THE EFFECT OF DIFFERENT AFFORESTATION TREE SPECIES ON PLANT DIVERSITY AFTER 50 YEARS ON MOUNT TAI, CHINA

ZHOU, J.[1] – GAO, Y.[2,3*] – WANG, Y.[2] – ZHAO, Y. J.[4]

[1]School of Life Sciences, Qufu Normal University, Jining 273 165, China
(e-mail: jingzhou-2004@163.com)

[2]Shandong Provincial Key Laboratory of Water and Soil Conservation and Environmental Protection, College of Resources and Environment, Linyi University, Linyi 276 005, China
(e-mail: wangyunsd@163.com)

[3]Linyi Scientific Exploration Laboratory, Linyi 276 037, China

[4]College of Agriculture and Forestry, Linyi University, Linyi 276005, China
(e-mail: zhaoyanjie1882@126.com)

*Corresponding author
e-mail: gaoyuan1182@tom.com

Abstract. The degree of forest vegetation restoration and reconstruction and the impact of different afforestation tree species on plant diversity in Mount Tai, China were evaluated. We selected 6 kinds of 50-year-old plantations along Tianwai village, Hongmen, Tianzhu peak and Taohuayuan lines. The results show that: 1) *Robinia pseudoacacia* plantation has significantly lower tree layer richness, Shannon-Wiener diversity and Simpson diversity than other plantations; *Pinus tabulaeformis* and larch tree plantations have significantly lower shrub layer Shannon -Wiener and Simpson diversity than other plantations, *Pinus tabulaeformis* and *Pinus densiflora* have significantly lower Pielou evenness than the other four plantations; *Pinus tabulaeformis* plantation and *Platycladus orientalis* plantation have significantly lower herb layer richness than the other four plantations, while *Pinus tabulaeformis* plantation has significantly lower Shannon-Wiener diversity and Simpson diversity than the other five plantations. 2) Species richness, Shannon-Wiener diversity and Simpson diversity of tree and shrub layers are all presented from highest to lowest in the following order: Mount Meng > Mount Tai > Mount Yi, while Mount Tai plantation has the highest herb layer species richness, Shannon-Wiener diversity and Simpson diversity. These results provide basis for the regulation and prediction of regional forest vegetation restoration and reconstruction in the future.
Keywords: *vegetation restoration, plant diversity, shrub layer, 50-year-old plantations, Mount Tai, plantation, plant diversity, soil, 50-year Forest Establishment*

Introduction

Biodiversity provides the basis for maintaining the stability of ecosystem structure and function (Wang et al., 2016), which represents one core issue in plant ecology (Kazakou et al., 2008). Changes in species diversity in the process of vegetation restoration reflect the degree of vegetation restoration, which is also a result of the combined effects of ecological processes such as community environmental evolution, population intrusion and diffusion (Kapás et al., 2020), and competition. Excessive studies have confirmed that plantation forests can effectively prevent land degradation and promote vegetation restoration (Depauw et al., 2019), but different initial afforestation tree species will lead to significantly different plant community structures and species diversity of plantation

forests (Togonidze and Akhalkatsi, 2015). Studies have shown that the use of exotic species for afforestation will weaken the natural restoration of native plants and reduce plant diversity of the community (Xue et al., 2016). However, studies also found that use of exotic species for afforestation can contribute to biodiversity conservation and protect successional tree species in the later stage, which will eventually be restored to native zonal vegetation and exotic species will be withdrawn (Assandri et al., 2016). Plantation forests are superior to enclosed forests in terms of biodiversity conservation potential, and its species of harmful plants are also fewer compared to the latter (Huang et al., 2015). To maintain stability of plantation forest ecosystem and maximize its functions, species diversity research after vegetation restoration is particularly important. There is a need to evaluate the vegetation restoration and reconstruction processes and effects based on the principle of biodiversity (Lindenmayer et al., 2018). For plantation forest more than 50 years old, dynamics research on vegetation restoration and reconstruction is ever more urgent due to the scarcity of samples (Chi et al., 2004; Fan et al., 2008; Gao et al., 2011).

Due to its complex and diverse ecological environmental conditions, the mountainous region has become a germplasm bank for species survival, reproduction and preservation (Tian and Li, 2012). Mount Tai, standing on the North China Plain, is the highest mountain in Shandong. Rich in wild plant resources, it is the mountain with the most diverse vegetation, and the highest number of endemic plant species in Shandong Province (Su et al., 2018), which is a dual heritage of world culture and nature, World Geopark, National Key Cultural Relics Protection Unit, National Key Scenic Spot and National 5A Tourist Attraction. The research on Mount Tai vegetation began with the front forest vegetation investigation of Mount Tai by the East China Forestry Investigation Team in 1950, the Mount Tai Vegetation Investigation Team of Botanical Geography Training Class of East China Normal University in 1956, and the Geobotany Investigation Team of Shandong University in 1957 (Kyohou, 1958). After more than 60 years of inheritance, there have been studies on plant diversity in some forest types (Chen et al., 2019) and some forest farms (Kuswanda et al., 2019).

