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Areas of Research

Plant growth regulation and exogenous substance application.

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Research Interests

Application of 5-aminolevulinic acid (5-ALA) in agriculture and its mechanisms

In recent 20 years, Wang's lab has mainly been focusing on study on 5-aminolevulinic acid (ALA) and its application in agriculture productions, including fruit trees, vegetables, flowers, and many other crops. ALA has long been known as an essential biosynthetic precursor of tetrapyrrole compounds such as chlorophylls and heme, however, it is not only a common natural non-protein amino acid but a magical substance, because it has been found involving in regulation in many aspects of plant growth and development. The follows are listed as examples which we are concerning.

1. **Photosynthesis**

   Photosynthesis is the basic origin of all organic compounds including our foods. ALA is well known to be a key precursor of chlorophyll biosynthesis; however, it may be involved in regulation of the whole process of photosynthesis, including stomatal movement（Physiol Plant 168: 709–724. 2020）, photosynthetic pigment biosynthesis and metabolism, photosynthetic electron transport chain and its branch chains, ATP and NADPH production, photosynthetic dark reaction, and water-water cycle, which provide the protective role to photosynthetic reaction centers against light inhibition. Some of regulations above induced by ALA are partially known, but more are still not clear, which need further study. We have found that ALA can improve almost all green plant growth and increase their production, thus the study of ALA functions in this field is of importance forever.

2. **Seed priming**

   Seed treatment and seed industry are important in modern agriculture. It has been found that exogenous ALA can promote seed germination under normal condition as well as stressful conditions, such as salinity, chilling and drought, which is very meaningful for agricultural production. This effect has been reported in many crops, however, the mechanisms are not yet clear. It is found that whether endosperm seeds or cotyledonous seeds, ALA can improve germination. Since seed germination is involved in storage nutrition metabolism and new organ establishment, therefore, seed priming by ALA and its mechanisms are an important yield of the lab.

3. **Root growth**

   We firstly reported that ALA promote root growth in strawberry plants, which may be involved in auxin polar transport regulation in root tips (Acta Physiol Plant 2019, 41: 85). Our further study showed that ALA induced flavonol accumulation in root tip, which is necessary for auxin transport. However, how ALA regulates flavonol biosynthesis in root tips is not clear. Therefore, more studies need to be conducted in the future. On the other hand, ALA has been found to improve greatly the underground organ growth in the crops such as radish, carrot, potato, sweet potato, peanut, taro, onion and garlic. In another word, ALA can increase their production much greater than the other crops. However, how ALA induces leaf nutrition translocation and accumulation in the roots has never been reported up to now. Thirdly, it was found that ALA can induce more root growth when plants encounter stressful conditions (Physiol Plant 168: 948–962. 2020). In sequential cropping soil, many crops cannot root well. However, ALA treatment can induce newer root occurrence in the kind of soil. The stimulatory effect of ALA has not been well studied before.

4. **Flower thinning**

   We firstly found that ALA can be used to thin surplus flowers and promote fruit development and quality in fruit tree production. It is found that ALA inhibited pollen germination and tube growth in stigma when flowers are open. We have reported some of mechanisms (Front Plant Sci, 2016, 7: 121; Sci Hort 2018, 241: 41–50), and more needs further study.

5. **Fruit coloration**

   Fruits such as apple, peach, strawberry and grape are often red in their pericarps, which is the result of anthocyanin accumulation. We firstly reported that ALA can induce anthocyanin accumulation in apple fruits, and the regulatory mechanisms have also been reported lately. ALA can induce up-expressions of structural genes (*CHS*, *CHI*, *UFGT*) involved in anthocyanin biosynthetic routes, but also induce transcript factors such as *MYB*, *bHLH*, and *MADS*, which can further regulate the up-expressions of the structural genes. Therefore, exogenous ALA has been suggested to apply to several important species of fruit tree productions.

6. **Stress tolerance**

The most magical functions of ALA which have been reported may be its improvement in plant stress tolerance. At least in the following aspects including chilling, heat, high light, low light, low nitrogen, drought, waterlogging, salinity, heavy metal pollution, sequential cropping, and herbicide injury, has ALA been found to be effective to alleviate injury and improve plant growth. Therefore, ALA has been suggested to be a multiple stress tolerance inducer. The plants treated by ALA are stronger and healthier, which can help to decrease germicide application and keep environment better. The mechanisms of ALA dealing with stresses are complex and far away from be elucidated. There must be general mechanisms for ALA to improve plant stress tolerance, however, in a specific kind of stress, ALA may induce the tolerance through different signal routes. We have reported ALA inducing salt tolerance (Physiol Plant 167: 5–20. 2019) and osmotic tolerance (Physiol Plant 168: 948–962. 2020), which are quite different from the others reported before. More work is needed further.

