Research Progress on Hawthorn Crataegus pinnatifida Cultivation Techniques and Landscape Application

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Abstract. Hawthorn (Crataegus pinnatifida), as a deciduous fruit tree belonging to the Rosaceae family and the Crataegus genus, not only possesses rich edible and medicinal values but also is widely used in landscape greening due to its unique ornamental characteristics. Hawthorn in landscape greening is susceptible to the influence of various environmental factors, which not only affect its growth and development but also severely restrict its yield and fruit quality. Therefore, exploring the cultivation techniques of hawthorn is of great theoretical and practical significance for its application in landscapes. This paper reviews the research progress on the cultivation and management techniques of hawthorn and its application in landscapes, including aspects such as variety selection and breeding, cultivation techniques, disease and pest control, ornamental value, and application forms. By analyzing the existing research findings, in order to address the challenges brought about by global climate change, scientific basis and technical support are provided for the cultivation and landscape application of hawthorn.

Keywords: Hawthorn; Cultivation Techniques; Landscape Application; Research Progress.

1. Ictntroduion

Hawthorn (Crataegus pinnatifida), also known as mountain red, sour red, and mountain sorb, is a deciduous tree or shrub belonging to the Rosaceae family and the Crataegus genus[1]. Its wild ancestors originated in China, where it is primarily distributed in the mountainous regions of northern China[2]. It is a traditional Chinese medicinal material that is both edible and medicinal. Hawthorn has a long cultivation history in China. Records indicate that its cultivation can be traced back to about 1,700 years ago. Currently, the annual production has reached several million tons, with extensive planting areas in the north, making it an essential fruit in the daily diet of the Chinese people[3]. Hawthorn is a treasure trove of resources. In addition to being eaten fresh, it is also widely used in the production of various processed foods, such as hawthorn powder, hawthorn beverages, and hawthorn jelly. The fruit kernels can be pressed for oil and can also be used to prepare activated carbon. The sturdy tree is an excellent material for crafts, possessing significant economic value.

Hawthorn is also an important tree species for landscape greening, playing a significant role in the improvement of urban ecological environment and landscape beautification[4]. Hawthorn is cold-resistant, drought-resistant, and poor soil-resistant, making it suitable for most areas of urban greening[5]. As a superficial-rooted tree species with a well-developed root system but underdeveloped taproot, hawthorn can adapt well to the soil replacement situations in landscape greening[6]. In landscape applications, the ornamental value and ecological functions of hawthorn have been widely recognized. However, hawthorn has certain requirements for environmental conditions, especially being more sensitive to soil and climate conditions, which to some extent limits its planting range and growth performance[7]. Therefore, its cultivation techniques and management methods still need to be further optimized and researched.

Therefore, research on hawthorn cultivation techniques and landscape applications is of great significance. In recent years, with the development of gardening technology and increasing attention to the ecological environment, research on hawthorn cultivation techniques and landscape

applications has gradually increased, mainly focusing on improving hawthorn yield and quality, enhancing its stress resistance, and optimizing landscape configuration. These studies will strongly promote the application of hawthorn in landscape greening and its industrial development, possessing significant ecological and economic value. This paper aims to review and summarize the research progress on hawthorn cultivation techniques and landscape applications, in order to provide references for subsequent related research and applications.

2. Research Progress on Hawthorn Cultivation

2.1 Variety Selection and Breeding

Hawthorn variety selection and breeding is an important part of hawthorn cultivation research. In recent years, significant progress has been made in the collection, organization, and innovation of germplasm resources. China is rich in hawthorn germplasm resources. A total of 240 resources have been collected, including 12 species or varieties such as Crataegus wilsonii (Huazhong Hawthorn), Crataegus kansuensis (Gansu Hawthorn), and Crataegus hupehensis (Hubei Hawthorn). These include 209 large-fruit hawthorn resources, 50 wild resources, 9 Crataegus pinnatifida Bge. cv. Fushanzha, and 12 rare and precious resources[8]. The collection of these resources has provided an important foundation for hawthorn variety selection and breeding.

In the aspect of variety selection and breeding, the 1970s and 1980s were the peak period for hawthorn variety selection and breeding in China[9]. Many excellent varieties were developed, such as Dajinxing, Damiqiu, Yubei Hong, Liaohong, and Xifeng Hong. These varieties were mainly obtained through seedling selection and hybrid breeding methods. Seedling - selected varieties, such as Tianbao Hong[10] and Yimeng Hong[11], have good fruit quality and resistance. Although hybrid breeding has been slow, it has also achieved certain results. Pan[12] et al. found through hybrid combination studies that there are significant differences in the fruit - setting rate and seed - kernel rate of hawthorn hybrids, providing a theoretical basis for hybrid breeding.

