



doi: <https://doi.org/10.20546/ijcrar.2021.907.010>

Role of Cytokinin in Plant Breeding-Review

Yechalew Sileshi*

Ethiopian Institutes of Agricultural Research, Jimma Agricultural Research Center, P.O. Box, 192, Jimma, Ethiopia

**Corresponding author*

Abstract

Developing varieties that are high yielding and tolerant to both biotic and a biotic stress with superior quality than the latterly released varieties is the challenging issues in crop improvement. However, such question can be answered through another alternative ways. Cytokinin is plant hormones that found naturally and influence the architecture and yield of plants. Cytokinins are parts of many plant processes, mainly to promote cell division, cell enlargement, flowering, fruiting, and delay of aging in leaves, seed development and stress tolerance also involved in the regulation of plant defense responses against some pathogens. Cytokinin play great role in plant breeding due to its great guidance in all plant process. Therefore, understanding the impact Cytokinin in crop breeding is paramount important. Hence, the aim of this paper is to assess the role cytokinin in plant breeding.

Article Info

Accepted: 20 July 2021
Available Online: 25 July 2021

Keywords

Cytokinin, Yield Improvement, A biotic stress.

Introduction

Plant breeding is the science of purposive manipulation of plants in order to develop desired characters for the benefit of human through different techniques (Sleeper and poehlman, 1995). The challenge issue to plant breeders is to develop varieties that are high yielding and tolerant to both biotic and a biotic stress with superior quality in communal methods of breeding. However, such challenging issue can be achieved in another alternative ways. Cytokinin is a plant hormone and plays a key role in breeding target due to their influence on plant architecture and yield (Schmülling, 2004). Cytokinin are parts of many plant processes and participates in all stages of development (Chiwocha *et al.*, 2005; Nikolic *et al.*, 2006; Riefler *et al.*, 2006). It activates the germination of seed under stresses condition such as salinity, drought, heavy metals and oxidative

(Khan and Ungar, 1997; Atici *et al.*, 2005). Cytokinin break stress-induced dormancy during germination in tomato, barley and cotton seeds (Bozcuk, 1981). Cytokinin have significant role in signaling effect for branch formation, sink strength, control the transition from the vegetative to the reproductive growth stage (Riefler *et al.*, 2006; Heyl *et al.*, 2012). Cytokinin is active in nodule formation in legumes crop (Murray *et al.*, 2007; Santner *et al.*, 2009). Crop yield can be maximized through increased seed number or seed size and quality improved potentially through the manipulation of transporters such as those loading amino acids or sugars into developing seeds. The plant hormone group, the cytokinins, is strongly impact in seed yield, both in terms of seed number and seed size. Cytokinin also have pivotal role in developing both biotic and a biotic stress tolerance crops. Hence, the aim of this paper is to review the role cytokinin in plant breeding.

Effect of Cytokinin on Preventing Leaf Senescence

Leaf is an important plant organ where carbohydrates, nutrients and some novel compounds are produced. Plant leaf is the key source for grain filling (Gan and Amasino, 1995). Leaf senescence is an important trait in crop improvement for increasing crop yield and improving quality of horticultural crops such vegetables after harvest (Guo and Gan, 2014). Transgenic plants harboring this system displayed significant delay in leaf senescence, substantial increase in yield and biomass, enhanced tolerance to drought and other stresses, and remarked improvement in postharvest performance.

The effect of cytokinin is well documented on senescence delaying (Paul, *et al.*). Other similar senescence associated gene promoters have also been used. This cytokinin biology based technology is approaching commercialization (Gan and Amasino, 1997).

The transcription factor biology-based technology can be exemplified using AtNAP. AtNAP is a senescence-specific transcription factor that regulates leaf (and fruit) senescence (Kou X *et al.*, 2012). Knocking out or down of this gene in Arabidopsis led to nearly 50% increase in leaf's photosynthetic longevity.

In principle, knocking out or down of its counterpart gene in a crop should lead to the similarly delayed leaf senescence phenotype and enhanced grain yield. This was well observed in maize and rice. Maize plants with suppressed ZmNAP expression had 15-30% increases in 1000-seed weight, and rice plants with suppressed OsNAP expression showed up to 24% increase in rice grain yield is reviewed.

