Application and Adaptability of Ornamental Grasses in Road Flower Borders in Hefei, Anhui Province

ZHAO Haishuang, ZHAO Zhiyan^{*}

(Department of Architecture and Landscape Design, Anhui Xinhua University, Hefei, Anhui 230088, China)

Abstract In-depth research was conducted on the types, seasonal patterns, spatial levels, overwintering, summering, drought resistance, and disease and pest resistance of ornamental grasses in the road flower borders of Hefei, Anhui Province. Through field investigations, a total of 36 ornamental grasses were identified, with Liliaceae having the most species and the Lamiaceae the least. The results show that there are more warm season ornamental grasses, of 23 species; *Acorus gramineus* and *Melinis minutiflora* have poor overwintering ability; *Arrhenatherum elatius, Festuca glauca*, and *Stipa tenuissima* have poor summer tolerance; most ornamental grasses have strong drought resistance and resistance to pests and diseases. The comprehensive investigation shows that ornamental grasses have good application prospects and adaptability in the road flower borders in Hefei city.

Keywords Ornamental grass, Hefei, Road flower border, Application, Adaptability DOI 10.16785/j.issn 1943-989x.2024.4.017

Urban road flower borders are an important component of urban beautification and ecological environment construction, and ornamental grasses have unique application advantages in road flower borders due to their diverse forms and strong ecological adaptability. Ornamental grasses are a general term for herbaceous plants that are beautiful in form and rich in color with stems and leaves as the main viewing parts, which are dominated with grasses of the Poaceae family, but also include the species of Cyperaceae, Juncaceae, Typhaceae, Polygonaceae, and so on^[1]. There are various types of ornamental grasses with beautiful postures, rich and colorful leaves, distinct seasonal characteristics, and strong resistance, making them a new type of garden plants^[2].

Located among the Jianghuai hills, Hefei, the capital city of Anhui Province, is one of the first garden cities in China with beautiful natural environment^[3]. The study on ornamental grasses in the road flower borders of Hefei is beneficial for improving the ecological environment, promoting sustainable and diverse development of garden greening. However, the application of ornamental grasses has not been widely used in the real designs of road flower borders in Hefei. For the introduction of plants, it is necessary to fully understand the ecological characteristics of the introduced plants, so as to prevent biological invasion and maintain ecological security^[4]. Ornamental grasses are an essential component of the road flower borders in Hefei, so it is essential to understand the adaptability of

ornamental grasses. When applying ornamental grass to narrow road spaces, it requires to create the best landscape effect, as well as guiding traffic and improving urban microclimate^[5]. Therefore, with ornamental grasses as the object, detailed analysis is made to their application and adaptability to the local environment in Hefei, in order to provide references for the future application of ornamental grasses in road flower borders in Hefei area.

1 Study area and research methods

1.1 Overview of Hefei

Located at 116°40'-117°58' E and 30°56' -32°33' N, Hefei has a subtropical monsoon humid climate, characterized by distinct four seasons, moderate rainfall, significant plum rain, abundant summer rain, and sufficient sunshine. The annual average temperature of Hefei is 15.7 °C, with an average temperature of -2 °C in January and 28.5 °C in July. Throughout the year, Hefei is cold in winter, hot in summer and mild warm in spring and autumn; it has an annual average rainfall of 1 000 mm, annual average sunshine of 2 100 h, and average frost free period of about 228 d^[6-7]. Hefei is dominated with vegetation of North Subtropical Evergreen Broad leaved Forest and Evergreen Broad leaved Deciduous Mixed Forest.

1.2 Investigation time and object

From March 2023 to March 2024, the types and growth status of ornamental grasses in the road flower borders were continuously observed and recorded in Hefei. Through a comprehensive survey of the road flower borders, field surveys were made to the flower borders of many important road sections in 8 regions of Hefei (Table 1). A detailed investigation was made to the ornamental grass resources used in the road flower borders, and the over-summering, overwintering as well as drought tolerance of each ornamental grass were tracked and recorded.

