Polyamines in Vegetable Production: A Universal Process with Diverse Roles

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Abstract

Vegetables vital an important role in human diet, as they are rich source of essential nutrients. For sustainable vegetable production and to meet the vegetable demand advancement in production techniques of vegetable crops is need of an hour. Use of polyamines as a tool for improving the vegetable production is found to be beneficial. Polyamine (PA) catabolic processes are performed by copper-containing amine oxidases (CuAOs) and flavin-containing PA oxidases (PAOs). So far, several CuAOs and PAOs have been identified in many plant species. Since PAs are involved in numerous physiological processes in plants and also play important role in ion channels regulation and transportation of different molecules in cell membrane. Polyamines are associated with many important processes such as DNA replication, RNA modification, synthesis of protein, modulation of enzyme activities and transcription in plants. Several studies have been conducted to study the effect of different polyamines (putrecine, spermidine, spermine etc.) on growth and development of vegetables for better outcome.

Key word: Polyamines, biotic and abiotic stress, Putrecine

Introduction

Polyamines are the organic poly-cation compounds consisting of two or more amino groups or positively charged aliphatic amines and are produced during metabolism that are extensively distributed in the cells of eukaryotes and prokaryotes. They were misunderstood as “ptomaine or food poisoning” substances by toxicologists. The commonly known PAs in plants are putrescine (Put), spermidine (Spd), and spermine (Spm), cadaverine (Cad) and thermospermine (t-Spm), a Spm isomer (Vuosku *et al.*, 2018). Among these, putrescine is considered as diamine while spermidine and spermine are classified as higher polyamines and the classification is based on the strength of the amines which increase from putrescine to spermidine and spermine. Usually, the more the amino groups, the stronger the physiological activity. They are involved in many physiological processes in like embryogenesis, organogenesis senescence, flower development, fruit maturation, fruit development and responses to environmental stress and are considered as new kind of plant bio-stimulants. They are also involved in plant growth and development, and ripening processes. Polyamines involve in many important processes such as DNA replication, RNA modification, synthesis of protein, modulation of enzyme activities and transcription (Nahar *et al*., 2016)

Polyamines in flowering, fruit setting and fruit retention

Exogenous application of polyamines to poorly flowering plants substantially increased their response to flowering. In rapeseed, lower level of polyamines was found to be beneficial for the initiation of flower bud differentiation and an higher level of polyamines were useful for development of flower bud. Crop yield is directly related to the fruit set after the pollination. Poor fruit set due to heavy post-bloom and pre-harvest drop rarely produce economic crop. Furthermore, ethylene was developed from pollinated flowers, which suggests that ethylene has a role of in fertilization. Application of putrescine during anthesis time increased fruit set and yield in vegetable crops (Xu, 2015).

Polyamines in stomatal movements

Stomata play an important role in the exchange of gases between the environment and plant. Potassium ions play significant role in controlling the opening and closing of stomata. Several studies have shown the inward potassium ions channel inhibiting factors (polyamines, abscisic acid and Ca2+ levels) usually inhibit the opening of stomata. Like abscisic acid, polyamines also have role in regulation of stomata with different mechanism, while abscisic acid brings out turgor loss by outward potassium ion channels and activating anion channels. In contrast, polyamines do not affect the anion channels or inward potassium ion channels, thus indicating the capability of some other targets of polyamine besides potassium ion channels in guard cells for initiation of closure of stomata. Regulation of stomata is one of the most reviewed plant response mechanisms to stresses. Several stress factors are well-known to elate polyamines. Whole-cell patch clamp analysis showed that the intracellular applications of all natural polyamines (spermine, spermidine, putrescine and cadaverine) induced the stomatal closure by inhibiting the inward potassium ion current across the plasma membrane of guard cells (Liu *et al*., 2000).

