Bangladesh J. Bot. **50**(2): 277-287, 2021 (June)

ANALYSIS OF PLANT COMPOSITION AND DIVERSITY ON URBAN SQUARE IN MUDANJIANG CITY, CHINA

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Keywords: City square, Rule, Species diversity, Correlation analysis

Abstract

In order to provide scientific basis for landscaping of square in Mudanjiang city, the rationality of plant application in 14 urban squares was analyzed by 10/20/30 “rule of thumb” states. The results showed that there were 38 common species which belonged to 15 families and 28 genera. The relative abundances of the most common species, genera and families were 39.8, 43.2 and 49.1%, respectively, which were all higher than the standard of 10/20/30 “rule of thumb” states, indicating that there was still some unreasonable phenomena in the square greening. The plant diversity index was quite different, and the Marglef index and Shannon-Wiener index were positively correlated with the square area and green area. The Pielou index had a positive correlation with the distance and a negative correlation relationship with the green rate.

Introduction

In the urban ecological environment, high species diversity could improve the anti-interference ability and stability of the ecosystem. The city would not suffer catastrophic destruction when pests and diseases invaded and would remain stable in the face of severe environmental changes (Kendal *et al.* 2014). Meanwhile, high species diversity could also provide more complex and diverse ecosystem functions (Jim and Liu 2001). Therefore, urban biodiversity plays an important role in urban ecosystems (Zhang and Jim 2014a).

In recent years, the research on urban biodiversity has become a hot topic. Some works have studied the species diversity of road species (Li *et al.* 2010, Nagendra and Gopal 2010, Chen *et al.* 2015), forest species in public settlements (Nagendra and Gopal 2010, Zhang and Jim 2014a), parks and landscape green spaces (Jim and Chen 2009, Zhu *et al.* 2009, Zhang and Jim 2014b,). The 10/20/30 ‘rule of thumb’ proposed by Santamour (1990) has been widely spread and accepted, which stated that relative abundance in urban forests should comprise not more than 10% of any species, 20% of any one genus or 30% of any single family, otherwise it would affect the health and stability of the forest ecosystem. This rule has been proved in many urban forest tree species allocations at home and abroad (Kendal *et al.* 2014, Zhang *et al.* 2016, Xiao *et al.* 2016). However, the previous studies have focused on a certain urban forest ecosystem for the large-scale research. Would it be applicable to a small-scale landscape perspective? Thus the present work was carried out.

Mudanjiang city, as the third largest city in Heilongjiang province, has important geographical location and forest vegetation resources. In the past, the research on the green space system in Mudanjiang city was focused on the plant diversity of squares and parks (Xu 2010, Xu *et al.* 2017). The diversity of square plant species is the basis of functional diversity and also an

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DOI: https://doi.org/10.3329/bjb.v50i2.54083

important manifestation of biodiversity in urban greening. The purpose of promoting the virtuous cycle of urban ecosystem can be achieved by building a favorable diversity of plants in the urban square. Therefore, it is of practical significance to study the plant diversity of urban square green space. Simultaneously, the indices of richness, diversity and evenness are often used to indicate different aspects of plant species diversity (Walker *et al.* 2009, Knapp *et al.* 2010, Jim and Zhang 2015). These indices were also used to explore the diversity of tree arbor configuration in urban squares. The main aspects of this study were: (1) to understand the composition of squares tree species, (2) to evaluate squares tree species by using the 10/20/30 rule, (3) to put forward reasonable suggestions for the landscaping of squares. The purpose of the study was to provide a scientific answer for the direction adjustment and tree species configuration for the landscaping in Mudanjiang city.

Materials and Methods

Mudanjiang city (44°60'N, 129°58' E) is located in the middle of the northern temperate zone and belonged to the temperate continental monsoon climate (semi-humid) with a mean annual temperature of 6.1°C and the average rainfall of about 579.7 mm.

The studied urban squares included two kinds of squares. Wenhua Square (G1), Jiangbin Square (G2), Mingzhu Square (G3), Railway Station West Square (G4) and Hongxing Square (G5) and leisure squares. Dongguang Square (G6), Xianglun Square (G7), Shenglin Square (G8), Xiaoyun Square (G9), Bei'an Square (G10), Zhonghua Square (G11), Yangming Square (G12), Xingzhong Square (G13) and Xinglong Square (G14) were traffic squares. The green spaces of squares were used as research objects to investigate the types of plants, the number of plants and the characteristics of the square. Next, the correlations between tree composition abundance, square diversity index and square characteristics were analyzed.