1.3 Study methods

The methods used in the study included searching for literature related to ornamental grasses in road flower borders in Hefei, investigating the application history of ornamental grasses and the impact of local climate and environment on their growth, and understanding the types and growth status of ornamental grasses in the road flower borders in Hefei. At the same time, in order to comprehensively investigate the ornamental grass resources and related content of road flower borders in Hefei, route investigation and regional investigation were combined so as to have a reasonable arrangement of time and route, and follow-up investigation was also conducted if conditions permitted, mainly investigating the types and growth status of ornamental grasses.

2 Results and analysis 2.1 Application of ornamental grasses in road flower borders in Hefei

2.1.1 Composition of ornamental grasses. Due to the suitable climate and environment in Hefei, as well as the strong resistance and easy

* Corresponding author.

Received: June 3, 2024 Accepted: July 4, 2024

Sponsored by National Training Programs of Innovation and Entrepreneurship for Undergraduates (202312216029); 2022 Training Programs of Innovation and Entrepreneurship for Undergraduates of Anhui Province (S202212216122); Key Research Project of Natural Sciences in Universities of Anhui Province (2023AH051816); General Teaching Research Project of Anhui Province (2022jyxm665).

maintenance of ornamental grasses, there are more and more varieties of ornamental grasses applied in more road flower borders. According to statistics, there are a total of 5 families, 22 genera, and 36 species of ornamental grasses in the road flower borders of Hefei. In terms of family composition, Poaceae has the most species, with a total number of 26, accounting for 72.2% of the total species; next is the Liliaceae, with a total of 5 species, accounting for 13.88% of the total; there are two species each in Acorus and Cyperaceae, each accounting for 5.55% of the total species; the number of species of Juncaceae is the least, with only one. In terms of genus composition, the number of Miscanthus is the largest, with a total of 5 species, accounting for 22.72% of the total genera; next come the Ranunculus and Salvia, with 4 species for each, accounting for 18.18% of the total genera; there are three species in Cortaderia, accounting for 13.63%; there are 2 species of Carex and 2 species of Acorus, each accounting for 9.09%. The rest are of individual genera, with a total of 16 species, namely, Juncus, Liriope, Phragmites, Calamagrostis, Eragrostis, Muhlenbergia, Festuca, Arrhenatherum, Phalaris, Pennisetum, Arundo, Chasmanthium, Imperata, Panicum, Stipa, and Melinis.

2.1.2 Season types of ornamental grasses. Ornamental grasses can be divided into warm season ornamental grasses and cold season ornamental grasses according to their growth activity. The suitable temperatures for the growth of warm season ornamental grasses range from 27 °C to 35 °C, and the grasses of this type start growing when the temperature rises in spring, flowering and sowing in summer and autumn, and become dormant in winter. The suitable temperature for the growth of cold season ornamental grasses is 15-25 °C, and the grasses of this type begin to grow in late winter or early spring, bloom from spring to early summer, and become dormant or grow slowly in high temperatures in summer. As is shown in Table 2, there are more warm season ornamental grasses than cold season ornamental grasses, with a total of 23 species, accounting for 63.88%; there are 13 species of cold season ornamental grasses, accounting for 36.11%. Among the ornamental grasses in Poaceae, the species of Pennisetum, Cenchrus, Miscanthus, and Cortaderia are all warm season ornamental grasses; the species of Liriope in Liliaceae is a kind of cold season ornamental grass, while the species of the Cyperaceae and Acorus are all cold season ornamental grasses. When applying cool and warm season ornamental grasses to road flower borders, ornamental grasses should be scientifically selected and reasonably matched according to seasonal changes and landscape sustainability to achieve the ideal landscape effect of road flower borders.

