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EFFECT OF CANOPY TRAINING METHODS ON THE YIELD OF JUJUBE CULTIVARS GROWN ON THE MELKOPLODNIY KISLIY 1 ROOTSTOCK

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ABSTRACT

This study evaluated the free-growing control, open-center (vase-shaped), sparse-tiered, and bush-shaped canopy training systems in the Zanhuangdazao, Junzao, Xiangzao, and Linyilizao jujube cultivars grown on the Melkoplodniy kisliy 1 rootstock during 2023-2025. Yield was determined as yield per tree (kg) and yield per unit area (t/ha). The table fully retains the Minimum, Mean, Maximum, LSD_{05}, LSD_{05}, %, and CV, % indicators for each cultivar and year. The experimental results showed that the modified central leader system was distinguished by higher yield indicators in most cases.

KEYWORDS: jujube, Ziziphus jujuba Mill., Melkoplodniy kisliy 1, canopy, training, yield, LSD_{05}, coefficient of variation.

Introduction. Canopy management in jujube (Ziziphus jujuba Mill.) orchards is an important agrotechnical practice affecting growth and yield formation. International studies have shown that pruning and canopy-volume management can influence yield, water consumption, and water-use efficiency in jujube plantations [1, 2]. A study published in 2026 also reported that tree shape affects canopy architecture, the distribution of fruit-bearing shoots, and within-canopy differentiation of fruit quality [3].

The aim of the study was to evaluate the effect of different canopy training methods on the yield of the Zanhuangdazao, Junzao, Xiangzao, and Linyilizao cultivars grown on the Melkoplodniy kisliy 1 rootstock during 2023–2025.

Materials and methods. The study objects were the Zanhuangdazao, Junzao, Xiangzao, and Linyilizao cultivars grown on the Melkoplodniy kisliy 1 rootstock. The experiment compared free-growing - control, open-center (vase-shaped), sparse-tiered, and bush-shaped training systems. The results for 2023, 2024, and 2025 are presented as yield per tree (kg) and yield per unit area (t/ha). For statistical characterization, the Minimum, Mean, Maximum, LSD_{05}, LSD_{05}, %, and CV, % values from the original table were retained exactly. Because the source file does not provide the number of replications or a bibliographic description of the statistical calculation method, no additional information was introduced.

Results and their analysis. When the effect of different canopy training methods on the yield of the Zanhuangdazao jujube cultivar grown on the Melkoplodniy kisliy 1 rootstock was analyzed by year, yield increased relative to the control in all trained treatments except the bush-shaped form.

In 2023, the free-growing (control) treatment produced 8.6 kg per tree and 10.7 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 11.8 kg and 14.7 t/ha, which were 3.2 kg

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or 37.2%, and 4.0 t/ha or 37.4% higher than the control, respectively. In the sparse-tiered training system, yield reached 13.1 kg per tree and 16.3 t/ha, exceeding the control by 4.5 kg or 52.3%, and 5.6 t/ha or 52.3%, respectively. In the bush-shaped treatment, yield was 8.0 kg per tree and 10.0 t/ha; the source text states a difference of 0.6 kg or 7.0%, and 0.7 t/ha or 6.5% relative to the control (Table 1).

In 2024, the free-growing (control) treatment produced 10.5 kg per tree and 13.1 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 13.6 kg and 17.0 t/ha, which were 3.1 kg or 29.5%, and 3.9 t/ha or 29.8% higher than the control, respectively. In the sparse-tiered training system, yield reached 15.8 kg per tree and 19.7 t/ha, exceeding the control by 5.3 kg or 50.5%, and 6.6 t/ha or 50.4%, respectively. In the bush-shaped treatment, yield was 10.1 kg per tree and 12.6 t/ha; the source text states a difference of 0.4 kg or 3.8%, and 0.5 t/ha or 3.8% relative to the control.

In 2025, the free-growing (control) treatment produced 12.8 kg per tree and 16.0 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 16.1 kg and 20.1 t/ha, which were 3.3 kg or 25.8%, and 4.1 t/ha or 25.6% higher than the control, respectively. In the sparse-tiered training system, yield reached 17.0 kg per tree and 21.2 t/ha, exceeding the control by 4.2 kg or 32.8%, and 5.2 t/ha or 32.5%, respectively. In the bush-shaped treatment, yield was 11.9 kg per tree and 14.8 t/ha; the source text states a difference of 0.9 kg or 7.0%, and 1.2 t/ha or 7.5% relative to the control.