Based on previous studies, this paper intends to conduct a field investigation on 50-year restoration and reconstruction of six main afforestation tree species in Mount Tai, evaluate the status and extent of forest vegetation restoration and reconstruction, and examine the impact of different afforestation tree species on plant diversity, thus providing a basis for the regulation and prediction of regional forest vegetation restoration and reconstruction in the future.

Materials and methods

Overview of the sample plot

Mount Tai is located in the middle of Shandong, China, with geographic coordinates of 36°05'–36°15'N, 117°05'–117°24' E, covering an area of 426 km^2. The main peak, Yuhuangding, with an altitude of 1545 m, is the highest peak in Shandong. The mountain is mainly composed of complex rock-crystalline gneiss and metamorphic granite, with a small amount of limestone and sandy shale. The soil types are mainly brown soil, ordinary acid brown soil, mountain dark brown soil and mountain shrubby meadow soil, with ordinary acid brown soil as the most common type. The climate is warm-temperate continental monsoon climate with four distinct seasons and sufficient sunlight. The annual average temperature is about 5.3 ℃ at the mountain top and 12.8 ℃ at the mountain foot. The average annual rainfall is about 1 125 mm at the mountain top, and 600 mm at

the mountain foot. The forest coverage rate is about 81.5%, and the main vegetation is *Pinus tabuliformis* forest, *Platycladus orientalis* forest, *Pinus densiflora* forest, *Pinus thunbergii* forest, *Quercus acutissima* forest, *Robinia pseudoacacia* forest and *Quercus variabilis* forest (Fu et al., 2009; Ma et al., 2010; Zhang et al., 2011). The map of the location of the sampling site was shown in *Figure S1*. The phenological differences between the studied species were shown in *Table S1*. We measured soil nutrients and the data was shown in *Table 1*. And soil nutrient detection methods refer to Donald (2020).

Table 1. Soil nutrients in sample plots

	Organic matter g·kg⁻¹	Total nitrogen g·kg⁻¹	Total phosphorus g·kg⁻¹	Total potassium g·kg⁻¹	Hydrolytic nitrogen mg·kg⁻¹	Available phosphorus mg·kg⁻¹	Available potassium mg·kg⁻¹
PT forest	81.0±11.3	3.3±0.3	1.5±0.2	11.7±0.7	235.9±44.8	83.6±7.5	70.3±7.8
PO forest	19.7±6.1	1.1±0.3	0.5±0.1	8.9±0.8	87.0±27.0	39.2±16.8	59.8±9.7
RP forest	37.3±6.2	2.3±0.4	0.8±0.1	7.7±0.5	194.7±43.6	32.2±7.0	69.8±16.4
PD forest	44.3±6.4	2.3±0.2	1.3±0.1	12.2±0.9	176.2±35.7	60.8±10.8	79.4±8.0
LK forest	72.9±7.5	4.0±0.2	1.8±0.1	10.2±0.6	528.5±207.2	81.4±2.7	92.9±22.2
PA forest	35.7±2.9	2.1±0.2	0.9±0.2	3.8±0.5	190.9±24.0	27.8±5.6	69.0±10.7

PT forest = *Pinus tabulaeformis* forest, PO forest = *Platycladus orientalis* forest, RP forest = *Robinia pseudoacacia* forest, PD forest = *Pinus densiflora* forest, LK forest = *Larix kaempferi* forest PA forest = *Pinus armandii* Franch. forest

Field investigation

The field investigation covered Tianwai Village route, Hongmen route, Tianzhu Peak route and Taohuayuan route. 50-year-old middle-aged forest was selected as the sample plot, and typical sampling method was taken for the forest investigation (Fang et al., 2004; Yu et al., 2009). A total of 42 sample plots were set up in the field, with a dimension of 30 m × 20 m. The selected sample plots are neat and can represent basic characteristics of the community.

The community level is divided into tree layer, shrub layer and herb layer for hierarchical statistics. According to investigation specifications for plant species diversity in mountainous areas (Fang et al., 2004) and method specifications for the inventory of plant communities (Yu et al., 2009), statistical specifications of the plot stratification are decided as: tree layer, 30 m × 20 m; shrub layer, 15 m × 15 m, located at the center of the sample plot, 1; herb layer, 1 m × 1 m, located at the four corners of the sample plot, 4. In tree layer measurement, record species and numbers of all woody plants with $(DBH) \geq 5$ cm and DBH of each wood; in shrub layer measurement, record species, numbers of all woody plants with $DBH < 5$ cm and DBH of each wood, including arbor seedlings, saplings and woody vines.