The field survey was made in the summer of 2017. The species names and number of plants of all woody plants in the square were surveyed. Species confirmation was determined as alien or native according to Flora of China (Editorial Committee of Flora of China 2013) and Flora of Heilongjiang (Zhou 2001). The relative abundance of species, genera and families of trees in each square were calculated. The calculation formula was R = Si/S.

Where Si is the number of species (genus, family) in the region, and S is the sum of the numbers of all species (genus, family) recorded in the region.

The square plant configuration was evaluated according to the 10/20/30 "rule of thumb". If the relative abundance of trees (genera, families) was lower than 10% (20%, 30%), the tree species selection for the greening design of the square was reasonable, and vice versa. Three kinds of species diversity indices were used to compare the species diversity among different urban squares.

Margalef index: $D = S - 1/lnN$ (Clarke and Stephenson 1975)

Shannon-Wiener index: $H' = - \Sigma Pi\ (lnPi)$ (Magurran 2003)

Pielou evenness index: $E = H'/lnS$ (Beisel and Moreteau 1997)

where, S is the total number of species; N is the total number of individuals; *Pi* represents the relative abundance of each species.

The distance from the train station to each square was measured by using google earth software. Relative abundance and diversity analysis were compiled and calculated by using Microsoft Excel 2003 software. The data for correlation analysis were collated in Microsoft Excel 2003 and plotted in SigmaPlot 12.5 software.

Results and Discussion

There were 38 kinds of tree species belonging to 15 families and 28 genera in 14 squares. The most common species accounted for 51.6% of all plants, which was dominant in 14 squares. Other tree species, such as *Sabina chinensis* and *Euonymus bungeanus* were auxiliary application (less than 5%). *Betula* (17.1%), and *Picea* (11.5%) were dominant genus in use (Table 1). The other genera were less than 10%, while 8 genera were less than 5% (Table 2). The families of Betulaceae (17.1%), Rosaceae (16.9%), Pinaceae (11.8%) and Oleaceae (10.8%) had higher application rates, other families were less than 5% (Table 3). Four leisure squares occupied their own dominant species except G2 and the proportion ranged from 34.8% to 77.8%. The main dominant species were *S. chinensis*, *Ulmus pumila*, *E. bungeanus*, *Betula platyphylla* and *Ligustrum obtusifolium* (Table1), which resulted in a higher proportion of genera and families in these species. It showed that the application of greening tree species in Leisure Squares of Mudanjiang city had certain characteristics, but it was insufficient according to the result of the 10/20/30 “rule of thumb”. Among the nine traffic plazas, there were only 2 or 3 plant species in four squares (Table 1). *Picea koraiensis*, *Padus virginiana* and *U. pumila* were widely used, and the relative abundance was greater than 17.1%. *P. koraiensis* was applied in eight squares except G11. The relative abundance of *Lonicera japonica, Rhus typhina, S. chinensis*, *Populus alba* and *E. bungeanus* were more than 10% in different squares, and the other tree species was less than 9.5% (Table 1). Among the genera with high degree, two squares were *Picea* and *Ulmus*, and the other five squares were *Rhus, Padus, Rose, Syringa* and *Popus*, respectively. The relative abundance of genus was higher than 20.4% except G8 (Table 2). The relative abundance of Rosaceae was higher in 4 squares while that of Ulmaceae in 2 squares was relatively high. The relative abundance of the other squares was more than 30%, with a maximum of 92.5%, except G8 and G9 (Table 3). This may be related to the type of trees used in the squares.

Kendal *et al.* (2014) selected 108 cities around the world (including Chinese cities) to verify the 10/20/30 “rule of thumb” proposed by Santamour (1990), and pointed out that the 10/20/30 "rule of thumb” was reasonable and universal. It was also found that in the present study this rule had a certain scientific significance in analysis of squares tree species in Mudanjiang city. This study showed that the common families, genera and species used in were Rosaceae, *Picea* and *P.koraiensis*, and the relative abundances were 39.8, 43.2 and 49.1%, respectively (Fig. 1), which were higher than the global average (20, 26 and 32%) in seven cities (19, 24 and 31%). The design needs to be further adjusted according to the study of the 10/20/30 rule.