When the effect of different canopy training methods on the yield of the Zanhuangdazao jujube cultivar grown on the Melkoplodniy kisliy 1 rootstock was analyzed by year, yield increased relative to the control in all trained treatments except the bush-shaped form.

In 2023, the free-growing (control) treatment produced 8.6 kg per tree and 10.7 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 11.8 kg and 14.7 t/ha, which were 3.2 kg or 37.2%, and 4.0 t/ha or 37.4% higher than the control, respectively. In the sparse-tiered training system, yield reached 13.1 kg per tree and 16.3 t/ha, exceeding the control by 4.5 kg or 52.3%, and 5.6 t/ha or 52.3%, respectively. In the bush-shaped treatment, yield was 8.0 kg per tree and 10.0 t/ha; the source text states a difference of 0.6 kg or 7.0%, and 0.7 t/ha or 6.5% relative to the control.

In 2024, the free-growing (control) treatment produced 10.5 kg per tree and 13.1 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 13.6 kg and 17.0 t/ha, which were 3.1 kg or 29.5%, and 3.9 t/ha or 29.8% higher than the control, respectively. In the sparse-tiered training system, yield reached 15.8 kg per tree and 19.7 t/ha, exceeding the control by 5.3 kg or 50.5%, and 6.6 t/ha or 50.4%, respectively. In the bush-shaped treatment, yield was 10.1 kg per tree and 12.6 t/ha; the source text states a difference of 0.4 kg or 3.8%, and 0.5 t/ha or 3.8% relative to the control.

Table 1. Effect of canopy training methods on the yield of jujube cultivars grown on the Melkoplodniy kisliy 1 rootstock, 2023–2025.

Experimental treatment	Yield by year						Average yield per tree, kg	Average yield per unit area, t/ha
	2023		2024		2025			
	Yield per tree, kg	Yield per unit area, t/ha	Yield per tree, kg	Yield per unit area, t/ha	Yield per tree, kg	Yield per unit area, t/ha		
Zanhuangdazao								
Free-growing - control	8,6	10,7	10,5	13,1	12,8	16,0	10,6	13,3
Open-center (vase-shaped)	11,8	14,7	13,6	17,0	16,1	20,1	13,8	17,3
Sparse-tiered	13,1	16,3	15,8	19,7	17,0	21,2	15,3	19,1

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Bush-shaped	8,0	10,0	10,1	12,6	11,9	14,8	10,0	12,5
Minimum	8,0	10,0	10,1	12,6	11,9	14,8	10,0	12,5
Mean	10,2	12,7	12,1	15,1	14,5	18,1	12,2	15,3
Maximum	13,1	16,3	15,8	19,7	17,0	21,2	15,3	19,1
LSD_{05}	0,15	0,26	0,14	0,25	0,20	0,42		
LSD_{05}, %	1,664	2,027	1,120	1,625	1,408	2,323		
CV, %	1,2	1,4	0,8	1,2	1,0	1,7		
Junzao								
Free-growing - control	7,9	9,8	9,8	12,2	12,3	15,3	10,0	12,4
Open-center (vase-shaped)	9,6	12,0	11,1	13,8	14,7	18,3	11,8	14,7
Sparse-tiered	12,3	15,3	14,5	18,1	16,3	20,3	14,4	17,9
Bush-shaped	7,4	9,2	9,3	11,6	11,4	14,2	9,4	11,7
Minimum	7,4	9,2	9,3	11,6	11,4	14,2	9,4	11,7
Mean	8,8	10,9	10,5	13,0	13,5	16,8	10,9	13,6
Maximum	12,3	15,3	14,5	18,1	16,3	20,3	14,4	17,9
LSD_{05}	0,15	0,38	0,24	0,47	0,42	0,54		
LSD_{05}, %	1,664	3,288	2,129	3,393	3,052	3,161		
CV, %	1,2	2,3	1,5	2,4	2,2	2,3		
Xiangzao								
Free-growing - control	7,5	9,3	9,6	12,0	11,2	14,0	9,4	11,8
Open-center (vase-shaped)	10,8	13,5	12,1	15,1	14,0	17,5	12,3	15,4
Sparse-tiered	11,4	14,2	13,7	17,1	15,2	19,0	13,4	16,8
Bush-shaped	7,0	8,7	9,1	11,3	11,5	14,3	9,2	11,4
Minimum	7,0	8,7	9,1	11,3	11,2	14,0	9,2	11,4
Mean	9,2	11,4	10,9	13,6	12,8	15,9	10,9	13,6
Maximum	11,4	14,2	13,7	17,1	15,2	19,0	13,4	16,8
LSD_{05}	0,34	0,30	0,44	0,32	0,32	0,44		
LSD_{05}, %	3,738	2,631	3,969	2,318	2,453	2,695		
CV, %	2,7	1,9	2,8	1,7	1,8	1,9		
Linyilizao								
Free-growing - control	6,9	8,6	9,0	11,2	11,5	14,3	9,1	11,4
Open-center (vase-shaped)	8,2	10,2	10,3	12,8	12,7	15,8	10,4	12,9
Sparse-tiered	10,2	12,7	12,8	16	14,5	18,1	12,5	15,6
Bush-shaped	7,4	9,2	8,5	10,6	10,5	13,1	8,8	11,0

