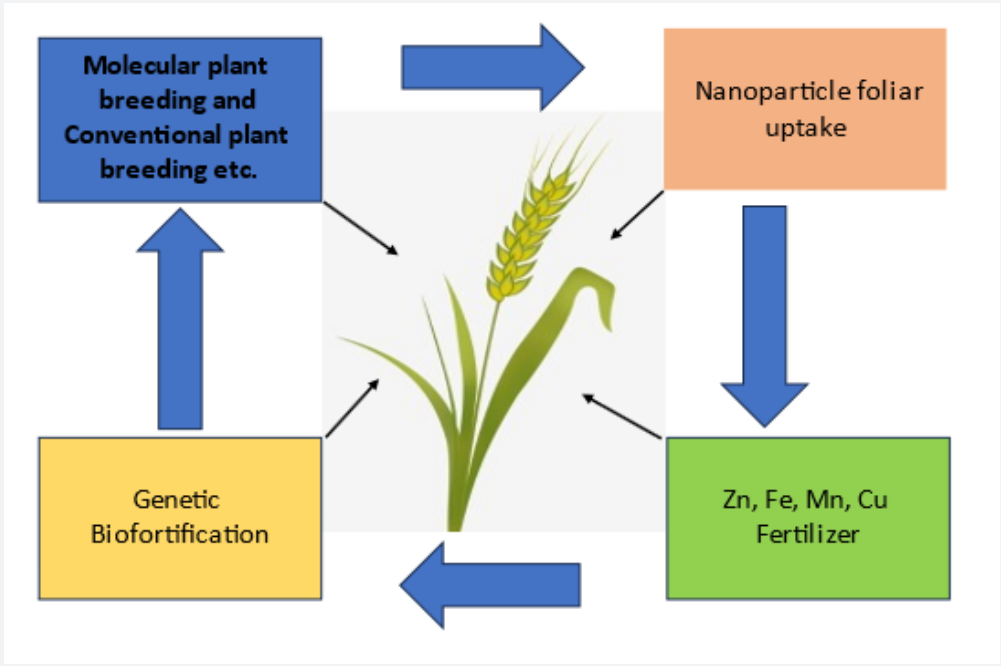

Figure 3: Schematic diagram of important users of crop bio-fortification.

Conclusion

Wheat is contemplated to be one of the most economically focal cereal crops in the world. Its production is prominent, but changing climate and cumulative consumption implies the necessity for further progress in its yield potential. Climate change is assumed to endure the simulation of biotic/abiotic stresses, and as a result, many portions of the earth will become reluctant to crop growing. On the other hand, for the fast-increasing residents and the changing climate, plea for wheat is predictable to increase quicker than the other main crops. Consequently, hoards in exploring and harnessing present genetic resources counting bio-fortified wheat and evidence regarding the function of cytokinins under normal and hostile circumstances for growing the production, grains holding sufficient nutrients and having an enough resistance response, influence of morphological indicators leaf tip necrosis, stay green traits, leaf molecular indicators, and other beneficial genetic material for producing sufficient grains that are rich in the essential nutrients to confirm food safety in the 21st century is the requirement of the day. Meanwhile cytokinins are the most influential endogenous materials controlling the physical and molecular responses, and they have an important responsibility during completion of the life cycle of plants to assign a adequate yield. Therefore, plant breeders could straightforwardly aim the cytokinins to increase beleaguered traits by applying least input, by way of cytokinins are recognized to be a key carter of seed production and it may well be the hormone that supports the second green uprising.

The Green Innovation improved crop production throughout the mid-20th century by leading dwarf genotypes of wheat which is accomplished of responding to a sophisticated dose of reproduction and sufficient irrigation without lodging. Currently there is a necessity of a second Green Revolution to gather out the necessity of a quickly expanding population. The Green Revolution was created on crops responsive to elevated soil fertility. However, currently there is a requirement to improve the genotypes of wheat which can achieve better under insufficient soil productiveness,

How to cite this article: Anindita R, Rupak C. Research Progress on the Role of Cytokinin as a Nutrients Enhancer. Agri Res& Tech: Open Access J. 2019; 28(1): 556362. DOI:10.19080/ARTOAJ.2023.28.556362

under stressed environments including heat, drought, metal poisonousness, and under biotic stresses. By concerning about the above facts, harnessing the cytokinin key hormones, discovering genetic resources and relating efficient molecular breeding methods, plant breeders can progress the higher and unchanging genotypes which will be able to provide to the food demand of the deprived people.

