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Construction of Dwarf-Dense Cultivation Models for High Yield in Bayberry and Adaptability Assessment of Representative Varieties

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Abstract This study mainly summarizes the role of dwarf-dense cultivation in increasing the yield and stabilizing the output of bayberries. It conducts an analysis from several aspects, such as dwarf pruning methods, density design of tree planting, and key technologies like water and fertilizer management. It comprehensively explains how these affect yield and fruit quality, and compares the performance of different bayberry varieties under dwarf-dense cultivation. To see if there are any differences among them in terms of disease and pest resistance, environmental stress resistance and planting management, and to combine some actual cases from the southeast coastal areas of China, the application effect and economic benefits of dwarf-dense cultivation in these regions were examined. This study hopes to provide some theoretical and technical references for future efficient planting models and adaptive management in various regions.
Keywords Bayberry; Dwarf-dense cultivation; Fruit quality; Variety adaptability; High-yield cultivation model

1 Introduction

Nowadays, the demand for high-yield and delicious bayberries is increasing, but the traditional open-field cultivation method can no longer keep up (Zhang et al., 2022; Qi et al., 2023). When it rains a lot or the weather is bad, the yield of bayberries is prone to problems and the quality of the fruits deteriorates, which makes it difficult for the bayberry industry to develop in the long term (Wu et al., 2021). Therefore, finding a planting method that is both stable in yield and efficient has become an issue that must be addressed at present.

Dwarf-dense cultivation is a good new approach. This method involves making the bayberry trees shorter, planting them denser, and then arranging the tree shape more reasonably (Liang et al., 2020; Zhang et al., 2023). Doing so can increase the yield per mu of land, and also make the fruits grow better and taste sweeter. Another advantage is that it is easier to pick, more efficient and safer (Wu et al., 2021). Because the trees are shorter, it is more convenient to take care of them with machines, and it is also more conducive to pest control and disease treatment. As a result, the economic benefits naturally increase.

This study aims to establish a dwarf-dense cultivation model for high yield suitable for bayberries. Several common varieties were tested to see if they adapt to different environments. Comparative analyses were conducted on pruning methods, planting density, and variety combinations. It was found that these techniques have a significant impact on yield, quality, and management efficiency. This study aims to provide a reference for the future development of a high-quality bayberry industry.

2 Principles of Dwarf-Dense Cultivation in Bayberry

2.1 Definition, core concepts, and technical characteristics

Dwarf-dense cultivation means making trees shorter and planting them more densely. This can make the orchard more efficient, be utilized better and the fruits grow more delicious. This method mainly relies on pruning, using dwarfing rootstocks and other means to keep the tree body at a relatively low height, which is convenient for picking and maintenance (Shi et al., 2018; Li et al., 2025). Generally speaking, the characteristics of this type of cultivation method are that the trees do not grow tall, the canopies are not large, the trees are planted closely together, and it is also suitable for management and fruit picking by machines.

2.2 Physiological and ecological basis for dwarfing and dense planting

Pruning off some large branches in summer can have a very good dwarfing effect. Studies have found that doing so can significantly reduce the height of bayberry trees, and significantly increase the weight, sweetness of individual fruits and the yield of each tree (Wang et al., 2023; Chu et al., 2025). For instance, after pruning, the tree height decreased by 76.88%, the single fruit weight increased by 15.30%, the sugar content rose by 11.20%, and the yield increased by 29.62%. When trees are shorter, light and air can enter, the photosynthesis of leaves is better, and the taste of fruits is also better (Wu et al., 2021).

2.3 Design parameters: plant height, canopy size, and planting density

Generally, in dwarf-dense cultivation, the height of the bayberry tree is controlled between 3 and 4 meters, and the tree crown should also be more compact. For instance, after pruning the large branches, the height of the bayberry tree is approximately 3.72 meters, which is much shorter than that of the tree without pruning. The arrangement of density depends on the growth of the variety and the management method. It should neither be planted too densely nor too sparsely. Good cultivation not only leads to high yield and good quality, but also makes fruit picking and daily management more convenient (Wu et al., 2021).