Most recently up to 10.3% increase in rice grain yield was also observed in the OsNAP-down-regulated rice lines (Liang *et al.*, 2014). In other crops including soybean and cotton this technology is applied. A study that regulated leaf senescence in tobacco leaves found that wild-type leaves yellowed while transgenic leaves remained mostly green.

It was hypothesized that cytokinin may affect enzymes that regulate protein synthesis and degradation (Wingler *et al.*, 1998). Hence leaf senescence is an imperative trait that negatively impacts on crop yield and quality. With the increasingly understanding of regulatory mechanisms of leaf senescence, emerging new technologies targeting the leaf senescence trait have been, and will continue to be, developed for crop improvement.

Effect of Cytokinin on Yield Improvement

Seed development is occur in two distinct phases. A positive correlation between cytokinin levels and the phase of cell division has been shown in developing fruits and seeds, in Cereals such as maize, wheat, rice, and barley have sharp, transiently elevated endogenous cytokinin levels immediately after anthesis. In wheat, for example, the sharp increase in endogenous cytokinins occurs during the phase of rapid endosperm nuclear and cell division in the developing grain a phase critical in establishing final sink size. Similar conclusions were reported for maize (Brugière *et al.*, 2008) and rice (Yang *et al.*, 2003). Cytokinins is strongly implicated in seed yield, both in terms of seed number and seed size.

On seed size and sink activity, the cytokinin biosynthetic gene family (the IPTs) and the gene family key to the destruction of cytokinins (the CKXs), as well as other gene families potentially affected by changing cytokinin levels that can suppress or depress the activity of some genes.

In soybean and lupin had shown that treatment with cytokinins increased pod set and/or delayed abscission of flowers and young pods (Crosby *et al.*, 198) indicating that cytokinin might be limiting in these processes in legumes. Carlson *et al.*, (1987) showed that the application of the cytokinin 6-benzylaminopurine (6-BAP) to soybean significantly increased pod initiation by 58% and doubled the number of positions which had a 100% probability of setting pods.

Similarly in lettuce addition of cytokinin (kinetin) product, increased yields when the product was applied twice after head formation (Jorge, 2004). In a field trial, application cytokinin increased the yield of rice by 45.8% compared to control (Zahir *et al.*, 2001). The transgenic tobacco showed increased seed weight, and increased carbohydrate and protein content by 7-8%, without any morphological abnormalities (Yang *et al.*, 2003).

Carlson (1987) indicated that the probability that a flower will produce a mature pod is dependent upon the total amount of cytokinin available to that flower throughout reproductive development, there is a close association between cytokinin flux and pod set in soybean, and the ability to enhance pod set through exogenous applications of 6-BAP. They stressed that to obtain significant increases in seed yield would require either a substantial increase in pod number or the identification

of mechanisms by which seed size could be maintained despite the increased reproductive load.

The Role of Cytokinin in Mitigation of Salt Stress in Crop

Cytokinin can also enhance resistance to salinity and high temperature in plants (Barciszewski *et al.*, 2000). Seed enhancement (seed priming) with cytokinins is reported to increase plant salt tolerance (Iqbal *et al.*, 2006a). It was hypothesized that cytokinins could increase salt tolerance in wheat plants by interacting with other plant hormones, especially auxins and ABA (Iqbal *et al.*, 2006a). Exogenous application of kinetin overcame the effects of salinity stress on the growth of wheat seedlings (Naqvi *et al.*, 1982) and treatment of potato plants with kinetin prior to salt stress diminished salt-related growth inhibition (Abdullah and Ahmad, 1990). However, earlier studies reported that application of kinetin to bean plants during salinity stress exacerbated its effects (Kirkham *et al.*, 1974).

The Role of Cytokinin to Develop Drought Tolerant Crop

Drought is a major factor in crop production, accumulation of osmotic compounds such as proline and changes in phytohormones are some of the most common response of plant to drought stress, proline accumulation is associated with improvement in drought tolerance in plant and evidence indicate that plant physiological fitness is largely governed by plant hormones. It is reported that application of exogenous cytokinin can improve tolerance to drought this is reported in many crop such as in turf grass, rice, soybean, potato (Zhang and Ervin, 2004).

