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Analysis of Short-Shoot Fuji Apple Tree Structure and Correlative Factors

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Abstract In order to clarify the correlation between short-shoot Fuji apple tree structure and different factors under different trimming and pruning modes, we investigate the trunk taperingness of free-spindle short-shoot Fuji and slender-spindle short-shoot Fuji, respectively, as well as the total thickness, average thickness, total length and average length of small main branches in the standard demonstration apple garden in Xingtang County of Hebei Province. By SPSS analysis, we study the correlation between trunk taperingness of trees with different shapes and the growth indices of their small main branches. The results show that the trunk taperingness of free-spindle short-shoot Fuji apple is negatively correlated with the total thickness, average thickness, total length and average length of small main branches, but the correlation is not significant; the trunk taperingness of slender-spindle short-shoot Fuji apple is negatively correlated with the total thickness but positively correlated with other factors, and the correlation with average length reaches a significant level. The results of this study can provide a scientific basis for guiding the high-density dwarf rootstock short-shoot Fuji apple tree trimming technology.

Key words Short-shoot Fuji, Tree structure, Analysis of correlative factors

1 Introduction

At present, the dwarf self-rooted rootstock or dwarf interstock is mostly used for high-density cultivation in the domestic and foreign apple production[1-2]. In accordance with the cultivation characteristics of dwarf stock apple tree structure and tree crown formation features, the young tree trimming should be completed within about 3 a and the first 2 - 3 a trimming is the key. The tree shape used is mostly slender-spindle or free-spindle[3-4]. The trunk diameter difference per unit length between the upper and lower portion of tree trunk is called taperingness[4]. The appropriate trimming and pruning according to the characteristics of different varieties of seedlings is the key technology to ensure young tree formation. The short-shoot Fuji varieties are widely applied in the production, but the trimming and pruning indices for high-density dwarf rootstock young apple trees are determined by some cultivation experience at home[5-6], and it lacks in-depth study and relevant data support. This paper studies the relationship between taperingness of trunk and the small main branches during pruning and trimming of high-density dwarf rootstock short-shoot Fuji apple tree, and systematically investigates the young tree trimming technology for high-density dwarf rootstock short-shoot Fuji apple, in order to provide a scientific basis for the development of high-density dwarf rootstock apple.

2 Materials and methods

In 2014, we selected the 6 - 8 a healthy short-shoot Fuji with short flourishing life, favorable conditions and adjacent location for experiment from the apple demonstration garden in Dong'an Taizhuang Village and Jialuoying Village of Xingtang County (apple-producing areas in central and southern Hebei) (high-density dwarf rootstock cultivation, spacing of 2 m × 3 m, Malus micromalus as base stock, SH38 as dwarf interstock). The test tree shapes include free-spindle (Huimin Duanzhi) and slender-spindle (Tianhong No. 2). In the test plot, 6 trees are randomly selected as object of study in eastern, southern, western, northern and central position, respectively. After the trees shed leaves in winter 2014, we measured the diameter at the base of the tree trunk, top branch diameter, length from interface to top branch, as well as the thickness and length of each small main branch along the center of the trunk. We calculated the trunk taperingness[%, (*base diameter - top branch diameter*)/*length from interface to top branch*], total thickness, average thickness, total length and average length of main branches. The statistical software SPSS 13.0 is employed to conduct correlation and significance (two-sided) analysis on trunk taperingness of short-shoot Fuji apple with different tree structure and thickness and length of small main branches[6-7], test replicate $n = 30$.

3 Results and analysis

3.1 Correlation analysis on free-spindle short-shoot Fuji apple trunk taperingness and growth indices of main branches

The free-spindle apple trunk taperingness is negatively correlated with total thickness, average thickness, total length and average length of main branches, but the correlation does not reach the significant level, while the correlation between growth indices of main branches is significantly positive (Table 1).

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Table 1 Correlation analysis on free-spindle short-shoot Fuji apple trunk taperingness and growth indices of main branches

Index	Item	Trunk taperingness	Total thickness of main branches	Average thickness of main branches	Total length of main branches	Average length of main branches
Trunk taperingness	Correlation	1.000				
	Significance (two-sided)					
Total thickness of main branches	Correlation	−0.228	1.000			
	Significance (two-sided)	0.434				
Average thickness of main branches	Correlation	−0.033	0.829**	1.000		
	Significance (two-sided)	0.910	0			
Total length of main branches	Correlation	−0.411	0.932**	0.719**	1.000	
	Significance (two-sided)	0.144	1.21E-06	0.004		
Average length of main branches	Correlation	−0.430	0.720**	0.701**	0.886**	1.000
	Significance (two-sided)	0.125	0.004	0.005	2.44E-05	

Note: * means significant level (two-sided), $P<0.05$; ** means highly significant level (two-sided), $P<0.01$, the same in the following table.