3 Model Construction for High Yield

3.1 Orchard layout and planting configuration

To achieve high yields of bayberries, the layout of the park and the planting density must be planned in advance. When cultivating with dwarf-dense plants, the spacing between plants and rows should be scientifically arranged according to different varieties and soil conditions. It is necessary to ensure that each tree has sufficient space to grow while increasing the total yield of the plot (Deng et al., 2012). For example, salt-tolerant waxberry can be selected as the rootstock. It is particularly suitable for the saline-alkali land along the southern coast. It can also enable the grafted waxberry to flower earlier, bear fruit faster, have larger fruits and better taste (Saeed et al., 2023). In addition, greenhouse cultivation is also very useful. It can not only avoid the trouble caused by rain, but also increase the yield and fruit quality (Wu et al., 2021).

3.2 Pruning and training systems for canopy optimization

If the trees are pruned shorter and denser, they will be easier to manage and the yield will also increase. If the large branches on the main trunk are pruned off in summer, the height of the tree will decrease by more than 70% in two years. Moreover, the fruit on each tree will increase in quantity, weight and sweetness, and it will be safer and less laborious to pick. Pruning can also make the tree crown more breathable and light-permeable, allowing the leaves to receive more sunlight, which is beneficial for the fruits to grow both beautifully and deliciously.

3.3 Nutrient, water, and soil management tailored to high-density orchards

Orchards with high-density planting have a higher demand for water and fertilizer. Therefore, the management of fertilizer and water must keep up. The soil can be improved first, and then the water and fertilizer plan can be determined according to different soils and varieties. The wax bayberry rootstock can also make the leaves greener and healthier, and the plant more drought-tolerant or disease-resistant (Saeed et al., 2023). Under greenhouse conditions, the sugar accumulation of fruits and the activities of related enzymes will be significantly enhanced, and the fruits will be sweeter and more delicious than those in the open field (Wu et al., 2021). Therefore, soil, varieties, water and fertilizer should be taken into consideration together to ensure high yield and good fruit quality in the orchard.

4 High-Yield Formation Mechanisms in Dwarf-Dense Bayberry Systems

4.1 Canopy light interception and photosynthetic efficiency improvement

Dwarf-dense cultivation can make the tree shape of the bayberry more compact and the distribution of leaves more reasonable, which is conducive to receiving more sunlight and also improves the overall photosynthetic efficiency. The shape and size of leaves are controlled by genes, and these characteristics directly affect the yield of trees. Nowadays, some studies have identified the relevant gene regions (QTLs) and key genes, laying the foundation for improving tree type and enhancing light efficiency in the future (Zhang et al., 2021). In addition, a good canopy structure can also allow sunlight to reach each leaf more evenly, which is beneficial for plants to store more energy and lay a better foundation for fruiting.

4.2 Source-sink relationships and fruit load regulation

Under the dwarf-dense cultivation model for high yield, the distribution of nutrients between leaves and fruits is extremely crucial. Studies have found that under optimized cultivation conditions, the sugar content in the fruit of bayberry is higher, and the activities of key glucose metabolism enzymes (such as sucrose phosphosynthase and acid invertase) are also stronger, which can make the fruit sweeter and larger (Wu et al., 2021; Sun et al., 2024). Meanwhile, some hormones, such as auxin, jasmonic acid and abscisic acid, also play a significant role in regulating fruit development and can help balance the nutrient distribution between leaves and fruits (Fu et al., 2025).

4.3 Impacts on flowering, fruit set, and fruit quality

Dwarf-dense cultivation not only leads to higher yields but also improves the quality of fruits. For example, planting some ryegrass in the orchard can not only improve the soil and root environment, but also increase the sugar, vitamin C and flavonoids in the fruit, and reduce the sourness (Li et al., 2023a). During the fruit development process, hormonal changes and nutrient metabolism within plants can also affect flowering, fruit setting and the taste of the fruit (Figure 1) (Sun et al., 2024; Fu et al., 2025). Growing bayberries in greenhouses can further increase the single fruit weight, sugar content and sugar-acid ratio, making the fruits taste sweeter and better (Wu et al., 2021).