The relative abundance of common species was more than 10% in all squares and with a difference of 5.78 times (Fig. 2). The dominant species of square ranged from 2 to 24 species. Most of tree species in the traffic squares basically did not meet the rule of the 10/20/30 “rule of thumb”, but most of them in leisure squares met the rule. The relative abundance of common genus was less than 20% in G2 and G8 which was more reasonable by evaluation of the rule, and it was higher than 20% in other squares and with a difference of 5.67 times. The relative abundance of the common family was less than 30% in G2, G8 and G9.

The relative abundance of common species, genera and families of different types of squares was higher than the basic standard line of the 10/20/30 “rule of thumb”. From the level of species, the relative abundance of the common species in leisure squares (42.2%), and traffic squares (37.4%) were 4.22 and 3.74 times higher than the standard. From the level of genera, the relative abundance of the common genus in leisure squares (42.5%) and traffic squares (43.9%) exceeded the standard 2.03 and 2.20 times. From the level of the families, the relative abundance of the common family in leisure square (44.9%) and traffic square (53.5%) were 1.5 and 1.78 times higher than the standard (Fig. 3). Based on the principle of 10/20/30 “rule of thumb”, the species, genera and families of greening tree species in various squares in Mudanjiang city were

Table 1. Distribution of wood species in urban squares in Mudanjiang city.

Species	Percentage	Percentage of wood species composition in square/%													
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14
Betula platyphylla	17.1	0.0	4.8	41.6	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	4.3	0.0
Picea koraiensis	11.3	22.2	14.1	8.2	4.7	8.8	7.5	20.0	6.7	19.8	15.1	0.0	30.8	43.4	22.2
Rhus typhina	8.9	0.0	5.2	8.2	0.0	0.0	92.5	0.0	6.0	13.0	0.0	0.0	0.0	17.4	0.0
Populus alba	8.1	0.0	0.0	14.4	11.6	6.9	0.0	0.0	0.0	8.6	15.7	20.4	0.0	0.0	0.0
Lonicera japonica	6.2	0.0	16.0	1.4	0.0	9.2	0.0	0.0	11.1	0.0	2.9	0.0	0.0	0.0	0.0
Ulmus pumila	6.0	0.0	0.0	3.6	33.7	18.4	0.0	0.0	0.0	0.0	30.3	1.9	18.5	8.7	0.0
Amygdalus triloba	5.7	0.0	13.3	5.3	0.0	0.0	0.0	0.0	4.8	0.0	1.7	0.0	16.9	0.0	0.0
Sabina chinensis	4.7	0.0	0.0	4.9	34.8	5.4	0.0	0.0	0.0	14.8	2.9	0.0	0.0	0.0	0.0
Euonymus bungeanus	4.1	0.0	0.0	0.1	0.0	41.0	0.0	0.0	17.1	0.0	0.0	0.0	0.0	19.6	0.0
Syringa oblat	3.2	0.0	6.2	1.6	1.6	5.4	0.0	0.0	6.7	0.0	6.4	0.0	0.0	0.0	0.0
Forsythia suspensa	3.2	0.0	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prunus maackii	2.8	0.0	8.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Padus virginiana	2.5	0.0	1.5	0.4	2.6	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ligustrum obtusifolium	2.3	77.8	1.8	2.3	0.0	0.0	0.0	0.0	9.5	0.0	0.0	0.0	0.0	0.0	0.0
Caragana arborescens	1.8	0.0	3.7	0.5	1.1	0.0	0.0	0.0	6.7	0.0	5.8	0.0	0.0	0.0	0.0
Others	12.1	0.0	10.6	23.5	11.0	4.9	0.0	20.0	27.8	43.8	19.2	77.8	33.8	6.6	77.8

Table 2. Distribution of wood genera in urban squares in Mudanjiang city.