Data processing

Four general diversity indexes are selected for calculation and analysis of plant diversity (Fang et al., 2004; Yu et al., 2009): Richness Index (*S,* Equation 1), Shannon-Wiener Diversity Index (*H,* Equation 2), Simpson Diversity Index (*P,* Equation 3) and Pielou Evenness Index (*E,* Equation 4). The calculation formulas are:

$$S = \text{plant species in the sample plot} \qquad \text{(Eq.1)}$$

$$H = -\sum_{i=1}^{S} P_i ln P_i \qquad \text{(Eq.2)}$$

$$P = 1 - \sum_{i=1}^{S} P_i{}^2 \qquad \text{(Eq.3)}$$

$$E = H / \ln S \qquad \text{(Eq.4)}$$

where, P_i is the ratio of the importance value of the i-th species to the total importance value of all species in the sample plot, importance value of shrub layer = (relative significance + relative density + relative frequency)/3, and importance value of herb layer = (relative height + relative density + relative frequency)/3.

Statistical analysis

The differences in plant diversity between forest types are analyzed by single factor method and T test. The inter-layer and intra-layer plant diversity correlation is interpreted by principal component analysis. Data analysis and chart production are completed using SPSS 17.0 and Excel 2003.

Results

Species diversity of six plantation forests in Mount Tai after 50 years of establishment

Species diversity of tree layer

Tree Species detected in the individual plots were shown in *Table S2*. Tree layer plant richness index, Shannon-Wiener diversity index, and Simpson diversity index present relatively consistent characteristics. That is, Robinia pseudoacacia plantation has significantly lower value than the other five plantation forests (*P*<0.05), while *Pinus tabulaeformis* plantation, *Platycladus orientalis* plantation, *Pinus densiflora* plantation, *Pinus armandi* plantation and larch tree plantation are not significantly different from each other (*Figure 1A1–Figure 1A3*). There is no significant difference in Pielou evenness index of the 6 plantations in Mount Tai (*Figure 1A4*).

Species diversity of shrub layer

Shrub layer plant richness index is not significantly different among the six plantations (*Figure 1B1*). *Pinus tabulaeformis* plantation and larch tree plantation have significantly lower Shannon-Wiener and Simpson diversity indexes than the other four species (*P*<0.05), *Platycladus orientalis* plantation, *Robinia pseudoacacia* plantation, *Pinus densiflora* plantation and *Pinus armandi* plantation are not significantly different from each other (*Figure 1B2-Figure 1B3*). *Pinus tabuliformis* plantation and *Pinus densiflora* plantation have significantly lower Pielou evenness index than the other four plantations (*P*<0.05). *Platycladus orientalis* plantation, *Robinia pseudoacacia* plantation, *Pinus armandi* plantation and larch tree plantation are not significantly different from each other (*Figure 1B4*).
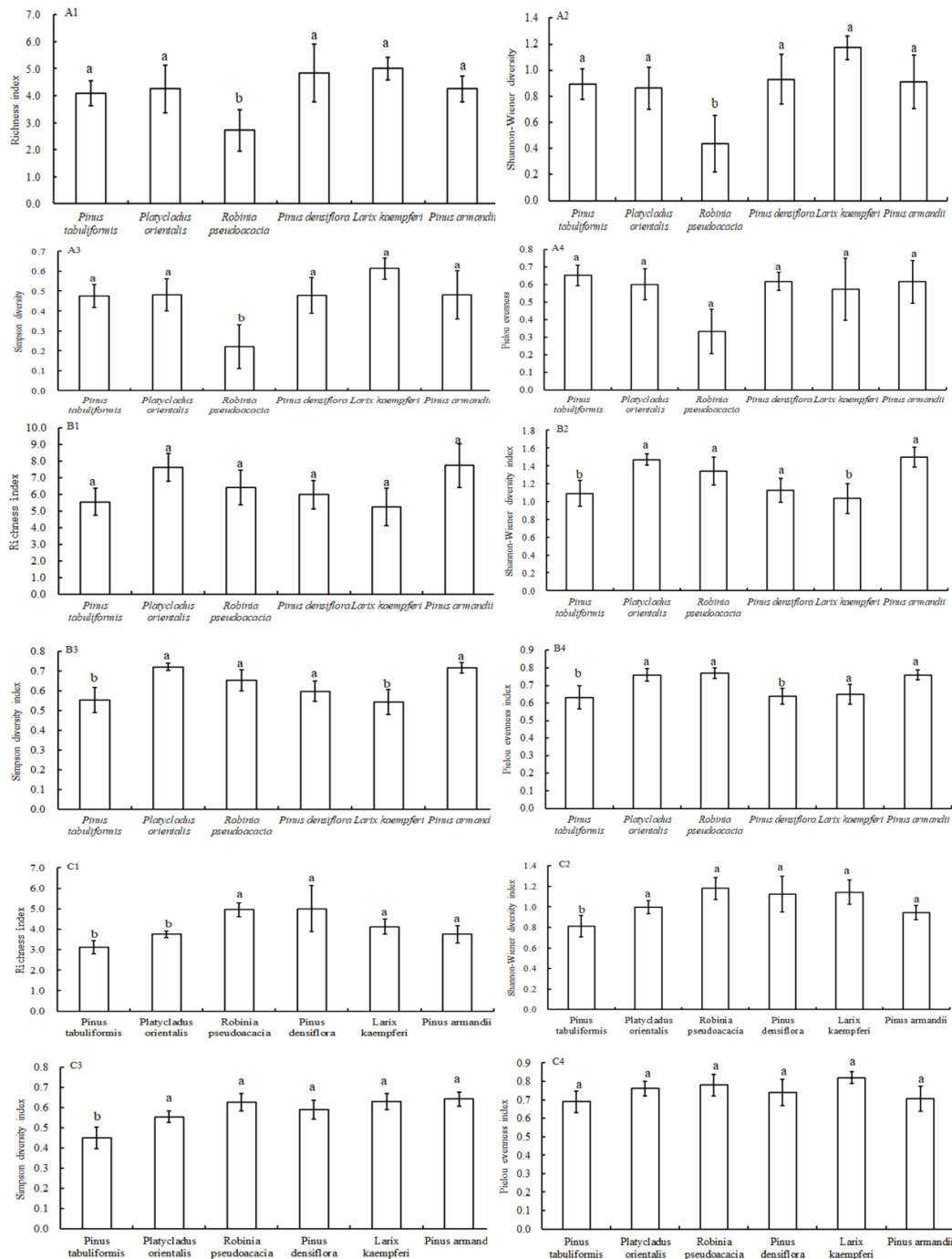
Figure 1. *The richness index, Shannon-Wiener diversity index, Simpson diversity index and Pielou evenness index of the tree layer (A1–A4), shrub layer (B1–B4) and herb layer (C1–C4) of the 6 main plantations in Mount Tai (Mean ± standard error) Different lowercase letters indicate significant differences among plantations (P<0.05)*