2.1.3 Spatial hierarchy of ornamental grass. The spatial hierarchy of different plant types of ornamental grasses applied in the road flower borders of Hefei can be divided into three layers: front view, middle view and background. The results show that tall ornamental grasses are mostly used as background plants in the flower borders, which can make the landscape more diverse and colorful for their strong contrast with the plants in front view and middle view, such as the species of the Cortaderia, Panicum, Miscanthus of Poaceae, mainly including C. selloana, C. selloana'Pumila', P. virgatum, M. sinensis Variegatus', M. sinensis 'Gracillimus' and A. donax; the ornamental grasses with a medium and beautiful plant type but unique flower inflorescence are arranged in the middle of the flower borders, mostly used as the main scenery for appreciation, and most of these grasses are the species of Pennisetum and Muhlen-bergia of Poaceae, such as P. alopecuroides, P. orientale 'Purple', P. glaucum, M. capillaris; ornamental grasses with low height or bright colors are usually planted in the front view of the flower borders, usually the grasses of Festuca, Melinis, and Stipa of Gramineae, Carex of Cyperaceae, Acorus of Acoraceae, Ophiopogon of Liliaceae, such as F. glauca, M. minutiflora, S. tenuissima, C. oshimensis Evergold', A. gramineus, L. muscari Variegata'.

2.2 Adaptability of ornamental grasses in road flower borders in Hefei

The over-wintering ability refers to whether a plant can naturally sprout and grow from its roots in spring after experiencing a winter season^[8]. Based on long-term field research and observation, it has been found that most of the ornamental grasses planted in the road flower borders of Hefei, such as Juncus of Juncaceae, Carex of Cyperaceae, Ophiopogon of Liliaceae, Muhlenbergia, Festuca, Phragmites, Pennisetum, Miscanthus, Panicum of Gramineae. More specifically, the ornamental grasses with strong cold resistance include C. selloana, M. sinensis 'Silberfeder', F. glauca, P. alopecuroides, C. epigeios, P. australis, C. oshimensis 'Evergold'; the ornamental grasses with poor over-wintering ability are A. gramineus and M. minutiflora, which have low survival rates in winter and require strengthened maintenance and management. Ornamental grasses can grow in any type of soil, and once planted, they do not require water and fertilizer management or maintenance, and rarely produce pests and diseases, making them the beautiful and cost-effective ornamental plant^[9]. The most prominent characteristics of ornamental grasses are drought tolerance and water conservation, and warm season grasses are better able to withstand long-term drought and high temperature climates^[10]. All the 23 species of warm season orna-mental grasses perform well in summer, and the ones with good landscape effects are M. capi-llaris, P. alopecuroides and P. virgatum. Among the 13 species of cold season ornamental grasses, A. elatius, F. glauca and S. tenuissima become dormant or even wither in summer, indicating that they are not tolerant to high temperatures, and have poor ornamental value.

Most of the ornamental grasses in Poaceae have good drought tolerance, such as *M. sinensis* 'Variegatus', *M. sinensis* 'Zebrinus', *C. selloana*, *C. selloana* 'Silver Comet', *S. tenuissima*. In

Table 1 Names of road flower borders surveyed in Hefei City

Table 1 Names of road hower borders surveyed in here City						
Region	Flower borders	Number				
Shushan District	Yuan; Wind; Harmony, Imagination; Slow life; Peace time; Forest miracle	7				
Binhu District	Beautiful blueprint; Literary family; Lounging around flower sea; Dancing butterflies; Clear flower stream Colorful Binhu	5				
Baohe District	Yiyuan Garden (Joyful Garden); Quyi Baohe (Chinese folk arts in Baohe); Forest stream landscape, Low-carbon travel—Jogging, Low-carbon travel—Cycling	5				
Yaohai District	Trees and flowers sea; Historical sky; High bright blue sky. Ink painting Huangshan; Looking into the east, all rivers running into the sea	4				
High-tech Zone	Footprints of time; Sometimes flowers fall, Flowers enchanting eyes; Nature's work and human intelligence; The sun and moon striving for changes	4				
Luyang District	Fragrant and graceful green border; Flowers streamed water rhyme; Beautiful wings (Tixiang's wings); Walking around the world, staying in Luyang	4				
Economic development zone	Semi-wild pond; Wings spreading, Colorful flower belts, Changes and unification	4				