Genus	Percentage	Percentage of wood genera composition in square/%													
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14
Betula	17.1	0.0	4.8	41.6	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	4.3	0.0
Picea	11.5	22.2	14.1	8.5	4.7	10.3	7.5	20.0	6.7	19.8	15.1	0.0	30.8	43.4	22.2
Rhus	8.9	0.0	5.2	8.2	0.0	0.0	92.5	0.0	6.0	13.0	0.0	0.0	0.0	17.4	0.0
Populus	8.1	0.0	0.0	14.4	11.6	6.9	0.0	0.0	0.0	8.6	15.7	20.4	0.0	0.0	0.0
Ulmus	6.7	0.0	0.0	3.6	35.8	18.4	0.0	0.0	0.0	0.0	30.3	1.9	18.5	8.7	77.8
Lonicera	6.2	0.0	16.0	1.4	0.0	9.2	0.0	0.0	11.1	0.0	15.1	0.0	0.0	0.0	0.0
Amygdalus	5.9	0.0	0.0	5.3	0.5	1.5	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0
Padus	0.0	10.4	2.4	2.6	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sabina	4.7	0.0	0.0	4.9	34.8	5.4	0.0	0.0	0.0	14.8	2.9	0.0	0.0	0.0	0.0
Syringa	4.2	0.0	6.2	1.6	1.6	5.4	0.0	0.0	6.7	22.9	8.7	0.0	0.0	0.0	0.0
Euonymus	4.1	0.0	0.0	0.0	0.0	41.0	0.0	0.0	17.1	0.0	0.0	0.0	0.0	19.6	0.0
Forsythia	3.2	0.0	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rosa	2.8	0.0	16.3	0.4	0.0	0.0	0.0	0.0	17.4	18.5	1.7	0.0	16.9	0.0	0.0
Ligustrum	2.3	77.8	1.8	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acer	2.0	0.0	6.0	1.4	0.0	0.0	0.0	0.0	1.2	0.6	0.6	0.0	0.0	2.2	0.0
Others	7.0	0.0	5.3	4.0	8.4	1.9	0.0	20.0	25.4	11.8	9.9	77.8	33.8	4.4	0.0

Table 3. Distribution of wood families in urban squares in Mudanjiang city.

Family	Percentage	Percentage of wood families composition in square/%													
		G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14
Betulaceae	17.1	0.0	4.8	41.6	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	4.3	0.0
Rosaceae	16.9	0.0	28.3	11.4	8.9	1.5	0.0	60.0	23.4	19.1	1.7	77.8	50.7	0.0	0.0
Pinaceae	11.8	22.2	14.1	8.8	4.7	10.3	7.5	20.0	6.7	19.8	18.6	0.0	30.8	43.4	22.2
Oleaceae	10.8	77.8	21.9	2.6	1.6	5.4	0.0	20.0	21.4	24.1	8.7	0.0	0.0	0.0	0.0
Anacardiaceae	8.9	0.0	5.2	8.2	0.0	0.0	92.5	0.0	6.0	13.0	0.0	0.0	0.0	17.4	0.0
Salicaceae	8.6	0.0	0.0	15.3	13.2	8.8	0.0	0.0	0.0	8.6	16.3	20.4	0.0	0.0	0.0
Ulmaceae	6.7	0.0	0.0	3.6	35.8	18.4	0.0	0.0	0.0	0.0	30.3	1.9	18.5	8.7	77.8
Caprifoliaceae	6.4	0.0	16.0	1.4	0.0	9.2	0.0	0.0	13.9	0.0	15.1	0.0	0.0	0.0	0.0
Cupressaceae	4.7	0.0	0.0	4.9	34.8	5.4	0.0	0.0	0.0	14.8	2.9	0.0	0.0	0.0	0.0
Celastraceae	4.1	0.0	0.0	1.6	0.0	41.0	0.0	0.0	17.1	0.0	0.0	0.0	0.0	19.6	0.0
Others	4.0	0.0	9.7	0.6	1.1	0.0	0.0	0.0	7.9	0.6	6.4	0.0	0.0	6.6	0.0

unreasonable. The main reason was that there were fewer tree species in each square greening design. All the species were all local native trees in Mudanjiang, except exotic species (*R. Typhina*) which occupied a large number in G6 due to its strong invasiveness (Wu 2008).