Education Background

Bachelor： Pomology, Department of Horticulture, Nanjing Agricultural University, 1981-1985

Master： Pomology, Department of Horticulture, Nanjing Agricultural University, 1985-1988

Doctor： Plant Physiology, Department of Agronomy, Nanjing Agricultural University, 1995-1999

Work experience

Assistant teacher, Department of Horticulture, Nanjing Agricultural University, 1988-1992

Lecturer, Department of Horticulture, Nanjing Agricultural University, 1992-1997

Associate Professor, College of Horticulture, Nanjing Agricultural University, 1998-2005

Professor, College of Horticulture, Nanjing Agricultural University, 2005-

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Honors and Awards

1. Agricultural Science and Technology Support Project of Jiangsu Province (BE2013327) Introduction of new varieties of high-quality figs and integrated innovation of high efficiency pesticide-free cultivation technology (2013-2016).

2. Nanjing 321 Talent Introduction Project (B07031). Research and application of agricultural inputs with 5-aminolevulinic acid as the main active ingredient (2013-2017)

3. National Natural Science Foundation of China (31772253). The mechanism of MdMADS1 transcription factors in ALA induced anthocyanin accumulation in apple (2018-2021).

4. Enterprise commissioning project. Studies on nutritional health and anticancer active

ingredients in fig (2018-2013).

5. Enterprise commissioning project. Development and application of new phytoremediation agent 5- ALA (2020-2024).
6. Projects of Jiangsu Agricultural Science and Technology Innovation Fund. Study on ALA application in the spring cold-prevention, surplus flower-thinning, fruit-preserving and quality improvement in the open pollination fruit trees and its supporting technology with UAV (2020-2022).

Selected Publication

1. Wang LJ, Jiang WB and Huang BJ. 2004. Promotion of 5-aminolevulinic acid on photosynthesis of melon (*Cucumis melo* L.) seedlings under low light and chilling. Physiol Plant, 121(2): 258-264

2. Wang LJ, Jiang WB, Liu H, Liu WQ, Kang L, Hou XL. 2005. Promotion of 5-aminolevulinic acid (ALA) on germination of pakchoi (*Brassica campestris* ssp. *chinensis* var. *communis* Tsen et Lee) seeds under salt stress. J Integrative Plant Biol, 47(9): 1084-1091

3. Saba AM, Hou XL, Wang LJ. 2008. Salt (NaCl) tolerance of non-heading Chinese cabbage (*Brassica campestris* spp. *chinensis* var. *communis* Tsen et Lee) at germination and seedling growth. EJEAFChe, 7(4):2872-2880

4. Saba AM, Hou XL, Wang LJ, Li Y. 2009. Promotive effect of 5-aminolevulinic acid on chlorophyll, antioxidative enzymes and photosynthesis of pakchoi (*Brassica campestris* ssp. *chinensis* var. *communis* Tsen et Lee). Acta Physiol Plant, 31: 51-57

5. Sun YP, Zhang ZP, Wang LJ. 2009. Promotion of 5-aminolevulinic acid (ALA) treatment on leaf photosynthesis is related with increase of antioxidant enzyme activity in watermelon seedlings grown under shade condition. Photosynthetica, 47: 347-354

6. Saba AM, Wang LJ, Hou XL. 2009. Promotive effect of 5-aminolevulinic acid on seed germination of pak choi (*Brassica camperstris* ssp. *chinensis*) under salt conditions. World Applied Science Journal, 7(11): 1367-1374

7. Saba AM, Hou XL, Wang LJ, Keerio MI. 2009. NaCl effects on germination and growth of pakchoi seedlings. Pak J Agr Agril Engg Vet Sci, 25(2): 9-18

8. Zhang ZP, Yao QH, Wang LJ. 2010. Expression of yeast *Hem1* gene in Arabidopsis plants improves salt tolerance. J Biochem Mol Biol, 43: 330-336

9. Wang LJ, Sun YP, Zhang ZP. 2010. Effects of 5-aminolevulinic acid (ALA) on photosynthesis and Chlorophyll fluorescence of watermelon in autumn-winter plastic tunnel. Acta Hort, 856: 159-166

10. Saba AM, Hou XL, Wang LJ. 2010. Morphlogical analysis of salt stress response of pak choi. EJEAFChe, 9(1): 248-254

11. Zhang ZP, Yao QH, Wang LJ. 2010. Expression of yeast *Hem1* controlled by Arabidopsis *HemA1* promoter enhances leaf photosynthesis in transgenic tobacco. Molecular Biol Reports, 43(5): 330-336

13. Shen M, Zhang ZP, Wang LJ. 2011. Effect of 5-aminolevulinic acid (ALA) on leaf photosynthesis and antioxidant activity in pear (*Pyrus Pyrifolia* Nakai). In: Photosynthesis/ Book 3", ISBN 979-953-307-665-1, pp 239-265

14. Wei ZY, Zhang ZP, Lee MR, Sun YP, Wang LJ. 2012. Effect of 5-aminolevulinic acid on leaf senescence and nitrogen metabolism of pakchoi (*Brassica campestris* ssp. *chinensis* var. *communis* Tsen et Lee) under different nitrate levels. J Plant Nutrition, 35: 49-63

15. Zhang ZP, Sheng M, Li C, Sun XE, Yao QH, Wang LJ. 2012. Expression of yeast *Hem1* controlled by Arabidopsis *HemA1* promoter enhances leaf photosynthesis in transgenic tomato. Acta Hort. 932: 305-312