References

1. Schnurbusch T (2019) Wheat and barley biology: towards new frontiers. Journal of Integrative Plant Biology 61(3): 198-203.
2. Alzaayid DTJ, Aloush RH (2021) Effect of cytokinin levels on some varieties of wheat on yield, growth and yield components. In IOP Conference Series: Earth and Environmental Science 910(1): 012090.
3. Pingali PL (2012) Green revolution: impacts, limits, and the path ahead. Proceedings of the national academy of sciences 109(31): 12302-12308.
4. Qin X, Fischer K, Yu S, Dubcovsky J, Tian L (2016) Distinct expression and function of carotenoid metabolic genes and homoeologs in developing wheat grains. BMC plant biology 16: 1-15.
5. Pingali P (2015) Agricultural policy and nutrition outcomes–getting beyond the preoccupation with staple grains. Food security 7: 583-591.
6. Giraldo P, Benavente E, Manzano AF, Gimenez E (2019) Worldwide research trends on wheat and barley: A bibliometric comparative analysis. Agronomy 9(7): 352.
7. Prasad R (2022) Cytokinin and its key role to enrich the plant nutrients and growth under adverse conditions-an update. Frontiers in Genetics 13: 883924.
8. Nadolska OA, Rajchel IK, Orczyk W, Gasparis S (2017) Major genes determining yield-related traits in wheat and barley. Theoretical and Applied Genetics 130: 1081-1098.
9. Joshi AK, Chand R (2002) Variation and inheritance of leaf angle, and its association with spot blotch (Bipolaris sorokiniana) severity in wheat (Triticum aestivum). Euphytica 124: 283-291.
10. Kumar U, Joshi AK, Kumar S, Chand R, Röder MS (2009) Mapping of resistance to spot blotch disease caused by Bipolaris sorokiniana in spring wheat. Theoretical and Applied Genetics 118(4): 783-792.
11. Kumar U, Kumar S, Prasad R, Order MS, Kumar S, et al. (2019) Genetic gain on resistance to spot blotch of wheat by developing lines with near immunity.
12. Lillemo M, Joshi AK, Prasad R, Chand R, Singh RP (2013) QTL for spot blotch resistance in bread wheat line Saar co-locate to the biotrophic disease resistance loci Lr34 and Lr46. Theoretical and applied genetics 126(3): 711-719.
13. Saari EE (1998) Leaf blight disease and associated soil-borne fungal pathogens of wheat in South and South East Asia. Helminthosporium blights of wheat: spot blotch and tan spot, pp.37-51.
14. Prasad R, Prasad LC, Chand R, Joshi AK (2013) Assessment of Diversity for Resistance to Spot Blotch Disease and its Association with Certain Phenotypic Traits in Barely. Field Crop Res 54: 195-200.
15. Gupta PK, Chand R, Vasistha NK, Pandey SP, Kumar U, et al. (2018) Spot blotch disease of wheat: the current status of research on genetics and breeding. Plant pathology 67(3): 508-531.
16. de Viedma LQ, Kohli MM (1997) Spot blotch and tan spot of wheat in Paraguay. Helminthosporium blights of wheat: Spot blotch and Tan spot, p.126.
17. Golembiewski RC, Vargas JM, Jones AL, Detweiler AR (1995) Detection of demethylation inhibitor (DMI) resistance in Sclerotinia homoeocarpa populations Plant Dis 79: 491-493.
18. Kieber JJ, Schaller GE (2018) Cytokinin signaling in plant development. Development 145(4): 149344.