One study found that applying cytokinin to cotton seedlings led to a 5–10% yield increase under drought conditions (Kazan *et al.*, 2015), similar transgenic tomato and maize with enhanced plant hormones are reported for drought tolerance, based on the ability of cytokinin to enhance plant cell division and regulate a range of plant activities including seed germination. (Miller *et al.*, 1955) and have role in developing drought tolerant crop. They can also affect the activities of meristemic cells in roots and shoots, as well as leaf senescence. In legumes nodule formation is severely affected by drought and cytokinin are effective in nodule formation during establishment of the N₂-fixing symbiosis and other interactions between plant and microbes (Murray *et al.*, 2007; To and Kieber, 2008; Santner *et al.*, 2009).

Cytokinin for Large Flower Size

Large flower size is one of the important traits that decide the economic success of a floricultural plant. This is clearly illustrated by the fact that many floricultural plants have relatively larger flowers than their corresponding wild species. However, a large flower trait takes a long time to breed because of the rare occurrence of mutations in genes responsible for flower size (Nishijima, 2007). Recent studies using model plants, such as *Arabidopsis*, has illustrated that flower size depends mainly on genes mediating plant hormone biosynthesis and signal transduction. Cytokinin response had great for the induces of large flower phenotype (Nishijima *et al.*, 2006).

Cytokinin is a class of plant specific hormones that play a central role during the cell cycle and influence numerous developmental activities. Cytokinins are involved primarily in cell growth and differentiation, but also affect apical dominance, axillary bud growth, and leaf senescence. Recent report clearly indicates that cytokinin is used in various breeding program such as, yield increment. Cytokinins can also enhance tolerance to the most challenging and changing biotic stress such as drought, salinity and high temperature. The application of enhanced plant hormones is greatly importance in breeding program that aid in developing important traits that are un-addressed by conventional breeding. The biological activities and chemistry of cytokinins are well defined but information is scant about their mode of action.

References

- Abdullah Z, Ahmad R.1990. Effect of pre- and post-kinetin treatments on salt tolerance of different potato cultivars growing on saline soils. *J Agron Crop Sci* 165: 94-102.
- Aikins C. A., Emery R. J., Smith P. M. C. 2011. Consequences of transforming narrow leafed lupin (*Lupinus angustifolius* L.) with an ipt gene under control of a flower-specific promoter. *Transgenic Res.*20: 1321–1332.
- Aikins C. A., Pigeaire A.1993. Applications of cytokinins to flowers to increase pod set in *Lupinus angustifolius*. *Aust. J. Agric. Res.* 44: 1799–1819.
- Amasino R. 2005. The 50th anniversary of a new plant hormone plant physiology.138:1177 1184
- Annu S. N, Anish S, Jiancheng S, and Paula E, Jameson. 2017. Differential Gene Expression in the