In recent years, molecular marker technology has been widely applied in hawthorn variety selection and breeding. The research by Yang[13] et al. has shown that molecular marker technologies such as RAPD (Random Amplified Polymorphic DNA), ISSR (Inter - Simple Sequence Repeat), and SSR (Simple Sequence Repeat) can effectively analyze the genetic diversity of hawthorn germplasm resources, providing a scientific basis for variety selection and breeding. Dai[14-16] et al. used RAPD and ISSR markers to analyze the genetic diversity of 35 hawthorn resources and found that the tested resources could be classified into two or three categories, providing important genetic information for hawthorn variety selection and breeding.

In addition, the reproductive biology research of hawthorn also provides an important reference for variety selection and breeding. The research by Yang[17] et al. has shown that the germination rate of hawthorn pollen and the growth rate of pollen tubes significantly affect fertilization ability. The germination rate of pollen in cultivated hawthorn varieties is relatively low, which may be related to their self - incompatibility. Therefore, in variety selection and breeding, selecting varieties with a large amount of pollen and high germination rate as pollination varieties can increase the success rate of hybrid breeding.

2.2 Cultivation Techniques

Cultivation techniques of hawthorn are the key to achieving high and stable yields, which cover various aspects ranging from site selection and orchard establishment to soil management, fertilization, and pruning. Firstly, regarding site selection and orchard establishment, hawthorn has strong adaptability, but it is preferable to choose sandy loam soil that is deep, loose, fertile, and well-drained. The orchard site should be selected in a place with ample sunlight and good ventilation. When planting on slopes, the gradient should not exceed 20° to reduce soil erosion[18]. In terms of planting methods, it is advisable to plant hawthorn from after leaf fall in autumn to before sprouting in spring. The plant spacing is generally 2.5m×4m or 3m×4m. When planting,

sufficient base fertilizer should be applied, mainly farmyard manure, supplemented with phosphate fertilizer and an appropriate amount of nitrogen fertilizer. Moreover, to improve the survival rate, attention should be paid to the spreading of the root system of the seedlings during planting, and the root-fixing water should be applied thoroughly in a timely manner.

Soil management is an essential part of hawthorn cultivation. Hawthorn has a high demand for soil fertility, so it is necessary to regularly carry out deep tillage to improve soil aeration and water retention. In terms of fertilization, base fertilizer is generally applied after fruit picking in autumn, mainly organic fertilizer, supplemented with phosphate fertilizer and an appropriate amount of nitrogen fertilizer. Top dressing should be carried out according to the growth of the tree and the amount of fruit, usually before flowering, during fruit enlargement and flower bud differentiation, mainly nitrogen fertilizer, phosphate fertilizer and potassium fertilizer. In addition, foliar fertilization is also an effective means of supplementing nutrients. Urea, monopotassium phosphate and other foliar fertilizers can be sprayed before and after flowering to promote flower bud differentiation and fruit development[19].

Pruning is an indispensable part of hawthorn cultivation, with the main purpose of regulating the tree structure, promoting ventilation and light transmission, and improving fruit quality. In the young tree stage, light pruning is the main focus, mainly to cultivate the tree shape and promote the expansion of the crown. In the initial fruiting stage and the full fruiting stage, appropriate pruning should be carried out according to the growth of the tree and the amount of fruit, thinning out dense branches and weak branches, and retracting the fruiting branch groups to maintain the robust growth of the tree. In addition, flower and fruit management is also an important measure to improve the yield and quality of hawthorn, including artificial pollination, thinning flowers and fruits, etc., to increase the fruit set rate and fruit quality[20].

3. Research Progress on the Landscape Application of Hawthorn

3.1 Ornamental Value

Hawthorn, as an important ornamental tree species, has extremely high ornamental value. Its ornamental characteristics are mainly reflected in aspects such as flowers, fruits, and leaves, which can add unique beauty to the landscape in different seasons. Hawthorn flowers are usually white, with a blooming period from May to June. The flowers are dense, forming corymb inflorescences, and have a unique fragrance that can attract a large number of insects for pollination. For example, the flowers of varieties such as "Da Jin Xing" and "Ze Zhou Hong" are lush when in full bloom, with their fragrance spreading far and wide, adding a touch of brightness to the spring landscape. In addition, some hawthorn varieties with strong ornamental value, such as "Hong Yun" and "Hong Bao Luo", have bright flower colors and beautiful flower shapes, further enhancing the ornamental value of hawthorn[21]. The fruit of hawthorn is its most prominent ornamental part, usually red or dark red, with a fruiting period from September to October. The fruits hang from the branches, creating a unique spectacle. For instance, the fruits of the green hawthorn variety "Winter King" remain on the tree throughout the winter, with their bright color adding splendor to the winter landscape[7]. Moreover, the shapes of hawthorn fruits are also distinctive. For example, the fruits of "Ji Ju Hawthorn" are bell-shaped, and those of green hawthorn are pear-shaped, further enriching the ornamental characteristics of hawthorn[5]. Hawthorn leaves also have a certain ornamental value. The leaves are usually triangular-ovate, with serrated edges and dark green color. In autumn, the leaf color turns red or yellow, creating rich seasonal changes. For example, the leaves of "Red Leaf Hawthorn" turn red in autumn, complementing the red fruits and adding rich color layers to the landscape[6].