Species diversity of herb layer

In herb layer, *Pinus tabulaeformis* plantation and *Platycladus orientalis* plantation have significantly lower richness index than the other four plantations (*P*<0.05), while *Robinia pseudoacacia* plantation, *Pinus densiflora* plantation, *Pinus armandi* plantation

and larch tree plantation are not significantly different from each other (*Figure 1C1*). Pinus tabulaeformis plantation has significantly lower Shannon-Wiener and Simpson diversity indexes than the other five plantations (*P<0.05*), *Platycladus orientalis* plantation, *Robinia pseudoacacia* plantation, *Pinus densiflora* plantation, *Pinus armandi* plantation and larch tree plantation are not significantly different from each other (*Figure 1C2–Figure 1C3*). There is no significant difference in Pielou evenness index between the 6 plantations in Mount Tai (*Figure 1C4*).

Correlation analysis of tree, shrub and herb species diversity

The four inter-layer diversity indexes of tree layer, shrub layer and herb layer of Mount Tai plantations are all significantly positively correlated and inter-layer richness index, Shannon-Wiener diversity index and Simpson diversity index show significant positive correlation between shrub layer and herb layer (*Table 2*).

Table 2. *Correlation of species diversity of tree, shrub and herb in the Taishan plantation*

	T−S	T−H	T−P	T−E	S−S	S−H	S−P	S−E	H−S	H−H	H−P	H−E
T−S	1.00											
T−H	0.89**	1.00										
T−P	0.80**	0.98**	1.00									
T−E	0.53**	0.77**	0.83**	1.00								
S−S	0.15	0.14	0.12*	0.02	1.00							
S−H	0.08	0.08	0.06	-0.06	0.88**	1.00						
S−P	0.05	0.08	0.07	-0.02	0.74**	0.96**	1.00					
S−E	-0.00	0.05	0.05	-0.01	0.32*	0.68**	0.81**	1.00				
H−S	-0.16	-0.24	-0.30*	-0.23	0.32*	0.35**	0.31*	0.19	1.00			
H−H	0.01	-0.09	-0.18	-0.19	0.36**	0.38**	0.35**	0.19	0.86**	1.00		
H−P	0.01	-0.07	-0.16	-0.21	0.35**	0.36**	0.33*	0.19	0.69**	0.87**	1.00	
H−E	0.07	-0.02	-0.09	-0.14	0.23	0.22	0.22	0.07	0.38**	0.72**	0.71**	1.00

T-S, tree layer richness index; T-H, tree layer Shannon-Wiener diversity index; T-P, tree layer Simpson diversity index; T-E, tree layer Pielou evenness index; S-S, shrub Layer richness index; S-H, shrub layer Shannon-Wiener diversity index; S-P, shrub layer Simpson diversity index; S-E, shrub layer Pielou evenness index; H-S, herb layer richness index; H−H, Shannon-Wiener diversity index of herb layer; H−P, Simpson diversity index of herb layer; H−E, Pielou evenness index of herb layer, *, *P<0.05*; **, *P<0.01*

## Differences in plant diversity between Mount Tai, Mount Meng and Mount Yi plantations

Species richness index

The species richness indexes of tree layer and shrub layer are both presented as that of Mount Meng plantation> Mount Tai plantation> Mount Yi plantation (*p <0.05*), while that of herb layer is presented as that of Mount Tai plantation> Mount Meng plantation> Mount Yi plantation (*P<0.05*) (*Figure 2A*).