16. Xie L, Wang ZH, Cheng XH, Gao JJ, Zhang ZP, Wang LJ. 2013. 5-Aminolevulinic acid promotes anthocyanin accumulation in Fuji apples. Plant Growth Regulation, 69: 295-303

17. Huang F, Li MF, Wang LJ, Li SP, He J. 2013. Mitigative effects of foliage spraying and root irrigation of ALA on banana plantlets exposed to cold stress. Agric Sci Technol, (06): 858-862

18. Li Y, Li HY, Wang FD, Li JJ, Zhang YH, Wang LJ, Gao JW. 2016. Comparative transcriptome analysis reveals effects of exogenous hematin on anthocyanin biosynthesis during strawberry fruit ripening. International Journal of Genomics, 6762731

19. An Y, Feng X, Liu L, Xiong L and Wang L. 2016. ALA-induced flavonols accumulation in guard cells is involved in scavenging H_2O_2 and inhibiting stomatal closure in Arabidopsis cotyledons. Front. Plant Sci. 7:1713

20. Feng X, An Y, Zheng J, Sun M and Wang L. 2016. Proteomics and SSH analyses of ALA-promoted fruit coloration and evidence for the involvement of a MADS-box gene, MdMADS1. Front.PlantSci.7: 1615

21. Li Y, Li ZQ, Wang LJ. 2016. Applications of 5-aminolevulinic acid on the physiological and biochemical characteristics of strawberry fruit during postharvest cold storage. Ciência Rural, Santa Maria, v.46, n.12, p.2103-2109

22. An Y, Qi L, Wang L. 2016. ALA pretreatment improves waterlogging tolerance of fig plants. PLoS ONE 11(1): e0147202.

23. An Y, Liu L, Chen L, Wang L. 2016. ALA inhibits aba-induced stomatal closure via reducing H_2O_2 and Ca^{2+} levels in guard cells. Front. Plant Sci. 2106, 7:482.

24. An Y, Li J, Duan C, Liu L, Sun Y, Cao R, Wang L. 2016. 5-Aminolevulinic acid thins pear fruits by inhibiting pollen tube growth via Ca^{2+}-ATPase-mediated ca^{2+} efflux. Front. Plant Sci. 7: 121.

25. Liu LB, Xiong LJ, An YY, Zheng J, Wang LJ. 2016. Flavonols induced by 5-aminolevulinic acid are involved in regulation of stomatal opening in apple leaves. Horticultural Plant J, 2 (6): 323–330.

26. Sun YP, Liu J, Cao RX, Huang YJ, Hall AM, Guo CB, Wang LJ. 2017. Effects of 5-aminolevulinic acid treatment on photosynthesis of strawberry. Photosynthetica，55 (2): 276-284

27. Zheng J, An YY, Feng XX, Wang LJ. 2017. Rhizospheric application with 5-aminolevulinic acid improves coloration and quality in ‘Fuji’ apples. Sci Hort, 224: 74–83

28. Zheng J, An YY, Wang LJ. 2018. 24-Epibrassinolide enhances 5-ALA induced anthocyanin and flavonol accumulation in calli of ‘Fuji’ apple flesh. Plant Cell Tiss Organ Cult, 134: 319-330

29. An YY, Lu WY, Li J, Wang LJ. 2018. ALA inhibits pear pollen tube growth through regulation of vesicle trafficking. Sci Hort 241: 41–50

30. An YY, Cheng DX, Cao RX, Sun YP, Tang Q, Wang LJ. 2019. 5‑Aminolevulinic acid (ALA) promotes primary root elongation through modulation of auxin transport in Arabidopsis. Acta Physiol Plant, 41: 85

31. Wu WW, He SS, An YY, Cao RX, Sun YP, Tang Q, Wang LJ. 2019. Hydrogen peroxide as a mediator of 5-aminolevulinic acid-induced Na^+ retention in roots for improving salt tolerance of strawberries. Physiol Plant 167: 5–20.

32. Li MF, Feng S, Li SP, Wu F, Wang F, Li CL, Fu YN, Bao DH, Wang LJ. 2019. Preharvest promotion or inhibition of colouration: Which is the more conducive to improving litchi postharvest quality? Sci Hort 254: 124–132

33. Cai CY, He SS, An YY, Wang LJ. 2020. Exogenous 5-aminolevulinic acid improves strawberry tolerance to osmotic stress and its possible mechanisms. Physiol Plant, 168: 948–962.

34. Fang X, An YY, Zheng J, Shangguan LF, Wang LJ. 2020. Genome-wide identification and comparative analysis of GST gene family in apple (*Malus domestica*) and their expressions under ALA treatment. Biotech, 10:307

35. An YY, Xiong LJ, Hu S, Wang LJ. 2020. PP2A and microtubules function in 5-aminolevulinic acid-mediated H_2O_2 signaling in Arabidopsis guard cells. Physiol Plant 168: 709–724

36. Li J, An YY, Wang LJ. 2020. Transcriptomic analysis of *Ficus carica* peels with a focus on the key genes for anthocyanin biosynthesis. Int. J. Mol. Sci. 21: 1245