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Minimum	6,9	8,6	8,5	10,6	10,5	13,1	8,8	11,0
Mean	7,8	9,7	9,7	12,0	12,1	15,1	9,8	12,2
Maximum	10,2	12,7	12,8	16,0	14,5	18,1	12,5	15,6
LSD_{05}	0,33	0,42	0,30	0,51	0,51	0,65		
LSD_{05}, %	4,057	4,115	2,908	4,067	4,182	4,214		
CV, %	2,9	2,9	2,1	2,9	3,0	3,0		

In 2025, the control treatment produced 12.8 kg per tree and 16.0 t/ha, whereas the open-center (vase-shaped) treatment produced 16.1 kg and 20.1 t/ha, respectively, which was 3.3 kg or 25.8%, and 4.1 t/ha or 25.6% higher than the control.

The sparse-tiered training system showed the highest yield, producing 17.0 kg per tree and 21.2 t/ha, which exceeded the control by 4.2 kg or 32.8%, and 5.2 t/ha or 32.5%, respectively. In the bush-shaped treatment, yield was 11.9 kg per tree and

14.8 t/ha, which was 0.9 kg or 7.0%, and 1.2 t/ha or 7.5% lower than the control, respectively.

According to the three-year average results, the control treatment produced 10.6 kg per tree and 13.2 t/ha. In the open-center (vase-shaped) treatment, these indicators were 13.8 kg and 17.2 t/ha, respectively, and the source text reports differences of 30.2% and 30.3% relative to the control. The sparse-tiered training system showed the highest result, with 15.3 kg per tree and 19.1 t/ha; the source text reports increases of 44.3% and 44.7%, respectively. For the bush-shaped treatment, the source text reports differences of 5.7% and 5.3% relative to the control.

When the effect of different canopy training methods on the yield of the Junzao jujube cultivar grown on the Melkoplodniy kisliy 1 rootstock was analyzed by year, yield increased in the open-center (vase-shaped) and sparse-tiered systems relative to the control, whereas it decreased in the bush-shaped form.

In 2023, the free-growing (control) treatment produced 7.9 kg per tree and 9.8 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 9.6 kg and 12.0 t/ha, which were 1.7 kg or 21.5%, and 2.2 t/ha or 22.4% higher than the control, respectively. In the sparse-tiered training system, yield reached 12.3 kg per tree and 15.3 t/ha, exceeding the control by 4.4 kg or 55.7%, and 5.5 t/ha or 56.1%, respectively. In the bush-shaped treatment, yield was 7.4 kg per tree and 9.2 t/ha; the source text states a difference of 0.5 kg or 6.3%, and 0.6 t/ha or 6.1% relative to the control.

In 2024, the free-growing (control) treatment produced 9.8 kg per tree and 12.2 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 11.1 kg and 13.8 t/ha, which were 1.3 kg or 13.3%, and 1.6 t/ha or 13.1% higher than the control, respectively. In the sparse-tiered training system, yield reached 14.5 kg per tree and 18.1 t/ha, exceeding the control by 4.7 kg or 48.0%, and 5.9 t/ha or 48.4%, respectively. In the bush-shaped treatment, yield was 9.3 kg per tree and 11.6 t/ha; the source text states a difference of 0.5 kg or 5.1%, and 0.6 t/ha or 4.9% relative to the control.