Polyamines in extension of shelf life

Ethylene is a senesce promoting hormone and promotes ripening of fruits. Both ethylene and polyamine has the same precursor i.e. S-adenosyl methionine, hence polyamines biosynthesis inhibit the biosynthesis of ethylene by competing for the common precursor, because both ethylene and polyamine have opposite effect on the senescence and fruit ripening. Many studies have indicated that the polyamines could inhibit the synthesis of 1-aminocyclopropane-1-carboxylic acid (precursor of ethylene) which reduces production of ethylene. Application of polyamines, their precursors and metabolites (putrescine, spermine, spermidine, γ-aminobutyric acid, methionine and diaminopropane) prolonged the storage life of tomato fruits, application of putrescine enhanced shelf life and quality of Punjab Ratta cultivar of tomato during storage (Li *et al*., 2004).

Polyamines in abiotic and biotic stress

Major abiotic stress factors are extreme temperature, frost, drought, salinity and pollutants. While biotic stress factors are the pathogens. It is a well known fact that all types of stresses produce species of reactive oxygen in the biological system which is highly toxic and leads to oxidative stress. Higher putrescene content was found to be associated with greater insect resistance in chinese cabbage.

Heat shock protein synthesis is one of the responsive mechanisms by the plant to prevent the harmful effects caused due to high temperature stress. Polyamines directly affect the synthesis of heat shock proteins by affecting the properties of cell. S-adenosyl-methionine decarboxylase is the major regulatory enzyme in the synthesis of polyamines. Under heat stress condition, transgenic tomato plants having S-adenosyl-methionine decarboxylase produced 1.7 to 2.4 times higher spermidine and spermine than non-transgenic tomato plants. Foliar application of spermidine improved the antioxidant enzymes activity in cucumber seedlings, which reduced the effects of high temperature. Application of spermidine at 4 mM in two cultivars of tomato improved the heat tolerance, pollen growth and tube germination under high temperature stress condition (Maestri *et al*., 2002).

Polyamines can be used to inhibit the chilling injury in vegetable crops which enhances the marketable life and quality of the produce. Chilling injury not only affects the

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shape of the produce but also deteriorates its quality. The imbalance occurred during the stress condition leads to the acidification of the cytoplasm with serious effects on the homeostasis and the metabolic regulation of living cells. Application of spermine or putrescine at 1 to 10 mM protected lysis of isolated protoplasts and reduced the breakdown of macromolecules. Exogenous application of polyamines reduces the chilling injury in various vegetable crops during storage. Post-harvest dipping of polyamines reported to reduce the chilling injury in cucumber (Velikova *et al*., 2000).

Drought and salt stress are the two major abiotic stresses in crop production. Endogenous application of spermine was strongly related to drought resistance in cherry tomato. he exogenous application of polyamines reduced the effects of NaCl stress and reduced damage in various vegetable crops. Generally, the plants rich in polyamines show strong tolerance to salt. It was indicated that the spermidine level in plants is an important indicator of salt tolerance (Meng *et al*., 2015). Application of polyamines in tomato plants was effective in amelioration of NaCl stress. Exogenous application of spermine and spermidine increased photosynthesis and reactive oxygen metabolism, which enhanced the growth of plant and reduced the inhibitory effects of salt stress. in soybean seedlings.

Application of polyamines or their precursors to the leaves of plants increased the activity of peroxidase and polyphenol oxidase in bean plant, which is related to the increased resistance against the attack of disease causing pathogens. Moreover, phenol synthesis is very important in various forms of resistance. The pathogen related protein activity develops resistance against viral and fungal infections in plants. Hiraga *et al*. (2000) reported that the polyamines might have a role in developing resistance against infection in plants by activating the protein gene.

Conclusion

Vegetables are the rich source of vitamins, minerals, nutrients and are essential for balanced diet. Major problem during transportation of vegetables is their poor shelf life, which is causing huge post-harvest losses. Polyamines (putrescine, spermine, spermidine etc.) have been involved in increasing the shelf life of vegetable crops. Along with enhancing the shelf life, they also promote growth and development of vegetable crops, and plays important role in tolerating the effects of various stresses (biotic and abiotic stresses). They help in persuading the resistance against diseases.

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