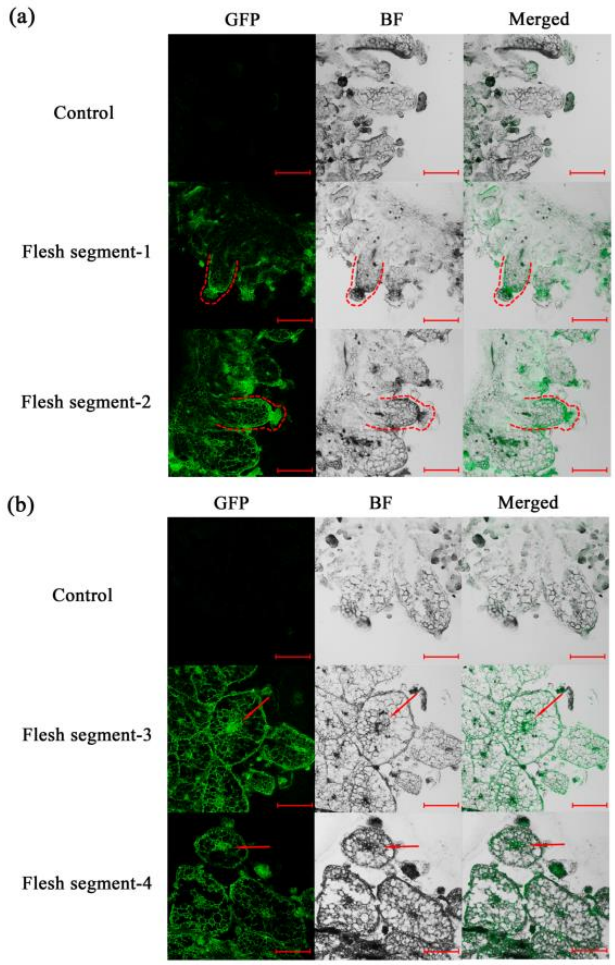

Figure 1 Immunofluorescence localization of auxin in the (a) longitudinal and (b) transverse sections of flesh segments (Adopted from Fu et al., 2025)

Image caption: The bayberry variety used for the immunofluorescence localization analysis was ‘Biqi’, and all scale bars were set to 200 μm. In (a), the dashed line indicates a longitudinal section of a single flesh segment, where the auxin fluorescence signals are enriched at the top and side walls of the flesh segment, forming a continuous linear distribution along the contour marked by the dashed line. In (b), the arrow indicates the central vascular bundle within the cross-section of the flesh segment, where the enrichment of auxin fluorescence signals is observed (Adopted from Fu et al., 2025)

5 Adaptability Assessment of Representative Bayberry Varieties

5.1 Criteria for assessing adaptability under dwarf-dense conditions

Under the dwarf-dense cultivation model, to assess whether a bayberry variety is suitable, several aspects should be mainly considered: whether the fruit is prone to rot, what the sweetness and acidity are like, whether the appearance is good, whether it can resist diseases and pests, whether it will be affected by drought or cold, and whether it is easy to manage. Research has found that different varieties of bayberries vary greatly in terms of whether the fruit is rotten or not and the appearance is good. This may be related to the metabolic products in the fruit. For instance, substances like Mesuagin, Arctigenin and Eugenin are related to the degree of fruit rot and the weight of the fruit. It may be used to determine which varieties are suitable for processing and storage (Liu et al., 2025).

5.2 Performance of early-, mid-, and late-maturing varieties in model orchards

In dwarf and densely planted orchards, varieties at different maturity times (early-maturing, mid-maturing, and late-maturing) perform differently. Some have high yields, some have good fruit quality, and some are more durable for storage. Although each variety is not specifically listed in the literature, many studies have pointed out that different types of bayberries vary in rot resistance, fruit quality and preservation time, all of which will affect their performance under high-density planting conditions (Liu et al., 2025). In addition, the old varieties of bayberries perform stronger in the face of pests and diseases and changes in the natural environment. Therefore, they may be more suitable for this dwarf-dense cultivation pattern (Li et al., 2024).

5.3 Pest/disease resistance, stress tolerance, and management requirements

Disease and pest resistance as well as stress resistance are particularly important aspects when selecting varieties. Some old varieties of bayberries can attract and utilize some beneficial microorganisms, such as Bacillus in the roots and stems, Pseudomonas in the leaves, and Mortierella in the soil around the roots. These microorganisms can help the trees resist diseases and pests. Meanwhile, some protective substances will also accumulate in these varieties, which can enhance resistance (Li et al., 2024). In terms of preventing branch blight, some varieties with strong resistance will quickly activate the “self-defense” mechanism after being attacked by pathogens, enhance lignin synthesis, and make it difficult for pathogens to invade (Figure 2) (Ren et al., 2021; Guo et al., 2024). Overall, these varieties with good resistance usually do not require too much pesticide application or special care, which can help fruit farmers save money and effort, and also make cultivation more efficient.