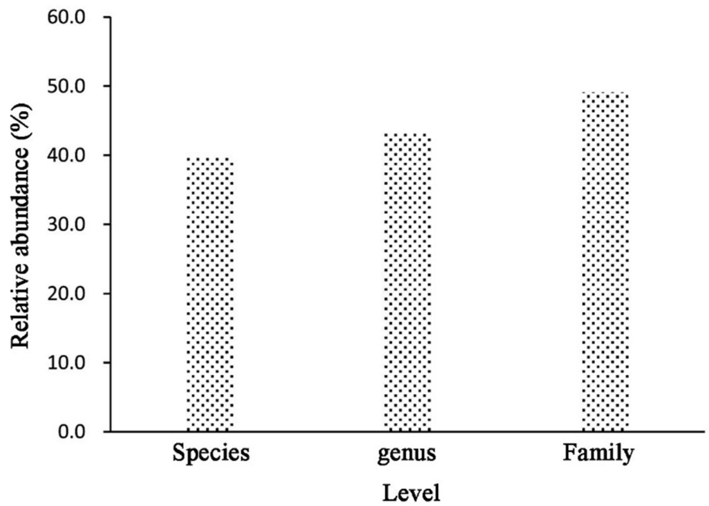

Fig. 1. Average relative abundance of the most common trees in Urban Squares at the levels of species, genus and family.

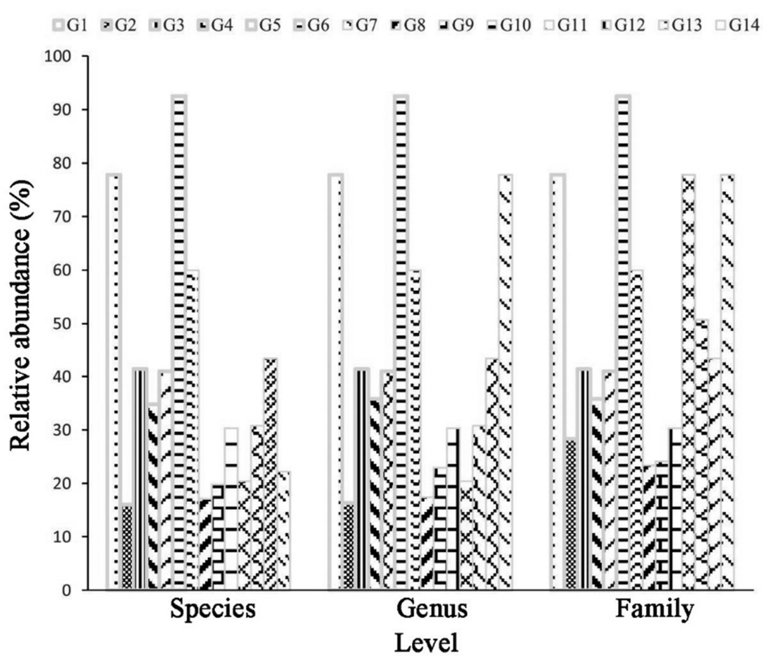

Fig. 2. Relative abundance of the most common trees of different squares at the species, genus and family levels.

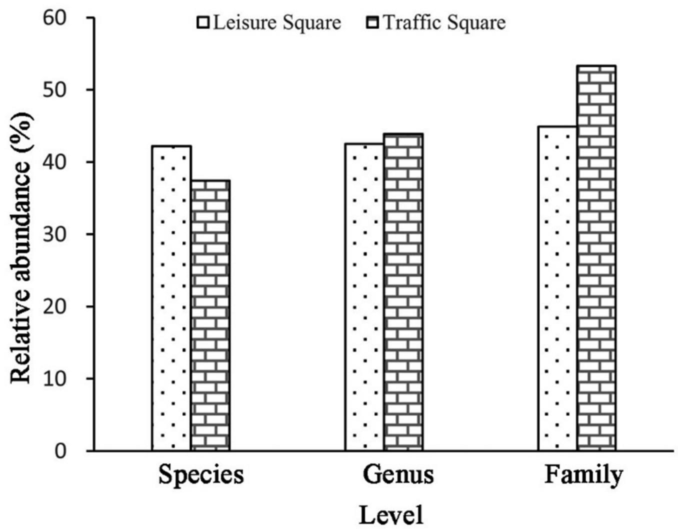

Fig. 3. Relative abundance of the most common trees of different kinds of squares at the species, genus and family levels.