19. Verma PK, Verma S, Chakrabarty D, Pandey N (2021) Biotechnological Approaches to Enhance Zinc Uptake and Utilization Efficiency in Cereal Crops. J Soil Sci Plant Nutr 21(5): 1-13.
20. Myers SS, Zanobetti A, Kloog I, Huybers P, Leakey AD, et al. (2014) Increasing CO_2 Threatens Human Nutrition. Nature 510(7503): 139-142.
21. Moreno JE, Plaza C, Saiz H, Manzano R, Flagmeier M, et al. (2019) Aridity and Reduced Soil Micronutrient Availability in Global Drylands. Nat. Sustain 2(5): 371-377.
22. Yadava DK, Choudhury PR, Hossain F, Kumar D, Sharma TR, et al. (2022) Biofortified Varieties: Sustainable Way to Alleviate Malnutrition. Fourth Edition. New Delhi: Indian Council of Agricultural Research, pp. 106.
23. Wang C, Zeng J, Li Y, Hu W, Chen L, et al. (2014) Enrichment of provitamin A content in wheat (Triticum aestivum L.) by introduction of the bacterial carotenoid biosynthetic genes CrtB and CrtI. Journal of Experimental Botany 65(9): 2545-2556.
24. Connorton JM, Jones ER, Rodríguez RI, Fairweather TS, Uauy C, et al. (2017) Wheat vacuolar iron transporter TaVIT2 transports Fe and Mn and is effective for biofortification. Plant Physiology 174(4): 2434-2444.
25. Singh SP, Gruissem W, and Bhullar NK (2017) Single genetic locus improvement of iron, zinc and β-carotene content in rice grains. Scientific Reports 7(1): 6883.
26. Beasley JT, Bonneau JP, Sánchez-Palacios JT, Moreno LT, Callahan DL, et al. (2019) Metabolic engineering of bread wheat improves grain iron concentration and bioavailability. Plant Biotechnology Journal 17(8): 1514-1526.
27. Liang Q, Wang K, Liu X, Riaz B, Jiang L, et al. (2019) Improved Folate Accumulation in Genetically Modified Maize and Wheat. J. Exp. Bot 70(5): 1539-1551.
28. Joshi AK, Chand R, Kumar S, Singh RP (2004) Leaf tip necrosis: a phenotypic marker associated with resistance to spot blotch disease in wheat. Crop Science 44(3): 792-796.
29. Joshi AK, Kumari M, Singh VP, Reddy CM, Kumar S, et al. (2007) Stay green trait: variation, inheritance and its association with spot blotch resistance in spring wheat (Triticum aestivum L.). Euphytica 153: 59-71.
30. Schwarz I, Scheirlinck MT, Otto E, Bartrina I, Schmidt RC, et al. (2020) Cytokinin regulates the activity of the inflorescence meristem and components of seed yield in oilseed rape. Journal of Experimental Botany 71(22): 7146-7159.
31. Cortleven A, Leuendorf JE, FrankM, Pezzetta D, Bolt S, Schmülling T, et al. (2019) Cytokinin Action in Response to Abiotic and Biotic Stresses in Plants. Plant, Cell. & Environ 42(3): 998-1018.
32. Zwack PJ, Rashotte AM (2015) Interactions between cytokinin signalling and abiotic stress responses. Journal of experimental botany, 66(16): 4863-4871.
33. Lynch JP (2007) Roots of the Second Green Revolution. Aust. Journal of Bot 55: 493-512.
34. Virk PS, Andersson MS, Arcos J, Govindaraj M, Pfeiffer WH, et al. (2021) Transition from targeted breeding to mainstreaming of biofortification traits in crop improvement programs. Frontiers in Plant Science 12: 703990.