6 Case Study: Implementation in a Commercial Bayberry Orchard

6.1 Site characteristics: location, climate, soil, and variety selection

This case park is located on the southeast coast of China and has a subtropical monsoon climate. It rains a lot throughout the year here and the temperature is relatively moderate, making it quite suitable for growing bayberries. The soil in the garden is mainly acidic red soil, but in some areas it is saline-alkali land. In order to adapt to different soil conditions, on saline-alkali land, they used *Morella cerifera* as the rootstock and grafted good varieties such as ‘Biqi’ onto it, so that they could grow normally and have high yields in saline-alkali land (Saeed et al., 2023). In the common red soil areas, ‘Biqi’, which has strong adaptability and good fruit quality, is mainly grown.

6.2 Model construction process and orchard management practices

The park has adopted the method of dwarf-dense planting. They pruned the large branches in summer. Two years later, the average height of the trees was only 3.72 meters, which was 76.88% shorter than the trees that were not pruned. When the trees are shorter, it becomes easier to pick and manage them. Moreover, the tree canopies are more ventilated and well-lit, which improves the quality and yield of the fruits. In saline-alkali plots, the grafted seedlings of the wax bayberry rootstock performed well, had strong stress resistance, grew fast, and could flower and bear fruit within 1~2 years after grafting (Saeed et al., 2023). The park has also adopted greenhouse cultivation technology, which can avoid the damage of rainy days to the fruits, extend the fruit-picking period and improve the quality of the fruits (Wu et al., 2021). In terms of daily management, they also pay attention to scientific fertilization, green pest and disease prevention, and water control to keep the bayberry trees healthy and high-yielding all the time.

6.3 Results: yield performance, fruit quality, and economic benefits

After pruning, the yield of each tree increased by 29.62%, the fruits became larger, the weight of each fruit rose by 15.3%, and the sugar content also increased by 11.2%. Moreover, the fruits are easier to pick, and the ground picking volume has increased by 236.45%. The 'Biqi' grafted with waxberry as the rootstock has larger fruits and a better sugar-acid ratio on saline-alkali land, and the selling price is also higher than that grown on ordinary rootstocks (Saeed et al., 2023). The fruits grown in greenhouses have better single fruit weight, sweetness and taste than those grown in the open air. The harvest period is also longer and the market price is higher (Wu et al., 2021). Overall, dwarf-dense cultivation, along with good rootstocks and facility management, have significantly improved the output, fruit quality and income of this park.

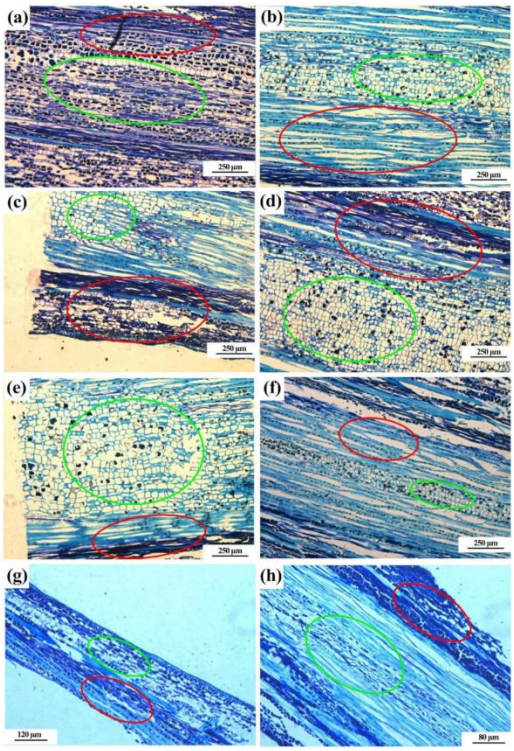

Figure 2 Microscopic observation on the longitudinal section of bayberry resistant (a,c,e,g) and susceptible (b,d,f,h) cultivars after 0, 6, 48 and 72 h of pathogen infection. The red circle represents phloem and xylem, while the green circle represents medulla (Adopted from Ren et al., 2021)

7 Limitations and Challenges

7.1 Soil fertility decline and root system constraints in long-term dense planting

Long-term high-density planting will cause the nutrients in the soil to be consumed more quickly. Over time, this can easily lead to a decline in soil fertility, affecting the growth and yield of trees. Planting too densely will also reduce the space of the root system, prevent the roots from spreading, and the ability to absorb water and nutrients will deteriorate. The growth and stress resistance of the plant will also be affected accordingly (Zhang et al., 2021; Saeed et al., 2023).