3.2 Correlation analysis on slender-spindle short-shoot Fuji apple trunk taperingness and growth indices of main branches

Slender-spindle apple trunk taperingness is negatively correlated with total thickness of main branches, but positively correlated with average thickness, total length and average length of main branches. And the correlation with average length of main branches reaches a significant level. The correlation between growth indices of main branches is positive, the correlation between total thickness and total length reaches a significant level, and the correlation between total length and average length reaches a highly significant level (Table 2).

Table 2 Correlation analysis on slender-spindle short-shoot Fuji apple trunk taperingness and growth indices of main branches

Index	Item	Trunk taperingness	Total thickness of main branches	Average thickness of main branches	Total length of main branches	Average length of main branches
Trunk taperingness	Correlation	1.000				
	Significance (two-sided)					
Total thickness of main branches	Correlation	−0.348	1.000			
	Significance (two-sided)	0.324				
Average thickness of main branches	Correlation	0.264	0.337	1.000		
	Significance (two-sided)	0.942	0.341			
Total length of main branches	Correlation	0.303	0.745*	0.254	1.000	
	Significance (two-sided)	0.395	0.013	0.478		
Average length of main branches	Correlation	0.705*	0.269	0.484	0.780**	1.000
	Significance (two-sided)	0.023	0.453	0.156	0.008	

4 Conclusions and discussions

The domestic and foreign studies of fruit tree structure focus on the full use of light to achieve high quality, appropriate planting density, reasonable group structure and individual spatial distribution. Good light system is the key to achieving high fruit quality and high yield. The dwarf trees focus on the advantages of the central trunk, and to maintain tree shape and achieve high quality and high yield, it is necessary to timely control too strong lateral branches and maintain the advantages of the central trunk. In addition, it is necessary to strictly control tree height, and the angle of elevation between extension and crown of two adjacent canopies should not be greater than 49°. There should be operation channel with width of more than 1.5 m between rows[7-8, 11]. The dwarf interstock has been widely used in China at present, and the tree shape mostly used includes slender-spindle and backbone type[9-10]. The structure of these tree shapes is characterized by a strong central trunk and a lot of small main branches, with large open angle and even distribution. There are no lateral branches on the main branches and it is extended along one single axis. The bearing branches grow on the central main branches and small main branches. In cultivating tree structure, the trimming in the first 2-3 a is very critical[10]. In order to clarify the correlation between short-shoot Fuji apple tree structure and various factors under different trimming and pruning modes, we investigate the trunk taperingness of free-spindle short-shoot Fuji and slender-spindle short-shoot Fuji, respectively, as well as the total thickness, average thickness, total length and average length of small main branches in the standard demonstration apple garden in Xingtang County of Hebei Province. By SPSS analysis, we study the correlation between trunk taperingness of trees with different shapes and the growth indices of their small main branches. The results show that the trunk taperingness of free-spindle short-shoot Fuji apple is negatively correlated with the total thickness, average thickness, total length and average length of small main branches, but the correlation is not significant, so we think that as for the trimming and pruning of backbone tree under high-density planting conditions, there is a need for a lot of small main branches in order to maintain the upright and strong growth of trunk and obtain ideal tree shape. Thus, in addition to appropriate increase in height during leader branch cutting, there is a need to perform bud-notching

before germination to trigger branches; meanwhile, the small main branches should increase open angle as soon as possible, shifting from the original September to May, in order to ease growth potential. The trunk taperingness of slender-spindle short-shoot Fuji apple is negatively correlated with the total thickness but positively correlated with other factors, and the correlation with average length reaches a significant level, so there is a need to increase the number of small main branches in order to obtain ideal slender-spindle tree shape and reduce the total thickness. Fundamentally, the transformation of different tree structure is to meet the needs for optimal lighting conditions required by the production of high quality fruits. Studies show that if the lighting conditions are good for trees, the fruit quality is good and the blossom buds also increase significantly[11]. Thus, for the dwarf high-density garden, the light inside crown can reach an optimal state by bud-notching, earlier expansion of the branch angle, adjustment of branch bending time, elevation of trunk height and other shaping measures[10, 12-13].

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(From page 85)

drying mode; the maximum hot air temperature was 140 ℃ under fluidized bed drying mode. The maximum hot air temperature was 60 ℃ for the rapeseed in the mixed flow drying process. After drying, the rapeseed must not have burnt seeds, water content should be equal to or lower than 8%, and moisture unevenness should be equal to or lower than 2%.

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