Table 4. The variations of diversity index of plants in different square.

Square	Margalef richness	Shannon-Wiener diversity	Pieloua evenness
G1	0.35	0.51	0.74
G2	2.50	2.53	0.88
G3	3.16	2.10	0.66
G4	2.10	1.72	0.69
G5	1.62	1.81	0.79
G6	0.20	0.27	0.39
G7	0.42	0.95	0.86
G8	2.53	2.52	0.93
G9	1.57	2.00	0.91
G10	2.14	2.03	0.82
G11	0.50	0.59	0.54
G12	0.72	1.34	0.97
G13	1.57	1.82	0.94
G14	0.30	0.53	0.76

Seen from Table 4, the plant richness index was from 0.2 to 3.16 in the Urban Square of Mudanjiang city, and the highest was in G3, which was 15.8 times higher than the lowest. The plant diversity index was from 0.27 - 2.53, and the higher was in G2, which was 9.37 higher times than the lowest. The plants evenness index was from 0.39 - 0.97, and the highest was G12, which is 2.49 times higher than the lowest. The three indices of the G6 were the lowest. From the

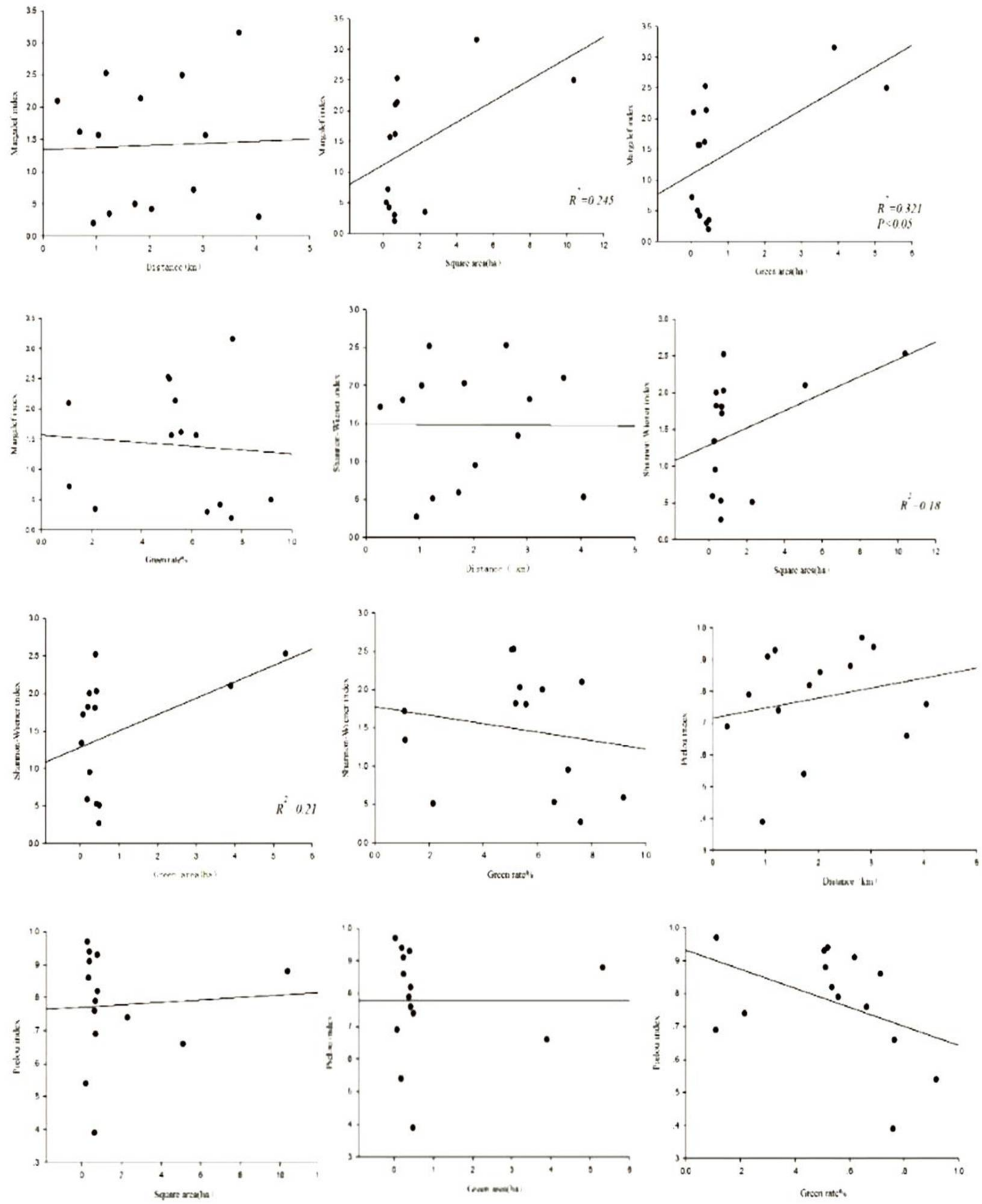

Fig. 4. Correlation between three diversity indexes and square characteristic.

perspective of diversity, the indices richness, diversity and evenness of the squares were quite different, which indicated that the greening in the square of Mudanjiang City may meet the demand from the perspective of landscape effect, but there were still some defects from the perspective of ecology. Overall, the richness index of the leisure square was 1.946, the diversity index was 1.734, the evenness index was 0.752, the richness index of the Traffic Square was 1.106, the diversity index was 1.339, and the evenness index was 0.791, which indicated that Mudanjiang paid attention to the choice of tree species in the design of Leisure Squares. The evenness index was high in the Traffic Squares because there were relatively few species. It is suggested to enrich the number of species in these squares (G1, G6, G7, G11, G12 and G14). Leisure square should increase color leaf species, such as *Prunus cerasifera, Physocarpus opulifolius.* and *P. amurensis,* the genus of *Acer* and the family of Leguminosae. To traffic square, only plants were considered in the design to meet traffic needs because the greening area was small in the past. However, in addition to traffic demand, modern traffic squares are also belonged to the leisure green space in the city. Therefore, the requirements of landscape should be met when the traffic squares are greening. It is recommended to increase the number of tree species used for road greening, such as *Pinus sylvestris* and *P. sylvestris* var. mongolica, *Larix gmelinii, Juniperus rigida* and *S. chinensis*, and shrub species, such as *Forsythia suspense*, *Padus racemosa, Acer ginnala* and *L.obtusifolium* (Tang and Zhang 2007).

