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Molecular Biology of Plant Tolerant to Acidic Soil Condition

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SUMMARY

Soil acidity is the condition in which the pH of the soil falls below 7. Soil pH level is a measure of concentration of hydrogen ion in the soil. The lower the pH level of soil, the greater the acidity. Acid soil is a worldwide problem to plant production. Acid toxicity is mainly caused by a lack of essential nutrients in the soil and excessive toxic metals in the plant root zone. Of the toxic metals, aluminum (Al) is the most prevalent and most toxic. Soil acidity has adverse effect on the plant growth in several growth condition. High soil acidity in the soil results in the damage of epidermal and cortical cell, depolarization of membrane, swollen the root hair and crack formation, reduction in root elongation, blockage of cell division and disruption of plasma membrane integrity. The plant respond to the acidic soil is performed with several components. Understanding the molecular basis of the plant tolerant to the acidic condition helps in better understanding of the physiological mechanism and for better understanding for further improvement.

INTRODUCTION

Plants are prone to different environmental stress which question the growth of the plant under that stress condition. Acid soil is a worldwide problem to plant production. Acid toxicity is mainly caused by a lack of essential nutrients in the soil and excessive toxic metals in the plant root zone. Of the toxic metals, aluminum (Al) is the most prevalent and most toxic. There are different ways of the formation of acidic soil. It can be through the rain water as we know that the rainwater is slightly acidic in nature. When we apply organic matter in the soil, it disintegrate into carbondioxide which on combination with water from the carbonic acid which leads to the formation of acidic soil also through the parent rock like granite. And the most important one being the application of ammonium fertilizer, this fertilizer release ammonium ion which on formation to nitrate ion release hydrogen ion which leads to the acidic soil. Acidic soil has adverse effect in the growth of the plant. It has toxic effect in morphological as well as physiological condition. Understanding its effect in the molecular level has now become important.

Molecular Biology of Plant Tolerant to Acidic Stress:

When there is high concentration of acidity in the soil, it will produce hydrogen proton and when the plant sensed hydrogen ion it will try to exclude the ions through P-ATPase and V-ATPase. But when the concentration is high it will enter the plasma membrane. So, the H+ ATPase present in the plasma membrane contributes to the maintainance of cellular pH and generate the H+ electrochemical gradient for the cellular influx and efflux of ions, particularly the influx of nutrient ions due to acidic nature of the soil, the root H+ ATPase activity increases. H+-ATPases are energy-driven membrane transporters of protons and seem to be the first to react to an increased concentration of protons in plant cells. After entering in the cytoplasm it can go to three different organelles. The hydrogen ion is required for the signaling pathway of auxin, salicylic acid etc. through the signaling pathway, either several transcription factors are being activated or formation of chaperon with the heat shock proteins take place. Chaperone ROF1 and ROF2 genes encode peptidyl-prolyl cis-trans isomerases with calmodulin binding, and regulate intracellular pH homeostasis, with the potential to interact with Hsp90/Hsp70 as co-chaperones.

These two genes showed different expression profiles in Arabidopsis plants: ROF1 was expressed under normal conditions, while ROF2 expression was only detectable following exposure to stress. As a result of many abiotic stresses, including high H+ rhizotoxicity around roots, the cell cytoplasm begins to acidify. This activates ROF2 with subsequent expression of both K+ transporters (AKT, HAK, and others) and H+-ATPase to enable proton pump-driven extrusion from the cytoplasm into the apoplast. Protons are then sequestered outside the root tissue. Also it lead to the activation of several transcription factors like STOP, STOP2, DREB, WRKY, NAC, HSF. A number of DREB family members were found to be responsive to acidity stress, showing changes (up- or downregulation) specifically in Arabidopsis root tip columella cells. HSFs act as TFs and regulate the expression of other genes but, at the same time, HSFs are co-ordinated and co-regulated by DREB TF. HsfA1a showed a direct response to pH stress and was highly activated in response to changing soil pH in Arabidopsis. Thus these transcription factors gave some upregulation or downregulation of transporter genes. Some transporter genes like NO3 needs to be transported outside the plant system to neutralize the acidity in the soil through the biochemical pH-stat mechanism. This is one of the mechanism for plant tolerant to acidic soil condition. Second mechanism is by activation of some genes in the mitochondria against the enzymes like superoxide dismutase, peroxidase, catalase etc.

In general, the AOX in plant mitochondria transfers electrons from the ubiquinone pool to oxygen without energy conservation. One of the most important roles of AOX is to ameliorate harmful ROS production when the cytochrome pathway is inhibited in the cell. Because of the activation of this gene it will lead to the adaptability of the plant under acidic soil condition. The third mechanism is the extension of cell wall. Cell-wall extension is mediated by a group of expansin genes that denature cell-wall proteins and increase cell-wall growth and extensibility, particular in low pH soils—a phenomenon named ‘acid growth’. Cell-wall acidification can promote expansin expression, inducing cell elongation and extension. Due to the extension and elongation, the acidity is neutralized inside the cell thus leads to the tolerance of the plant. Either of these 3 mechanism leads to the tolerance of plant under acidic soil condition.

CONCLUSION

Nowadays agriculture is threatened by a number of abiotic stress with acidic condition one of the major stress prevailing in the country. So, knowing the gentic basis of tolerance mechanism of a plant is necessary to cope up and producing plants with tolereance mechanism. So, efforts have been made by Plant breeder in developing abiotic stress resistant crop plants but plant breeding methods alone are not sufficient enough. Thus it calls for the need of Genetic engineering in combination with plant breeding in crop improvement has become a great importance in assuring world future food security.

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