Shannon-Wiener diversity index

Shannon-Wiener diversity index of tree layer and shrub layer is presented as that of Mount Meng plantation> Mount Tai plantation> Mount Yi plantation (*P*<0.05), while the herb layer is presented as that of Mount Tai plantation> Mount Yi plantation> Mount Meng plantation. Lin (*P*<0.05) (*Figure 2B*).

■, tree layer; ▦, shrub layer; □, herb layer
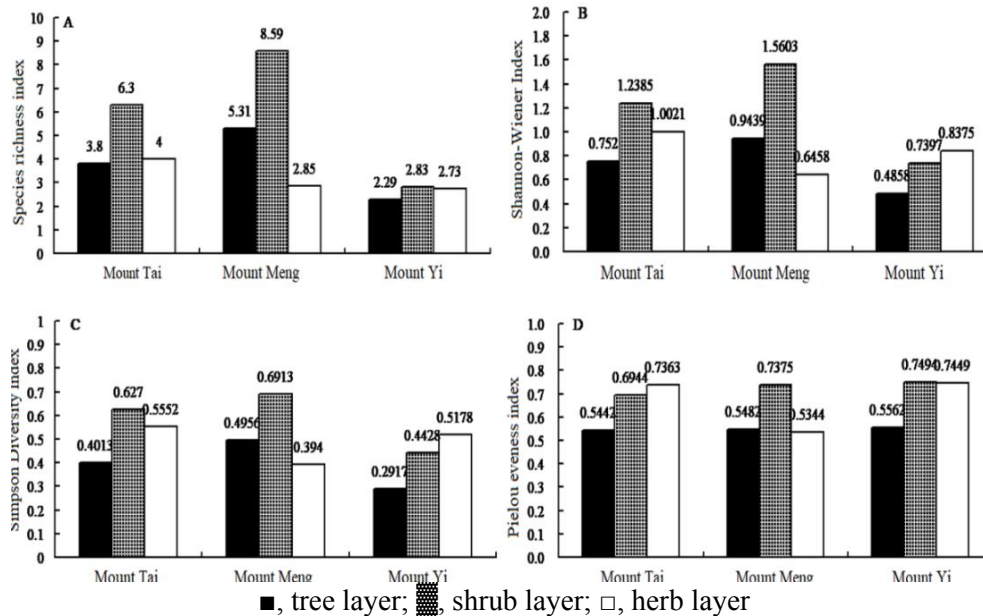
Figure 2. *The abundance index (A), Shannon-Wiener diversity index (B), Simpson diversity index (C), and Pielou evenness index (D) of the tree layer and shrub layer of Taishan, Mengshan and Yishan plantations and herb layer difference*

Simpson diversity index

Simpson diversity index of tree layer and shrub layer is presented as that of Mount Meng plantation> Mount Tai plantation> Mount Yi plantation, while the herb layer is presented as that of Mount Tai plantation> Mount Yi plantation> Mount Meng plantation (*Figure 2C*).

Pielou eveness index

Pielou evenness indexes of tree layer and shrub layer are both presented as that of Mount Yi plantation> Mount Meng plantation> Mount Tai plantation, while the herb layer is presented as that of Mount Yi plantation>T Mount Tai plantation> Mount Meng plantation (*Figure 2D*).

Discussion

Most of the existing vegetation in Mount Tai is plantation forest after the founding of the People's Republic of China, with a few natural forests and secondary forests. The six main plantations are subjected to dual influence of vegetation evolution history and interference from human activities. The vegetation types, plant communities and species diversity are mainly affected by artificial afforestation in the early stage and tourism

activities and natural succession in the later period. The six plantations in Mount Tai have been enclosed for 50 years. Under strict and effective local forestry management, soil and water conservation is fine, the forest coverage rate is significantly increased, plant species are significantly increased, so the forest vegetation is restored and rebuilt smoothly, but different plantations differ greatly.

Robinia pseudoacacia plantation in Mount Tai has significantly lower tree layer richness index, Shannon-Wiener diversity index and Simpson diversity index than the other five plantations. This may be due to the inhibition of *Robinia pseudoacacia* forest growth on the understory (Wu et al., 2017). Therefore, we should carry out thinning management for the existing stands with high canopy density in time to promote the growth of lower vegetation, reasonably allocate trees, shrubs and grasses, enrich the community hierarchy and improve the ecological function of *Robinia pseudoacacia* forest. *Pinus tabulaeformis* plantation and larch tree plantation have significantly lower shrub layer Shannon -Wiener diversity index and Simpson diversity index than the other four plantations, *Pinus tabulaeformis* plantation and *Pinus densiflora* have significantly lower Pielou evenness index than the other four plantations; *Pinus tabulaeformis* plantation and *Platycladus orientalis* plantation have significantly lower herb layer richness index than the other four plantations, while *Pinus tabulaeformis* plantation has significantly lower Shannon-Wiener diversity index and Simpson diversity than the other five plantations. On the whole, among the six main plantations in Mount Tai, *Robinia pseudoacacia* plantation has the lowest plant diversity in the tree layer, while *Pinus tabulaeformis* plantation has the lowest plant diversity in the shrub and herb layers. This result was inconsistent with our previous research in Mengshan mountain, which may be caused by the difference of afforestation time, geographical location, soil and climate between the two mountains (Gao et al., 2009).