The indices richness and diversity of the square were positively correlated with the square area and the green area (R^2= 0.245, R^2= 0.321 and R^2= 0.18, R^2= 0.21), and there was a significant correlation between the richness index and the square green area (Fig. 4). There was a little positive correlation between evenness index and the distance. There was a certain negative relationship between the three indices and greening rate of the square. Among the three negative relationships, the negative relationship between the evenness index and the greening rate was more obvious. According to the results, it is suggested that the diversity and richness of species should be taken into account when the traffic square is greening in Mudanjiang city.

Due to the different geographical location, environment and management of each square, the types and levels of plants were also different. For example, there was a large amount of plants and many kinds of plants in G2 and G3. On the contrary, the plant structure of the G1 and G4 were single, and the plants grew badly due to more vehicles and poor air quality. Some studies have shown that, to a certain extent, the simple community structure, monotonous species and unitary hierarchy would increase the probability of pest infestation (Kendal *et al.* 2014, Santamour 1990, Tang and Zhang 2007).

The species composition of 14 urban squares in Mudanjiang city, China was analyzed by 10/20/30 “rule of thumb”. Findings were: (1) there were 38 common species belonged to 15 families and 28 genera in squares. (2) The plant diversity index of squares was quite different, and the Marglef index and Shannon-Wiener index were positively correlated with the square area and green area, the Pielou index had a positive correlation with the distance and a negative correlation relationship with the green rate.

Acknowledgements

The authors are grateful for financial support from the Basic Research Business Fee Support Project in Heilongjiang Province (1353MSYYB012) and the General Project of Mudanjiang Normal College (YB2020008).

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(Manuscript received on 23 May, 2019; revised on 14 July, 2020)