7.2 Risk of pest and disease accumulation under dense canopies

Dwarf-dense cultivation bring trees closer together, making their branches and leaves denser, and preventing sunlight and air from entering. In this case, pests and diseases are more likely to occur. Once they occur, not only is it more difficult to control, but also the cost of prevention and control will increase. In severe cases, it will even affect the quantity and quality of fruits (Saeed et al., 2023).

7.3 Labor, cost, and technology adoption issues

Dwarf-dense cultivation has higher technical requirements for pruning, pest and disease control, soil management, etc., and the management cost will also increase. Meanwhile, some new technologies and equipment have

relatively high usage thresholds, and not all farmers can master them. Some farmers have limited technical skills and a low acceptance of the new method, which also affects the promotion of the dwarf-dense cultivation model (Li et al., 2023b).

8 Concluding Remarks

By controlling the height of the trees and the planting density, dwarf-dense cultivation has improved both the yield and quality of bayberries. Growing in a greenhouse can make the fruits larger, with more sugar content and better taste. It can also reduce the impact of rainy days on the fruits, extend the harvest period and increase economic benefits. In addition, some old varieties of bayberries have strong resistance to diseases and pests and can also tolerate drought and cold. This may be related to the microorganisms in their roots and the metabolic products in their bodies. Choosing these varieties to plant in different regions will make them more adaptable to the local environment. Nowadays, some intelligent technologies like YOLOv7-CS can automatically identify and count the number of fruits to estimate the yield, which is accurate and time-saving, providing assistance for the management of dwarf-dense cultivation and the selection of varieties.

If it is in an area with abundant rainfall and a short fruit-picking period, it is recommended to give priority to promoting the method of greenhouse combined with dwarf-dense cultivation. This can improve the quality and quantity of fruits. When choosing varieties, it is best to pick those with strong resistance to diseases and pests, and also consider whether they are suitable for the local climate and soil. At the same time, the role of root microorganisms can be utilized to help trees better absorb nutrients and enhance the performance of the entire orchard. Combined with intelligent devices, precise management can be carried out for different areas and varieties, making the orchard more efficient.

The future development of the bayberry industry can strive in three directions: breeding, improvement of planting methods and intelligent management. On the one hand, genes that are highly adaptable to the environment can be identified from old varieties and combined with microbial research to cultivate new varieties that are both high-yielding and disease-resistant. On the other hand, it is necessary to continue optimizing greenhouse conditions, planting density and fertilizer and water management methods. This can lead to better quality fruits and also save costs. At the same time, promote technologies like deep learning fruit recognition to make yield estimation and daily management smarter and more accurate, and drive the development of bayberry cultivation towards efficiency, greenness and sustainability.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Chu L., Liu D., Li C., and Liu J.H., 2025, Dwarfing of fruit trees: from old cognitions to new insights, Horticulture Advances, 3: 7. https://doi.org/10.1007/s44281-025-00063-w

Deng J., Ran J., Wang Z., Fan Z., Wang G., Ji M., Liu J., Wang Y., Liu J., and Brown J.H., 2012, Models and tests of optimal density and maximal yield for crop plants, Proc. Natl. Acad. Sci. U.S.A., 109(39): 15823-15828. https://doi.org/10.1073/pnas.1210955109

Fu Y., Zhang S., Yang L., Zong Y., Li Y., Qi X., Chen W., Liao F., and Guo W., 2025, Comprehensive analysis of hormonal signaling pathways and gene expression in flesh segment development of Chinese bayberry (*Myrica rubra*), Plants, 14(4): 571. https://doi.org/10.3390/plants14040571

Guo J., Li G., Ijaz M., Hafeez R., Ibrahim E., Ahmed T., Qi X., Zhang S., Ali H., Li B., and Ren H., 2024, Transcriptomic and metabolomic analyses reveal that lignin biosynthesis contributes to bayberry (*Myrica rubra*) defence responses against twig blight, Plant Stress, 13: 100514. https://doi.org/10.1016/j.stress.2024.100514

Li C., Li G., Qi X., Yu Z., Abdallah Y., Ogunyemi S., Zhang S., Ren H., Mohany M., Al-Rejaie S., Li B., and Liu E., 2023a, The effects of accompanying ryegrass on bayberry trees by change of soil property, rhizosphere microbial community structure, and metabolites, Plants, 12(21): 3669. https://doi.org/10.3390/plants12213669

Li G., Wang Z., Ren H., Qi X., Han H., Ding X., Sun L., Hafeez R., Wang Q., and Li B., 2024, Ancient bayberry increased stress resistance by enriching tissue-specific microbiome and metabolites, Physiologia Plantarum, 176(2): e14314.
https://doi.org/10.1111/ppl.14314