Table 2 Types of ornamental grasses in the road hower borders in here of	Table 2	Types of ornamental	grasses in the road flower borders in Hefei Cit
--	---------	---------------------	---

No.	Latin name	Family name	Genus name	Season type	Plant height /cm	Wintering ability
1	Juncus effusus	Juncaceae	Juncus	Cool season	27-91	Good
2	Carex oshimensis 'Evergold'	Cyperaceae	Carex	Cool season	20-40	Good
3	Carex nemostachys	Cyperaceae	Carex	Cool season	30-60	Good
4	Acorus gramineus	Acoraceae	Acorus	Cool season	20-30	Poor
5	Acorus gramineus 'Ogan'	Acoraceae	Acorus	Cool season	20-30	Normal
6	Ophiopogon japonicus	Liliaceae	Ophiopogon	Cool season	10-40	Good
7	O.Japonicus 'nana'	Liliaceae	Ophiopogon	Cool season	5-10	Good
8	Liriope muscari 'Variegata'	Liliaceae	Liriope	Cool season	25-30	Good
9	Ophiopogon bodinieri	Liliaceae	Ophiopogon	Warm season	14-30	Good
10	Ophiopogon jaburan	Liliaceae	Ophiopogon	Warm season	5-30	Good
11	Phragmites australis	Gramineae	Phragmites	Warm season	100-300	Good
12	Calamagrostis epigeios	Gramineae	Calamagrostis	Cool season	45-100	Good
13	Eragrostis pilosa	Gramineae	Eragrostis	Warm season	15-80	Good
14	Muhlenbergia capillaris	Gramineae	Muhlenbergia	Warm season	30-90	Normal
15	Festuca glauca	Gramineae	Festuca	Cool season	20-40	Good
16	Arrhenatherum elatius	Gramineae	Arrhenatherum	Cool season	50-100	Good
17	Phalaris arundinacea	Gramineae	Phalaris	Cool season	20-30	Good
18	Pennisetum alopecuroides 'Little Bunny'	Gramineae	Pennisetum	Warm season	15-30	Good
19	Pennisetum orientale 'Purple'	Gramineae	Pennisetum	Warm season	80-140	Good
20	Pennisetum alopecuroides	Gramineae	Pennisetum	Warm season	30-120	Good
21	Pennisetum glaucum	Gramineae	Pennisetum	Warm season	100-300	Good
22	Pennisetum setaceum 'Rubrum'	Gramineae	Cenchrus	Warm season	30-120	Normal
23	Miscanthus sinensis 'Variegatus'	Gramineae	Miscanthus	Warm season	120-180	Normal
24	Miscanthus sinensis 'Zebrinus'	Gramineae	Miscanthus	Warm season	75-150	Good
25	Miscanthus sinensis 'Gracillimus'	Gramineae	Miscanthus	Warm season	100-200	Good
26	Miscanthus sinensis 'Morning Light'	Gramineae	Miscanthus	Warm season	80-150	Good
27	Miscanthus sinensis 'Silberfeder'	Gramineae	Miscanthus	Warm season	150-180	Good
28	Arundo donax	Gramineae	Arundo	Warm season	300-600	Good
29	Cortaderia selloana	Gramineae	Cortaderia	Warm season	200-500	Good
30	Cortaderia selloana 'Pumila'	Gramineae	Cortaderia	Warm season	120-300	Normal
31	Cortaderia selloana 'Silver Comet'	Gramineae	Cortaderia	Warm season	50-120	Good
32	Chasmanthium latifolium	Gramineae	Chasmanthium	Warm season	50-120	Good
33	Imperata cylindrical 'Rubra'	Gramineae	Imperata	Warm season	25-50	Normal
34	Panicum virgatum	Gramineae	Panicum	Warm season	100-200	Good
35	Stipa tenuissima	Gramineae	Stipa	Cool season	30-50	Normal
36	Melinis minutiflora	Gramineae	Melinis	Warm season	30-50	Poor

Poaceae, the ornamental grasses that are not drought tolerant are *A. donax* and *P. arundinacea*; *A. gramineus* and *A. gramineus* 'Ogan', and they prefer water and humidity; *O. jaburan* has poor drought tolerance. Through nearly a year of observation and recording, these 36 ornamental grasses show strong resistance to diseases and pests. In addition to *P. arundinacea* and *E. pilosa* that had rust disease and yellow leaves, other ornamental grass plants performed well and have not suffered from diseases and pests.