- Meristem and during Early Fruit Growth of *Pisum sativum* L. Identifies Potential Targets for Breeding. *Int. J. Mol. Sci.* 18, 428.
- Ashikari, M., Sakakibara H., Lin S. Y., Yamamoto T., Takashi T., Nishimura A, Angeles E. R., Qian Q., Kitano H., Matsuoka M. 2005. Cytokinin oxidase regulates rice grain production. *Science*. 309:741–745.
- Atia A., Debez A., Barhoumi Z., Smaoui A., Abdely C. 2009. ABA GA3, and nitratemay control seed germination of *Crithmum maritimum* (Apiaceae) under saline conditions. *Com Rend Biol.* 332: 704–710.
- Atici O., Agar G., Battal P. 2005. Changes in phytohormone contents in chickpea seeds germinating under lead or zink stress. *Biol Plant.* 49: 215–222.
- Barciszewski J, Siboska G, Rattan SIS, Clark BFC. 2000. Occurrence, biosynthesis and properties of kinetin (N6-furfuryladenine). *Plant Growth Regul.* 32: 257-265
- Bartrina I, Otto E., Strnad M., Werner T., Schmülling T. 2011. Cytokinin regulates the activity of reproductive meristems, flower organ size, ovule formation, and thus seed yield in *Arabidopsis thaliana*. *Plant Cell.* 23:69–80.
- Brugière N, Humbert S, Rizzo N, Bohn J, Habben JE. 2008. A member of the maize isopentenyl transferase gene family, *Zea mays* isopentenyltransferase 2 (ZmIPT2), encodes a cytokinin biosynthetic enzyme expressed during kernel development. *Plant Molecular Biology.* 67: 215–229.
- C. M. Busing, R. C. Shoemaker and R. M. Benbow. 1994. "Early Events of Multiple Bud Formation and Shoot De-velopment in Soybean Embryonic Axes Treated with the Cytokinin, 6-Benzylaminopurine. *American Journal of Botany.* Vol. 81:1435-1448.
- Carlson D. R., Dyer D. J., Cotterman C. D., Durley, R. C. 1987. The physiological-basis for cytokinin induced increases in pod set in IX93-100 soybeans. *Plant Physiol.* 84:233–239.
- Chen C M, Ert J R, Leisner S M, Chang C C. 1985. localaztion of cytokinin biosnthetic sites in pea plants and carrot roots.
- Chiwocha, S. D., Cutler, A. J., Abrams, S. R., Ambrose, S. J., Yang, J. 2005. The *etr1- 2* mutation in *Arabidopsis thaliana* affects the abscisic acid, auxin, cytokinin and gibberellin metabolic pathways during maintenance of seed dormancy, moist-chilling and germination. *Plant J.* 42, 35–48.
- Ch Y., Suh S. K., Park H. K., Wood A. 2002. Impact of 2,4-DP and BAP upon pod set and seed yield of soybean treated at reproductive stages. *Plant Growth Regul.* 36: 215–221.
- Crosby K. E., Aung L. H., Buss G. R. 1981. Influence of 6-benzylaminopurine on fruit-set and seed development in two soybean, *Glycine max* (L.) Merr. genotypes. *Plant Physiol.*
- Davies P J. 2004. *Plant hormones: biosynthesis, signal transduction, action.* Kluwer Academic Press, the Netherlands
- Dyer D. J., Carlson D. R., Cotterman, C. D., Sikorski J. A., Ditson S. L. 1987. Soybean pod set enhancement with synthetic cytokinin analogs. *Plant Physiol.* 84:240–243.
- Gan S. 2010. The hormonal regulation of senescence, in *Plant Hormones: Biosynthesis, Signal Transduction,* Springer: Dordrecht, The Netherlands. 597-617.
- Gan S, Amasino R M. 1995. Inhibition of leaf senescence by autoregulated production of cytokinin. *Science* 270: 1986-1988.
- Gan S, Amasino R M. 1997. Making sense of senescence. *Molecular genetics regulation and manipulation of leaf senescence.* *Plant Physiol* 113: 313-319.
- Gan S, Hortensteiner S. 2013. *Frontiers in plant senescence research: from bench to bank.* *Plant MolBiol* 82: 503-504.
- Guo Y, Gan S. 2006. AtNAP, a NAC family transcription factor, has an important role in leaf senescence. *Plant J* 46: 601-612.
- Guo Y, Gan S. 2014. Translational researches on leaf senescence for enhancing plant productivity and quality. *Journal of Experimental Botany.*
- Ikram-ul-Haq, M. U. Dahot, Morpho. 2007. *Physiological Aspects of Micro-Propagating Banana under Different Hormonal Conditions.* *Asian Journal of Plant Sciences.* Vol. 6: 496-501.
- Iqbal M, Ashraf M, Jamil A. 2006a. Seed enhancement with cytokinins: changes in growth and grain yield in salt stressed wheat plants. *Plant Growth Regul* 50: 29-39
- Jorge Fonseca. 2004. Evaluation of the effect of cytokinin products on yield of head lettuce; The University of Arizona – Yuma Agricultural Center, Yuma AZ
- Kazan k. 2015. Diverse roles of jasmonates and ethylene in abiotic stress tolerance: trends plant sci. vol. 20: 219-229