How to cite this article: Anindita R, Rupak C. Research Progress on the Role of Cytokinin as a Nutrients Enhancer. Agri Res& Tech: Open Access J. 2019; 28(1): 556362. DOI:10.19080/ARTOAJ.2023.28.556362

35. Yuan Y, Cairns JE, Babu R, Gowda M, Makumbi D, et al. (2019) Genome-wide association mapping and genomic prediction analyses reveal the genetic architecture of grain yield and flowering time under drought and heat stress conditions in maize. Frontiers in plant science 9: 1919.

36. Jighly A, Lin Z, Pembleton LW, Cogan NO, Spangenberg GC, et al. (2019) Boosting genetic gain in allogamous crops via speed breeding and genomic selection. Frontiers in plant science 10: 1364.

37. Mishra DC, AroraD, Budhlakoti N, Solanke AU, Mithra SAC, et al. (2022) Identification of potential cytokinin responsive key genes in rice treated with trans-zeatin through systems biology approach. Frontiers in Genetics 12: 780599.

38. Hönig M, Plíhalová L, Husičková A, Nisler J, Doležal K, et al. (2018) Role of cytokinins in senescence, antioxidant defence and photosynthesis. International journal of molecular sciences 19(12): 4045.

39. Rivero RM, Kojima M, Gepstein A, Sakakibara H, Mittler R, et al. (2007) Delayed leaf senescence induces extreme drought tolerance in a flowering plant. Proceedings of the National Academy of Sciences 104(49) : 19631-19636.

40. Mi X, Wang X, Wu H, Gan L, Ding J, et al. (2017) Characterization and expression analysis of cytokinin biosynthesis genes in Fragaria vesca. Plant Growth Regulation 82: 139-149.

41. Prerostova S, Dobrev PI, Gaudinova A, Knirsch V, Körber N, et al. (2018) Cytokinins: Their impact on molecular and growth responses to drought stress and recovery in Arabidopsis. Frontiers in plant science 9: 655.

42. Gan S, Amasino RM (1996) Cytokinins in plant senescence: from spray and pray to clone and play. Bioessays 18(7): 557-565.

43. Haberer G, Kieber JJ (2002) Cytokinins. New insights into a classic phytohormone. Plant physiology, 128(2): 354-362.

44. Liu Y, Zhang M, Meng Z, Wang B, Chen M (2020) Research progress on the roles of cytokinin in plant response to stress. International journal of molecular sciences 21(18): 6574.

45. Kane AV, Dinh DM, Ward HD (2015) Childhood malnutrition and the intestinal microbiome. Pediatric research 77(1): 256-262.

46. Boliko MC (2019) FAO and the situation of food security and nutrition in the world. Journal of nutritional science and vitaminology, 65(Supplement): S4-S8.

47. UNEP (2021) Food Systems Hold Key to Ending World Hunger.

48. Wakeel A, Farooq M, Bashir K, Ozturk L (2018) Micronutrient malnutrition and biofortification: recent advances and future perspectives. Plant micronutrient use efficiency, pp.225-243.

49. Shariatipour N, Heidari B (2020) Genetic-based biofortification of staple food crops to meet zinc and iron deficiency-related challenges. Plant micronutrients: deficiency and toxicity management, pp.173-223.

50. Akhtar S, Das JK, Ismail T, Wahid M, Saeed W, et al. (2021) Nutritional perspectives for the prevention and mitigation of COVID-19. Nutrition reviews 79(3): 289-300.

51. Koç E, Karayiğit, B (2022) Assessment of biofortification approaches used to improve micronutrient-dense plants that are a sustainable solution to combat hidden hunger. Journal of Soil Science and Plant Nutrition 22(1): 475-500.

52. Jinek M, Chylinski K, Fonfara I, Hauer M, Doudna JA, et al. (2012) A programmable dual-RNA–guided DNA endonuclease in adaptive bacterial immunity. science 337(6096): 816-821.

53. Malik KA, Maqbool A (2020) Transgenic crops for biofortification. Frontiers in Sustainable Food Systems 4: 571402.

54. Eckerstorfer MF, Engelhard M, Heissenberger A, Simon S, Teichmann H (2019) Plants developed by new genetic modification techniques-comparison of existing regulatory frameworks in the EU and non-EU countries. Frontiers in Bioengineering and Biotechnology 7: 26.

55. Lusser M, Parisi C, Plan D, Cerezo ER (2012) Deployment of new biotechnologies in plant breeding. Nature biotechnology 30(3): 231-239.

DOI: 10.19080/ARTOAJ.2023.28.556362

How to cite this article: Anindita R, Rupak C. Research Progress on the Role of Cytokinin as a Nutrients Enhancer. Agri Res& Tech: Open Access J. 2019; 28(1): 556362. DOI:10.19080/ARTOAJ.2023.28.556362