3 Conclusion

Hefei has a rich road flower border resources, and the ornamental grasses play an important role in creating a diverse seasonal landscape throughout the four seasons. Over the course of about a year, a total of 36 ornamental grasses were used in the road flower borders of Hefei, including 26 species from the Poaceae family, 5 species from the Liliaceae family, 2 species from the Acorus family, 2 species from the Cyperaceae family, and 1 species from the Juncaceae family. There are 10 more warm season ornamental grass species than cold season ornamental grass species, totaling 23 species. The results show that O. jaburan which shows low tolerance to drought, A. gramineus and M. minutiflora which have poor overwintering ability, A. elatius, F. glauca and S. tenuissima which have poor over-summering ability. In addition to the above species, most ornamental grasses have strong adaptability in Hefei. Research has shown that ornamental grasses have strong adaptability and a wide variety of applicable species. It is necessary to vigorously develop their usable space and fully utilize their landscaping function in road flower borders to enhance the diversity of road plants and landscape viewing in Hefei. The study on the application and adaptability of ornamental grasses in the road flower borders of Hefei can provide theoretical and practical support for the selection and maintenance management of ornamental grasses, so as to have a more and reasonable scientific application in the road flower borders of Hefei.

References

- Li, X.Q., Yin, Z. & Yang, J. C., et al. (2022). Study on adaptability of 23 ornamental grasses in Nanjing. *Acta Agriculturae Jiangxi*, 34(4), 192-198.
- [2] Shi, L., Wang, J. L. (2016). Application and (To be continued in P79)

Journal of Landscape Research

life: The mediating role of perceived restorative experiences. *Tourism Science*, *35*(4), 76-96.

- [2] Qiu, H., Wang, G. & Ren, L. et al. (2022). The impact of restorative destination environments on tourists' well-being and environmentally responsible behavior: A reasonable person model. *Tourism Management Perspectives*, 44, 101028.
- [3] Zhang, Y. G., Huang, Y. J. & Cheng, J. J. et al. (2019). The influence of multidimensional deconstruction of stressors on enhancing urban residents' well-being: From the perspective of rural tourism and leisure involvement. *Geographical Research*, 38(4), 971-987.
- [4] Jia, H. M., Zhang, Y. L. (2022). A research on the generation mechanism of tourist well-being in virtual reality tourism product experience: Based on the embodied experience view. *Tourism Science*, *36*(3), 17-35.
- [5] Sun, J. X. (2017). Traditional village: Theoretical connotation and development path. *Tourism Tribune*, 32(1), 1-3.
- [6] Huang, J., Huang, A. M. & Yang, F. F. et al. (2022). Tourists' perceived restorative qualities and postvisit behavioral intention: The mechanism and boundary condition. *Tourism Tribune*, 37(2), 31-45.
- [7] Nie, J. (2020). Research on the status quo and countermeasures of rural tourism in Yangshuo based on tourists' happiness experience. *Tourism Overview*, 324(15), 112-114.
- [8] Meng, Q. L. (2019). Research on the relationship

between rural tourism experience value and tourists' well-being (Doctoral thesis). Retrieved from China National Knowledge Infrastructure.