Li S., Tao T., Zhang Y., Li M., and Qu H., 2023b, YOLO v7-CS: a YOLO v7-based model for lightweight bayberry target detection count, Agronomy, 13(12): 2952.
https://doi.org/10.3390/agronomy13122952

Li Y., Wang X., Zhang Z., Liang J., Sun H., and Li J., 2025, Design and test investigation of a 3WZ-600 profiling sprayer for dwarf-dense planting jujube orchard, Biosystems Engineering, 250: 213-224.
https://doi.org/10.1016/j.biosystemseng.2024.12.015

Liang R., Chen X., Zhang B., Peng X., Meng H., Jiang P., Li J., Zhou P., and Kan Z., 2020, Tests and analyses on mechanical characteristics of dwarf-dense-early major cotton variety stalks, International Agrophysics, 34(3): 333-342.
https://doi.org/10.31545/intagr/122575

Liu J., Gong B., Zhang P., Wu J., Yi C., Wang C., and Kong Y., 2025, Identification of characteristic metabolites, anti-corrosion and reprocessing characteristics of six different types of Chinese bayberry resources, Microchemical Journal, 209: 112649.
https://doi.org/10.1016/j.microc.2025.112649

Qi X.J., Liang S.M., Chen H.B., Yu Z.P., Sun L., Zheng X., and Zhang S.W., 2023, Effects of forcing cultivation on the leaf morphology, fruit ripening and quality of *Myrica rubra*, Journal of Fruit Science, 40(11): 2403-2412.

Ren H., Wu Y., Ahmed T., Qi X., and Li B., 2021, Response of resistant and susceptible bayberry cultivars to infection of twig blight pathogen by histological observation and gibberellin related genes expression, Pathogens, 10(4): 402.
https://doi.org/10.3390/pathogens10040402

Saeed M., Zhao H., Chen Z., Ju P., Wang G., Zhou C., Jia H., Zhu C., Jia H., Jiao Y., Gao Z., and Zhao L., 2023, Wax bayberry is a suitable rootstock for Chinese red bayberry cultivated in saline-alkali soil, Scientia Horticulturae, 323: 112463.
https://doi.org/10.1016/j.scienta.2023.112463

Shi P., Liu H., He X., Lu H., and Ye J., 2018, The influence of water and fertilizer coupling on physiological change and yield of dwarf dense planting jujube under drip irrigation, Journal of Nuclear Agricultural Sciences, 32(1): 177-187.
https://doi.org/10.11869/j.issn.100-8551.2018.01.0177

Sun L., Zhang S., Yu Z., Zheng X., Liang S., Ren H., and Qi X., 2024, Transcription-associated metabolomic analysis reveals the mechanism of fruit ripening during the development of Chinese bayberry, International Journal of Molecular Sciences, 25(16): 8654.
https://doi.org/10.3390/ijms25168654

Wang J., Xue L., Zhang X., Hou Y., Zheng K., Fu D., and Dong W., 2023, A new function of *MbIAA19* identified to modulate *Malus* plants dwarfing growth, Plants, 12(17): 3097.
https://doi.org/10.3390/plants12173097

Wu B., Zhang C., Gao Y., Zheng W., and Xu K., 2021, Changes in sugar accumulation and related enzyme activities of red bayberry (*Myrica rubra*) in greenhouse cultivation, Horticulturae, 7(11): 429.
https://doi.org/10.3390/horticulturae7110429

Zhang S., Sun Y., Lu S., Wang L., Liu S., Wang Z., Dai M., Gao J., and Miao H., 2023, Design and experiment of brush-roller ginkgo leaf picker for the dwarf dense planting mode, Journal of Agricultural Engineering, 54(4): 1541.
https://doi.org/10.4081/jae.2023.1541

Zhang S., Yu Z., Qi X., Wang Z., Zheng Y., Ren H., Liang S., and Zheng X., 2021, Construction of a high-density genetic map and identification of leaf trait-related QTLs in Chinese bayberry (*Myrica rubra*), Frontiers in Plant Science, 12: 675855.
https://doi.org/10.3389/fpls.2021.675855

Zhang S., Yu Z., Sun L., Ren H., Zheng X., Liang S., and Qi X., 2022, An overview of the nutritional value, health properties, and future challenges of Chinese bayberry, PeerJ 10: e13070
https://doi.org/10.7717/peerj.13070