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Roles of Arabidopsis Bax inhibitor-1 in delaying methyl jasmonate-induced leaf senescence

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Previous studies have reported that methyl jasmonate (MeJA) can promote plant senescence. *Arabidopsis thaliana* BI1 (AtBI1) participates in leaf senescence and JA signal pathway. Our recent report has suggested that AtBI1 plays a crucial role in MeJA-induced leaf senescence. Concomitantly, cytosolic calcium [$(Ca^{2+})_{cyt}$] and MPK6, a mitogen-activated protein kinase (MAPK), participate in the process of MeJA-induced leaf senescence. And *AtBI1* might play its roles in delaying MeJA-induced leaf senescence by suppressing the $[Ca^{2+}]_{cyt}$-dependent activation of MPK6. Our study contributes to the understanding of the function and mechanism of AtBI1 in plant senescence. Though some of signaling molecules have been elucidated in this type of plant senescence, the mechanism of AtBI-1 functions in reducing the $[Ca^{2+}]_{cyt}$ during MeJA-induced leaf senescence needs further improvement, and the source and location of Ca^{2+} are still not clear enough. By using the Arabidopsis and MeJA as the research model, the subsequent researches have been performed to investigate the upstream regulation and downstream function of Ca^{2+} in this type of plant senescence.

Keywords: leaf senescence, Arabidopsis Bax inhibitor-1, calcium, methyl jasmonate, mitogen-activated protein kinase 6

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Bax inhibitor-1 (BI1) protein was first isolated to prevent Bax-induced cell death in yeast.[1] BI1 has seven trans-membrane domains and predominantly localizes to the ER membrane.[2] In plants, homologs of BI1 are cloned and characterized to various extents.[3] Plant BI-1 plays important roles in the response to many abiotic and biotic stresses. Recent researches have reported that expression of plant BI1 is upregulated during plant senescence.[4] Nowadays, more and more attention has been paid to study the mechanism of leaf senescence, which is helpful for understanding of senescence mediation, providing theoretical foundation for screening and genetic manipulation of hyper-resistant crop. Our recent works have shown a function of AtBI-1 during MeJA-induced leaf senescence: overexpression of AtBI-1 delays MeJA-induced leaf senescence (**Fig. 1**).[5] We also found that MeJA induced the calcium flux from ER. However, AtBI-1 inhibited the process of calcium flux. Ca^{2+} modulated the activation of MPK6 and then regulated the leaf senescence (**Fig. 1**).[5] These findings prompt us to carry out further investigations to determine the signaling mechanism of plant senescence and to dig out the roles of AtBI-1 in plant senescence.

Calcium (Ca^{2+}) is a ubiquitous intracellular second messenger that plays important roles in death pathways.[6,7] The rise of $[Ca^{2+}]_{cyt}$ is considered as the result of uptake from extracellular or the release from internal stores, such as the endoplasmic reticulum (**Fig. 1**). It has been reported that Ca^{2+} participates in the regulation of senescence and ripening processes in plants.[8] Hence, to realize the direct regulatory signal molecules of Ca^{2+} and how does Ca^{2+} translate the senescence signal during the plant senescence will be a meaningful and interesting work, which will provide direct experimental evidences to determine the relationship between AtBI-1 and Ca^{2+} in the senescence network.

Mitogen-activated protein kinase (MAPK) cascades are involved in various

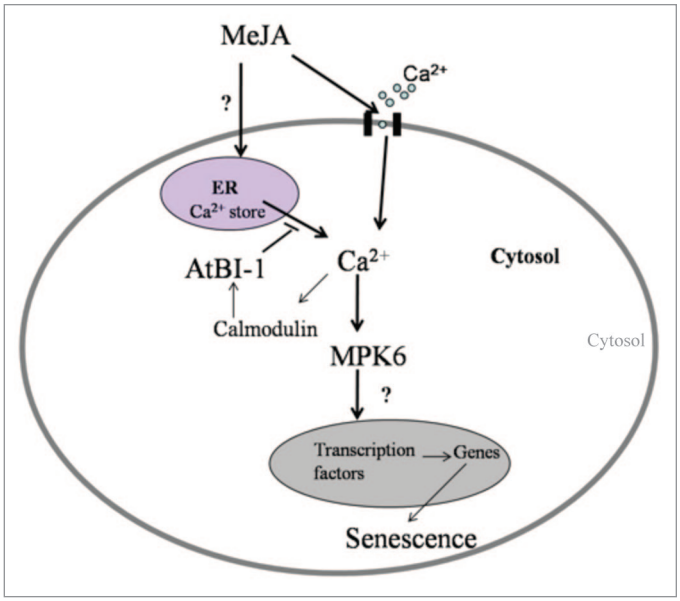

Figure 1. Proposed working model for AtBI-1 delaying MeJA-induced leaf senescence. AtBI1, *Arabidopsis thaliana* Bax inhibitor-1; Ca^{2+}, calcium; CaM, calmodulin; MPK6, mitogen-activated protein kinase 6; MeJA, methyl jasmonate. For detailed explanation, see the text.