The four inter-layer diversity indexes of tree layer, shrub layer and herb layer of Mount Tai plantations are all significantly positively correlated, while inter-layer richness index, Shannon-Wiener diversity index and Simpson diversity index show significant positive correlation between shrub layer and herb layer.

According to the investigation, the six main plantations in Mount Tai display sparseness within the trees and simplification of the community appearance, which may be due to the different growth habits and reproduction strategies of plants. For example, perennial forbs have strong tolerance and cushion against disturbances, while shrubs and semi-shrubs are sensitive to interference (Zheng et al., 2008; Gao, 2009). Species richness index, Shannon-Wiener diversity index and Simpson diversity index of tree layer and shrub layer are all presented as that of Mount Meng plantation> Mount Tai plantation> Mount Yi plantation, while Mount Tai plantation has the highest herb layer species richness index, Shannon-Wiener diversity index and Simpson diversity index, though it has the lowest tree layer and shrub layer Pielou evenness index. The understory shrub and herb layer vegetation generally features shade tolerance and fast growth rate, which can easily form a thick and dense evergreen understory shrub and herb layer in the forest ecosystem, thus limiting the natural regeneration of trees, and restricting forest regeneration to a certain extent (Kobayashi et al., 2010).

Conclusion

In the current study, the degree of forest vegetation restoration and reconstruction and the impact of different afforestation tree species on plant diversity in Mount Tai, China

were evaluated. Compared with previous studies, this paper further discusses the effect of different after station tree species on plant diversity after 50 years on Mount Tai, China. Plantation in Mount Tai obviously has the function of protecting and improving soil particle and pore structure. The preservation and improvement of soil structure and function has become an indispensable prerequisite for the success of artificial afforestation in Mount Tai. Further research should focus on the differences of microbial communities and functional microorganisms in rhizosphere and bulk soil of afforestation tree species.
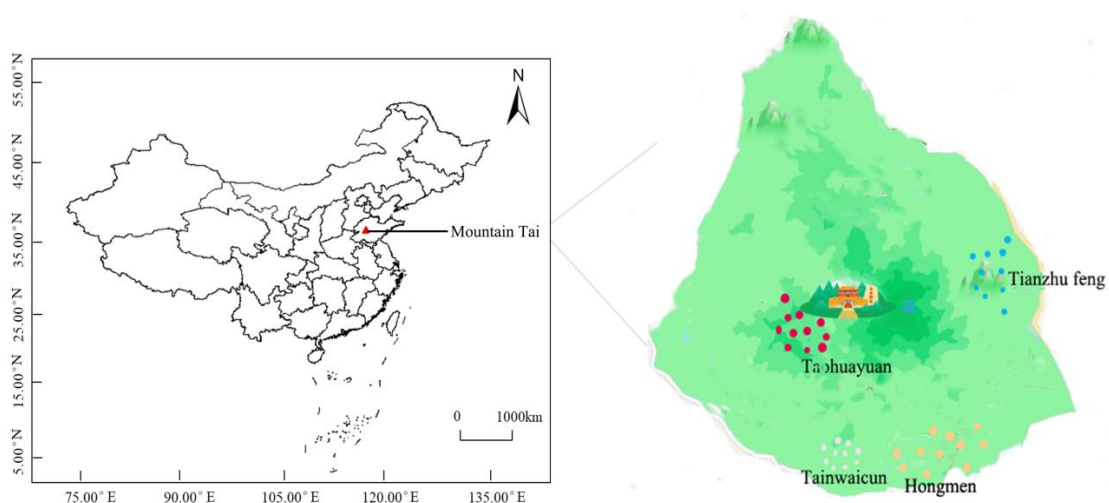
REFERENCES

[1] Assandri, G., Bogliani, G., Pedrini, P., Brambilla, M. (2016): Land-use and bird occurrence at the urban margin: implications for planning and conservation. – North-Western Journal of Zoology 13(1): e161601.

[2] Chen, L., Han, W., Liu, D., Liu, G. (2019): How forest gaps shaped plant diversity along an elevational gradient in wolong national nature reserve? – Journal of Geographical Sciences 29(7): 1081-1097.