Hawthorn trees not only have high ornamental value in their flowers, fruits, and leaves, but also have distinct seasonal changes, which can add unique beauty to the landscape in different seasons. Their ornamental characteristics are not only reflected in color and shape but also have rich connotations in Chinese culture, often being endowed with auspicious meanings such as good

fortune, longevity, and abundance, making them an indispensable tree species in landscape greening.

3.2 Application Forms

Hawthorn has a variety of application forms in landscape gardening, mainly including solitary planting and group planting, as shown in Figure 1, which can meet the needs of different landscape designs.

Solitary planting is one of the common application forms of hawthorn in gardens. A solitary hawthorn tree can serve as a focal point in the garden landscape. Varieties with beautiful tree shapes and abundant fruits, such as "Da Jin Xing" and "Ze Zhou Hong," are usually chosen for this purpose. They are planted in open lawns, squares, or by the lakeside as the main tree species[22]. For example, in Hangzhou Tiandu City Tianhu Garden, three large ginkgo trees of different sizes were planted on the lawn by the artificial lake, complementing the tall architectural arches in the background and becoming a main landscape by the lake. Solitary hawthorn not only highlights its individual beauty but also forms a good contrast with the surrounding environment, enhancing the sense of hierarchy and three-dimensionality of the landscape.

Cluster planting involves planting several hawthorn trees together to create an overall landscape effect. Cluster-planted hawthorn can be mixed with other tree species to form a rich sense of layers and color changes[23]. For instance, in some roadsides of Jinhua Jiangbin Residential Area, firethorn was planted as a fruit hedge. In early summer, it blooms with white flowers, and in autumn and winter, the deep red fruits remain on the tree for a long time, forming a strong seasonal contrast with the upper-layer trees and other plants, enriching the landscape color of the residential area in winter.

Group planting is the practice of planting many hawthorn trees together to create a larger landscape effect. Group-planted hawthorn is usually used in large-scale landscape designs such as parks and green spaces, capable of forming a spectacular landscape. For example, in Minxing New Village in Shanghai, there is a ginkgo grove of about 1,400 square meters and a loquat grove of 1,400 square meters. These fruit - viewing forests not only beautify the environment but also serve ecological functions, improving the quality of the entire residential area's greening environment.

Hawthorn can also be used as street trees and hedges. As street trees, hawthorn varieties with upright tree posture and vigorous growth are usually chosen, planted on both sides of the road to form a green corridor. As hedges, hawthorn is combined with herbaceous plants or clump - forming plants, planted on both sides of the road or around buildings to create a strip - like fruit - viewing landscape.

Fig. 1 Diagrams of Solitary and Group Planting

3.3 Ecological Function

Hawthorn not only has ornamental value and diverse application forms in landscape greening, but also plays an important role in ecological functions. Its ecological functions are mainly reflected in improving urban environmental conditions, maintaining biodiversity, purifying the air, and regulating the climate.

Firstly, hawthorn can improve urban environmental conditions. With its dense crown and numerous leaves, hawthorn is capable of effectively absorbing harmful gases in the air, such as sulfur dioxide and nitrogen oxides, thus purifying the air. In addition, hawthorn has a well - developed root system that can fix the soil, prevent soil erosion, and improve soil structure[24]. For example, the root system of hawthorn can secrete organic acids and enzymes, which promote the activation of insoluble nutrients in the soil and enhance soil fertility. Secondly, hawthorn can maintain biodiversity. Hawthorn has a long flowering and fruiting period, providing a food source for various insects and birds. For instance, the flowers of hawthorn can attract pollinating insects such as bees and butterflies, promoting plant pollination and reproduction. The fruits of hawthorn can provide food for birds, attracting a variety of birds to inhabit the area and increasing biodiversity in the garden. Lastly, hawthorn can regulate the climate. With its dense crown, hawthorn can effectively block sunlight, reduce ground temperature, and regulate the local climate[25]. Moreover, through transpiration, the leaves of hawthorn can release a large amount of water vapor, increasing air humidity and improving the microclimate environment of the city.

4. Conclusion

Hawthorn, a plant with both edible and ornamental value, has seen certain progress in its cultivation techniques and garden application research. By optimizing planting techniques and expanding application forms, hawthorn has played a significant role in ecological restoration, environmental protection, and garden beautification.

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