biotic and abiotic stress responses.[9,10] It has been suggested that MPK6 plays roles in leaf senescence.[9] In our paper, the activation of MPK6 was increased during MeJA-induced leaf senescence, and the *mpk6* mutant delayed leaf senescence.[5] MKK3-MPK6 cascades participate in JA signaling pathway.[11] Previous studies suggested that Ca^{2+} might function upstream of the MAPK activation in some stimuli responses. Our data has determined that MeJA-induced MPK6 activation could be arrested after pretreatment with Ca^{2+} scavenger BAPTA-AM.[5] But it hasn't been know which MAPKK activates MPK6 in the senescence process. It has been reported that a specific MAPK cascade induce the expression of specific WRKY transcription factors.[13] It is unclear whether MPK6 regulate any WRKY transcription factors during the MeJA-induced leaf senescence. Our future work will focus on the upstream regulation of Ca^{2+} and downstream function cascades of MPK6 during MeJA-induced leaf senescence. These subsequent researches will certainly contribute to the signal transduction pathways in MeJA-induced leaf senescence.

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References

1. Xu Q, Reed JC. Bax inhibitor-1, a mammalian apoptosis suppressor identified by functional screening in yeast. Mol Cell 1998; 1:337-46; PMID:9660918; http://dx.doi.org/10.1016/S1097-2765(00)80034-9.
2. Chae HJ, Kim HR, Xu C, Bailly-Maitre B, Krajewska M, Krajewski S, et al. *BI-1* regulates an apoptosis pathway linked to endoplasmic reticulum stress. Mol Cell 2004; 15:355-66; PMID:15304216; http://dx.doi.org/10.1016/j.molcel.2004.06.038.
3. Kawai-Yamada M, Jin LH, Yoshinaga K, Hirata A, Uchimiya H. Mammalian Bax-induced plant cell death can be down-regulated by overexpression of Arabidopsis Bax Inhibitor-1 (AtBI-1). Proc Natl Acad Sci U S A 2001; 98:12295-300; PMID:11593047; http://dx.doi.org/10.1073/pnas.211423998.
4. Yamada T, Ichimura K, Kanekatsu M, van Doorn WG. Homologs of genes associated with programmed cell death in animal cells are differentially expressed during senescence of Ipomoea nil petals. Plant Cell Physiol 2009; 50:610-25; PMID:19182226; http://dx.doi.org/10.1093/pcp/pcp019.
5. Yue HY, Nie SJ, Xing D. Over-expression of Arabidopsis Bax inhibitor-1 delays methyl jasmonate-induced leaf senescence by suppressing the activation of MAP kinase 6. J Exp Bot 2012; 63:4463-74; http://dx.doi.org/10.1093/jxb/ers122; PMID:22563118.
6. Clapham DE. Calcium signaling. Cell 2007; 131:1047-58; PMID:18083096; http://dx.doi.org/10.1016/j.cell.2007.11.028.
7. Sanders D, Pelloux J, Brownlee C, Harper JF. Calcium at the crossroads of signalling. Plant Cell 2002; 14:401-17.
8. Chou CM, Kao CH. Methyl jasmonate, calcium, and leaf senescence in rice. Plant Physiol 1992; 99:1693-4; PMID:16669094; http://dx.doi.org/10.1104/pp.99.4.1693.
9. Zhou C, Cai Z, Guo Y, Gan S. An arabidopsis mitogen-activated protein kinase cascade, MKK9-MPK6, plays a role in leaf senescence. Plant Physiol 2009; 150:167-77; PMID:19251906; http://dx.doi.org/10.1104/pp.108.133439.
10. Takahashi F, Yoshida R, Ichimura K, Mizoguchi T, Seo S, Yonezawa M, et al. The mitogen-activated protein kinase cascade MKK3-MPK6 is an important part of the jasmonate signal transduction pathway in *Arabidopsis*. Plant Cell 2007; 19:805-18; PMID:17369371; http://dx.doi.org/10.1105/tpc.106.046581.
11. Takahashi F, Yoshida R, Ichimura K, Mizoguchi T, Seo S, Yonezawa M, et al. The mitogen-activated protein kinase cascade MKK3-MPK6 is an important part of the jasmonate signal transduction pathway in Arabidopsis. Plant Cell 2007; 19:805-18; PMID:17369371; http://dx.doi.org/10.1105/tpc.106.046581.
12. Romeis T, Ludwig AA, Martin R, Jones JD. Calcium-dependent protein kinases play an essential role in a plant defence response. EMBO J 2001; 20:5556-67; PMID:11597999; http://dx.doi.org/10.1093/emboj/20.20.5556.
13. Asai T, Tena G, Plotnikova J, Willmann MR, Chiu WL, Gomez-Gomez L, et al. MAP kinase signalling cascade in Arabidopsis innate immunity. Nature 2002; 415:977-83; PMID:11875555; http://dx.doi.org/10.1038/415977a.