[3] Depauw, L., Perring, M. P., Brunet, J., Maes, S. L., Verheyen, K. (2019): Interactive effects of past land use and recent forest management on the understorey community in temperate oak forests in South Sweden. – Journal of Vegetation Science 30(5): 917-928.

[4] Donald, C., Phillimon, N., Henry, M., Felix, C. (2020): Fire alters the availability of soil nutrients and accelerates growth of Eucalyptus grandis in Zambia. – Journal of Forestry Research 31: 1637-1645.

[5] Fan, B., Sang, W. G., Li, G. Q., Liu, R. G., Chen, L. Z., Wang, K. (2008): Long-term protection effects of national reserve to forest vegetation in 4 decades: biodiversity change analysis of major forest types in Changbai Mountain Nature Reserve, China. – Science in China 10: 948.

[6] Fang, J., Shen, Z., Tang, Z., Wang, Z. (2004): The Protocol for the Survey Plan for Plant Species Diversity of China's Mountains. – Biodiversity Science 12(1): 5-9.

[7] Gao, Y. (2009): Effect of tourism on species composition in Mount Meng, Shandong Province. – World Sci-Tech Research and Development 31(4): 708-710.

[8] Gao, Y., Chen, Y., Dong, H., Hao, J., Ci, H. (2011): Vegetation and species diversity change analysis in 50 years in Tashan Mountain, Shandong Province, China. – Acta Ecologica Sinica 31(20): 5984-5991.

[9] Huang, X. R., He, F., Pang, S. L., Hou, Y. R., Lu, G. D. (2015): Understory biodiversity of plantations on karst mountains in Guangxi and its relation to environmental factors. – Chinese Journal of Ecology 34(11): 3024-3033.

[10] Kapás, R., Plue, J., Kimberley, A., Cousins, S. (2020): Grazing livestock increases both vegetation and seed bank diversity in remnant and restored grasslands. – Journal of Vegetation Science 31(6): 1053-1065.

[11] Kazakou, E., Dimitrakopoulos, P. G., Baker, A., Reeves, R. D., Troumbis, A. Y. (2008): Hypotheses, mechanisms and trade-offs of tolerance and adaptation to serpentine soils: From species to ecosystem level. – Biological Reviews 83(4): 495-508.

[12] Kobayashi, T., Shimano, K., Muraoka, H. (2010): Effect of light availability on the carbon gain of beech (Fagus crenata) seedlings with reference to the density of dwarf bamboo

(Sasa kurilensis) in an understory of Japan Sea type beech forest. – Plant Species Biology 19(1): 33-46.

[13] Kyohou, G. Y. (1958): The vegetation of Chaoyang Dong, Taishan, and its vicinity. – Journal of Shandong University: natural science 8(1): 243-256.

[14] Lindenmayer, D., Blanchard, W., Crane, M., Michael, D., Sato, C. (2018): Biodiversity benefits of vegetation restoration are undermined by livestock grazing. – Restoration Ecology 26(06): 1157-1164.

[15] Su, Y., Li, J., Qiu, J., Jin, Z., Fang, X., Chao, Y., Wang, J., Zhou, H. (2018): Current situation investigation and analysis of medicinal plant resources in Mount Tai area. – Chinese Wild Plant Resources 37(5): 1006-9690.

[16] Tian, Z., Li, Z. (2012): The vertical distribution of vegetation patterns and its relationship with environment factors at the northern slope of Ili River Valley: a bimodal distribution pattern. – Acta Ecologica Sinica 32(4): 1151-1162.

[17] Togonidze, N., Akhalkatsi, M. (2015): Variability of plant species diversity during the natural restoration of the subalpine birch forest in the Central Great Caucasus. – Turkish Journal of Botany 39: 458-471.

[18] Wang, S., Loreau, M., Jordan, F. (2016): Biodiversity and ecosystem stability across scales in metacommunities. – Ecology Letters 19(5): 510-518.

[19] Wu, D., Jiao, W., Yu, W. (2017): Species composition and community characteristics of 15-year-old Robinia pseudoacacia forest and natural vegetation in Ansai, Shaanxi province. – Research of Soil and Water Conservation 24(4): 12-16.

[20] Xue, S., Zhu, F., Kong, X., Wu, C., Huang, L., Huang, N., Hartley, W. (2016): A review of the characterization and revegetation of bauxite residues (red mud). – Environmental Science & Pollution Research 23(2): 1120-1132.

[21] Yu, D., Jiang, Y., Wang, Z., Zheng, C., Zhu, J., Wang, X., Shen, H., Fang, J., Tang, Z., He, J. (2009): Methods and protocols for plant community inventory. – Biodiversity Science 17(6): 533-548.

[22] Zheng, W., Zhu, J., Pan, C. (2008): Effect of tourism disturbance intensity on plant species diversity of meadow community in Kanasi Nature Reserve. – Acta Agrestia Sinica 16(6): 624-629, 635.