- [9] De Botton, A. (2002). *The art of travel*. New York: Pantheon Books, 23-78.
- [10] Zhang, Y. G., Cheng, J. J. & Zhu, G. X. et al. (2019). Research on the influential mechanism of nostalgia, leisure involvement, place attachment and environmentally responsible behavior. *Journal of Arid Land Resources and Environment*, 33(5), 190-196.
- [11] He, J. M., Li, L. H. (2002). Discussion on the concept of "rural tourism". *Journal of Southwest University (Social Science Edition)*, 28(5), 125-128.
- [12] Li, M. Y. (2023). Research on the influence of nostalgia of rural tourists in Zhejiang GY on tourism destinations (Master's thesis). Retrieved from China National Knowledge Infrastructure.
- [13] Yu, R. Z., Huang, Z. F. & Bao, J. Q. et al. (2022). The influence of rural tourists' nostalgia on subjective well-being and recreational behavior intention. *Tourism Tribune*, 37(7), 107-118.
- [14] Yu, R. Z., Huang, Z. F. & He, Z. L. et al. (2022). A study on the driving mechanism of the subjective sense of well-being of rural tourists from the motivation perspective: A case study of the traditional ancient villages on south Anhui. *Tourism Science*, *36*(6), 90-105.
- [15] Gao, J., Li, M. J. & Wu, B. H. (2017). Relationship between emotion and behavior in Zhiqing's nostalgia tourism. Areal Research and Develop-

ment, 36(2), 61-67.

- [16] Kim, H., Lee, S. & Uysal, M. et al. (2015). Naturebased tourism: Motivation and subjective wellbeing. *Journal of Travel & Tourism Marketing*, 32(Sup1), S76-S96.
- [17] Chen, X. Y., Huang, R. & Hong, X. T. et al. (2020). The measurement of xiangchou and its resource value in traditional village tourism destinations: A case study in Southern Jiangsu. *Journal of Natural Resources*, 35(7), 1602-1616.
- [18] Routledge, C., Wildschut, T. & Sedikides, C. et al. (2012). The power of the past: Nostalgia as a meaning-making resource. *Memory*, 20(5), 452-460.
- [19] Wang, P., Zhang, D. L. (2022). The influence of environmental cognition on the loyalty of rural boarding summer vacationers: The mediating role of place attachment and a sense of wellbeing. *Journal of Southwest Minzu University* (*Humanities and Social Sciences Edition*), 43(8), 43-49.
- [20] Wu, D., Shen, C. & Wang, E. et al. (2019). Impact of the perceived authenticity of heritage sites on subjective well-being: A study of the mediating role of place attachment and satisfaction. *Sustainability*, 11(21), 6148.
- [21] Liu, J. W., Liu, X. B. & Huang, X. Y. et al. (2022). Conservation and activation strategy of traditional villages along the South China Historical Trail. *Hubei Agricultural Sciences*, *61*(4), 111-114.

(Continued from P72)

adaptability of ornamental grasses in Guangzhou. *Journal of Henan Forestry Science and Technology*, *36*(3), 22-24.

- [3] Tang, W. L., Han, X. X. (2019). Application of road flower borders in Hefei City about the microspace Transformation. *Journal of Changchun Normal University*, 38(8), 83-90.
- [4] Zhao, T. R., Zhang, Q. J., & Cai, J. L., et al. (2011). Study on the character of growth and propagation of ornamental grasses. *Northern*

Horticulture, (15), 103-106.

- [5] Lu, S. Y. (2022). Research on flower border plants and their applications in Hefei, China. Hefei: Anhui Agricultural University.
- [6] Ma, D. L., Liao, Q. L., & Zhu, G. Q. (2008). Characteristics of temperature variation over the past 53 years in Hefei, China. *Meteorology and Disaster Reduction Research*, (9), 43-47.
- [7] Hua, S., Zha, L. S. (2018). Anhui Geography. Beijing: Beijing Normal University Press.
- [8] Wang, R., Zhu, L. (2023). Adaptability and

landscape application of perennial herbaceous plants in Shenyang, China. *Chinese Landscape Architecture*, 39 (2), 127-132.

- [9] Gao, H., Liu, J. X. (2005). Species, ornamental value, and landscape configuration of ornamental grasses in Nanjing, China. *Grassland* and Turf, (3), 13-16.
- [10] Zhang, J. (2023). Research on the characteristics and landscape application of ornamental grasses in Fuzhou, China. *Forestry Prospect and Design*, 43(4), 25-29.