- Kerong Zhang, Ludger Diederich, and Peter C. L. John.2005. Implications for Mechanisms of Cytokinin Response and Plant Development: Plant Physiol. 2005 Jan; 137: 308–316
- Khan M. A., Ungar I. A.1997. Alleviation of seed dormancy in the desert for *Zygo-phyllym simplex* L. from Pakistan. Ann Bot. 80: 395–400.
- Kieber J J.2002. Tribute to Folke Skoog recent advances in our understanding of cytokinin biology.j.plant growth regul :21:1.2.
- Liang C, Wang Y, Zhu Y, Tang J, Hu B, *et al.*, 2014. OsNAP connects abscisic acid and leaf senescence by fine-tuning abscisic acid biosynthesis and directly targeting senescence associated genes in rice. ProcNatlAcadSci USA.
- Mansfield S. G., Bowman J.1993. Embryogenesis. In Arabidopsis. In: Bowman,J. (Ed.), An Atlas of Morphology and Development. Berl., Springer-Verlag. pp.49–362.
- Miller C O, Skoog F, Okumura F S, von Saltza M H, Strong F M.1955b. Structure and synthesis of kinetin. J Am Chem Soc 78: 2662–2663.
- Mok, D. W. S., Mok, M. C. 2001 Cytokinin Metabolism and Action.
- N. Jafari R. Y. Othman and N. Khalid. 2011.Effect of Ben- zylaminopurine (BAP) Pulsing on in Vitro Shoot Multi- plication of *Musa acuminata* (Banana) cv. Berangan,” Af- rican Journal of Biotechnology.Vol. 10.
- Naqvi S S M, Ansari R, Kuawada A N.1982. Responses of salt stressed wheat seedlings to kinetin. Plant Sci Lett 26: 279-283.
- Nishijima T. and K. Shima. 2006. Change in flower morphology of *Torenia fournieri* Lind. induced by forchlorfenuron application. Sci. Hortic. 109: 254–261.
- Peterson C. M., Williams J. C., Kuang, A. X. 1990.Increased pod set of determinate cultivars of soybean, *Glycine max*, with 6-benzylaminopurine. Bot. Gaz. 151: 322–330.
- Plant-growth-hormones (<http://www.untamedscience.com/biology/plants/plant-growth-hormones/>). Assessed on April 01 2017
- Rajendra Bari Jonathan D. G. Jones.2009.Role of plant hormones in plant defence responses :Plant Mol Biol 69:473–488.
- Rhind N Russell P. 2001. Roles of the mitotic inhibitors Wee1 and Mik1 in the G2 DNA damage and replication checkpoints. Mol Cell Biol.21: 1499–1508
- Riefler M., Novak O., Strnad M., Schumling T. 2006. Arabidopsis cytokinin receptor mutants reveal functions in shoot growth, leaf senescence, seed Size, germination, root development, and cytokinin metabolism. Plant Cell 18,40–54.
- Schumling, T. 2004. Cytokinin. In Encyclopedia of Biological Chemistry (Eds. Lennarz, W., Lane, M. D.) Academic Press/Elsevier Science.
- Thomas T H.1992. Some reflections on the relationship between endogenous hormones and light-mediated seed dormancy. Plant Growth Regul 11: 239-248.
- Wingler A von Schaewen A, Leegood R C, Lea P J. Quick W P.1998. Regulation of leaf senescence by cytokinin suger and light plant physiol.1:329-335.
- Yang J, Zhang J, Wang Z, Zhu Q. 2003. Hormones in the grains in relation to sink strength and postanthesis development of spikelets in rice. Plant Growth Regulation 41:185–195.
- Zhang x., Ervin E. H.2004. Cytokinin containing seaweed and humic acid extracts associated with creeping bentgrass leaf cytokinin and drought resistance.crop sci.44:1737-1745
- Sleper and poehlman. 1995.Breeding field crops. Page 3

How to cite this article:

Yechalew Sileshi. 2021. Role of Cytokinin in Plant Breeding: - Review. *Int.J.Curr.Res.Aca.Rev.* 9(07), 71-75. doi: <https://doi.org/10.20546/ijcrar.2021.907.010>