Research Progress of Plant Calcium Nutrition and Calcium / Cold Signal Interaction

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Abstract. Calcium, as the second messenger inside plants, is extensively involved in plant response and transduction of various stress signals. Plants shall generate calcium signals of specificity under stress, and this shall give a rise to a series of intracellular physiological and biochemical responses. Calcium ions, under cold stress, are able to lower phase transition temperature of membrane lipids, while also able to strengthen plant cold resistance through maintaining soluble sugar and protein content in cells, and increasing unsaturated lipid or fatty acid content in membrane lipids. A general review of research home and abroad over recent years is presented hereby on plant calcium nutrition and calcium/cold signal interaction and regulation.

Introduction

Calcium plays an important role in plant physiological metabolism and intracellular signal transduction. Ca^{2+} is regulatory for plants during their adaptation to environment (Zou Juanzi et al., 2014). Currently, it is discovered that under cold stress, plants use intracellular calcium ions as the second messenger to mediate biochemical reactions, and this shall initiate a rapid rise of intracellular Ca^{2+} level (Bush DS., 1995). Some researchers have confirmed for the time being that calcium is regulatory to plant photosynthesis under cold stress. Therefore, researches on calcium regulation under cold stress prove to be of importance to agriculture production.

Perception of Cold Signals by Plants

It is discovered that there are three cold signal transduction pathways: cold response due to membrane fluidity changes caused by low temperature; cold response due to chloroplast energy conversion imbalance; cold response from plants based on protein phosphorylation (Miura K et al., 2013).

At the moment, a portion of plant cold-resistance genes has been isolated and identified, of which they are cor15a, ltil40 (Nordin K et al.,1991), rab18 (Ling V et al.,1992) and rd29 (Yamaguchi Shinozaki K et al.,1993) for *Arabidopsis thaliana*, hva1 (Marttila S et al.,1996) and blt4 (Phillips JR et al.,1997) for barley, together with lip15 for rice and the similar (Sell S et al.,2004).

Plant Calcium Nutrition Effects and Regulatory Mechanism for Calcium / Cold Signal Interaction

Calcium, one of the essential elements for plant nutrients, is a necessary mineral element as not easily to be moved inside plants. It serves as the bridge between membrane phospholipid phosphate group and protein carboxyl in terms of cellular structure as well as physiological functions (Anireddy SN et al., 2011; Zhou Wei et al., 2007). Calcium ions, as the intracellular signal substances involved in responses to environmental stimulus at the same time, play an important part in regulating plant in response to biotic stress and abiotic stress.

The present studies confirm that there are two modes for calcium signals to regulate physiological responses. One is that calcium signals induce cellular response independently, during which intracellular calcium signals, as essential to responses, shall stimulate specific calcium ions to change, and then stimulate specificity change in a way further. The other one is that stimulus, which not only shall help to generate calcium signals, but also generate other signals. Both modes jointly regulate physiological and biochemical responses.

Knight and others believed that low temperature led to membrane fluidity reduction, so that membrane rigidity allowed the Ca^{2+} pathway to open up for Ca^{2+} inflow (Knight MR et al.,1991). Kratsch and Wise believed that responses from plant cells to low temperature stress were mainly from chloroplast. Plant cell chloroplast was much sensitive to low temperature, so low temperature was able to change PSII reduction inside chloroplast, causing it to generate reactive oxygen species (ROS) of high level. Then ROS would activate such Ca^{2+} reservoirs as endoplasmic reticulum, vacuole, mitochondrion and the similar, facilitating release of Ca^{2+} from these reservoirs into cytoplasm (Kratsch HA et al., 2000).

Regulation Mechanism for Calcium / Cold Signal Interaction and Its Application

As previous studies have found, exogenous calcium was able to improve photosynthesis and photosynthetic apparatus functions for many varieties of crops under abiotic stress (Zhu Xiaojun et al., 2004).

As studies on tomatoes under low night temperature stress have indicated, exogenous calcium not only improved net photosynthetic rate of tomato leaves under low night temperature stress, but also mitigated stomatal conductance (GS), intercellular CO_2 concentration (Ci) and transpiration rate decline (Tr). Since Ca^{2+} could maintain stomatal conductance, ensuring ample CO_2 transportation and CO_2 concentration of leaves, then it would mitigate low night temperature stress (Liu Yifei et al., 2012).The exogenous calcium as applied could improve root activity of tomato seedlings remarkably, and it was regulatory to oxygen metabolism of root activity and effective to enhance osmotica regulators of protective enzyme activity so as to mitigate low night temperature stress, facilitating photosynthate accumulation at the same time (Liu Yifei et al., 2012). Pretreatment with $CaCl_2$ could mitigate low night temperature stress to tomatoes when carbon assimilation, PQ pool size, linear and cyclic electron transport, xanthophyll cycle and ATP enzyme activity were all improved (Zhang Guoxian, 2014).

As some studies have suggested, Ca^{2+} could maintain higher photosynthetic intensity in wheat leaves under low night temperature stress. It was because Ca^{2+} would mitigate light damage by maintaining activities of ribulose-1,5-bisphosphate carboxylase, ensuring higher level of chlorophyll a and chlorophyll b, together with photosynthetic intensity and carotenoids content, too (You Jihong et al., 2002).

Conclusions

Studies on molecular and physiological mechanisms for calcium nutrient to mitigate low temperature stress for plants, together with cloning and identification of their detailed functional genes, are mostly carried out on these plants such as *arabidopsis thaliana* and rice. Relevant studies on other types of plants are rather restricted. Does there exist any new regulating ways? What are *the major genes in calcium / cold signal interaction*? In particular, how could the temporal and spatial expression of the major genes in calcium / cold signal interaction eliminate photosynthesis disturbance for crops under low temperature? These scientific issues above mentioned need further consideration and research by us.

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