APPENDIX

Figure S1. *The map of the location of the sampling sites*

Table S1. *Phenological differences between the studied species*

	Average DBH (cm)	Forest canopy density (%)	Tree density (/ha)
PT forest	20.43	76	567
PO forest	11.63	73	1000
RP forest	15.03	81	733
PD forest	16.97	75	800
LK forest	18.33	92	1033
PA forest	19.42	86	900

PT forest = *Pinus tabulaeformis* forest, PO forest = *Platycladus orientalis* forest, RP forest = *Robinia pseudoacacia* forest, PD forest = *Pinus densiflora* forest, LK forest = *Larix kaempferi* forest PA forest = *Pinus armandii* Franch. forest

Table S2. *Species detected in the individual plots*

PT forest	PO forest	RP forest	PD forest	LK forest	PA forest
Pinus bungeana Zucc. et Endi	*Platycladus orientalis (Linn.) Franco*	*Pinus densiflora Sieb. et Zucc.*	*Platycladus orientalis (Linn.) Franco*	*Pinus densiflora Sieb. et Zucc.*	*Grewia biloba G. Don var.parviflora (Bunge)H.-M*
Platycladus orientalis (Linn.) Franco	*Pinus densiflora Sieb. et Zucc.*	*Ailanthus altissima (Mill.) Swingle*	*Pinus densiflora Sieb. et Zucc.*	*Tilia tuan Szyszyl.*	*Pinus densiflora Sieb. et Zucc.*
Pinus densiflora Sieb. et Zucc.	*Ailanthus altissima (Mill.) Swingle*	*Robinia pseudoacacia Linn.*	*Ailanthus altissima (Mill.) Swingle*	*Pinus thunbergii Parlatore*	*Carpinus turczaninowii Hance*
Robinia pseudoacacia Linn.	*Robinia pseudoacacia Linn.*	*Quercus aliena Blume*	*Robinia pseudoacacia Linn.*	*Lespedeza bicolor Turcz.*	*Pinus armandii Franch.*
Kalopanax septemlobus (Thunb.) Koidz.	*Broussonetia kazinoki S. et Z.*	*Pinus armandii Franch.*	*Tilia tuan Szyszyl.*	*Sorbus pohuashanensis (Hance) Hedl.*	*Phellodendron amurense Rupr.*
Celtis koraiensis Nakai	*Albizia julibrissin Durazz.*	*Pistacia chinensis Bunge*	*Broussonetia kazinoki S. et Z.*	*Pinus armandii Franch.*	*Forsythia suspensa (Thunb.) Vahl*
Quercus serrata Murray var. brevipetiolata (A.DC.) Nakai	*Pinus thunbergii Parlatore*	*Diospyros lotus Linn.*	*Pinus thunbergii Parlatore*	*Alnus sibirica Fisch. ex Turcz*	*Albizia kalkora(Roxb．)Prain*
Tilia tuan Szyszyl.	*Quercus dentata Thunb.*	*Quercus acutissima Carr.*	*Pistacia chinensis Bunge*	*Larix kaempferi (Lambert) Carriere*	*Quercus variabilis Blume*
Carpinus turczaninowii Hance	*Cotinus coggygria Scop.*	*Pyrus pyrifolia (Burm. F.) Nakai*	*Vitex negundo Linn. var.*	*Malus baccata (Linn.) Borkh.*	*Acer saccharum Marsh.*
Quercus dentata Thunb.	*Koelreuteria paniculata Laxm.*	*Amygdalus davidiana (Carr.) C. de Vos*	*Diospyros lotus Linn.*	*Pinus tabulaeformis Carr.*	*Pinus tabulaeformis Carr.*
Sorbus pohuashanensis (Hance) Hedl.	*Quercus acutissima Carr.*	*Crataegus pinnatifida Bge.*	*Decaspermum gracilentum (Hance) Merr. et Perry*		
Tilia japonica Simonk.	*Pyrus pyrifolia (Burm. F.) Nakai*	*Quercus variabilis Blume*	*Quercus acutissima Carr.*		
Pinus armandii Franch.	*Albizia kalkora(Roxb．)Prain*		*Populus tomentosa Carr.*		
Phellodendron amurense Rupr.	*Quercus variabilis Blume*		*Morus mongolica (Bur.) Schneid.*		
Pistacia chinensis Bunge	*Populus alba Linn.*		*Albizia kalkora(Roxb．)Prain*		
Morus australis Poir.	*Pinus tabulaeformis Carr.*		*Quercus variabilis Blume*		
Vitex negundo Linn. var.	*Acer truncatum Bunge*		*Pinus tabulaeformis Carr.*		
Decaspermum gracilentum (Hance) Merr. et Perry			*Ulmus pumila Linn.*		
Quercus acutissima Carr.					
Larix kaempferi (Lambert) Carriere					

PT forest	PO forest	RP forest	PD forest	LK forest	PA forest
Albizia kalkora(Roxb．)Prain					
Malus baccata (Linn.) Borkh					
Crataegus pinnatifida Bge.					
Pinus tabulaeformis Carr.					