In 2025, the free-growing (control) treatment produced 12.3 kg per tree and 15.3 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 14.7 kg and 18.3 t/ha, which were 2.4 kg or 19.5%, and 3.0 t/ha or 19.6% higher than the control, respectively. In the sparse-tiered training system, yield reached 16.3 kg per tree and 20.3 t/ha, exceeding the control by 4.0 kg or 32.5%, and 5.0 t/ha or 32.7%, respectively. In the bush-shaped treatment, yield was 11.4 kg per tree and 14.2 t/ha; the source text states a difference of 0.9 kg or 7.3%, and 1.1 t/ha or 7.2% relative to the control.

According to the three-year average results, the control treatment produced 10.0 kg per tree and 12.5 t/ha. In the open-center (vase-shaped) treatment, these indicators were 11.8 kg and 14.7 t/ha, respectively,

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and the source text reports differences of 18.0% and 17.6% relative to the control. The sparse-tiered training system showed the highest result, with 14.3 kg per tree and 17.8 t/ha; the source text reports increases of 43.0% and 42.4%, respectively. For the bush-shaped treatment, the source text reports differences of 7.0% and 7.2% relative to the control.

When the effect of different canopy training methods on the yield of the Xiangzao jujube cultivar grown on the Melkoplodniy kisliy 1 rootstock was analyzed by year, yield increased in the open-center (vase-shaped) and sparse-tiered systems relative to the control, whereas in the bush-shaped form it remained close to the control level.

In 2023, the free-growing (control) treatment produced 7.5 kg per tree and 9.3 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 10.8 kg and 13.5 t/ha, which were 3.3 kg or 44.0%, and 4.2 t/ha or 45.2% higher than the control, respectively. In the sparse-tiered training system, yield reached 11.4 kg per tree and 14.2 t/ha, exceeding the control by 3.9 kg or 52.0%, and 4.9 t/ha or 52.7%, respectively. In the bush-shaped treatment, yield was 7.0 kg per tree and 8.7 t/ha; the source text states a difference of 0.5 kg or 6.7%, and 0.6 t/ha or 6.5% relative to the control.

In 2024, the free-growing (control) treatment produced 9.6 kg per tree and 12.0 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 12.1 kg and 15.1 t/ha, which were 2.5 kg or 26.0%, and 3.1 t/ha or 25.8% higher than the control, respectively. In the sparse-tiered training system, yield reached 13.7 kg per tree and 17.1 t/ha, exceeding the control by 4.1 kg or 42.7%, and 5.1 t/ha or 42.5%, respectively. In the bush-shaped treatment, yield was 9.1 kg per tree and 11.3 t/ha; the source text states a difference of 0.5 kg or 5.2%, and 0.7 t/ha or 5.8% relative to the control.

In 2025, the free-growing (control) treatment produced 11.2 kg per tree and 14.0 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 14.0 kg and 17.5 t/ha, which were 2.8 kg or 25.0%, and 3.5 t/ha or 25.0% higher than the control, respectively. In the sparse-tiered training system, yield reached 15.2 kg per tree and 19.0 t/ha, exceeding the control by 4.0 kg or 35.7%, and 5.0 t/ha or 35.7%, respectively. In the bush-shaped treatment, yield was 11.5 kg per tree and 14.3 t/ha; the source text states a difference of 0.3 kg or 2.7%, and 0.3 t/ha or 2.1% relative to the control.

According to the three-year average results, the control treatment produced 9.4 kg per tree and 11.7 t/ha. In the open-center (vase-shaped) treatment, these indicators were 12.3 kg and 15.3 t/ha, respectively, and the source text reports differences of 30.9% and 30.8% relative to the control. The sparse-tiered training system showed the highest result, with 13.4 kg per tree and 16.7 t/ha; the source text reports increases of 42.6% and 42.7%, respectively. For the bush-shaped treatment, the source text reports differences of 2.1% and 1.7% relative to the control.

When the effect of different canopy training methods on the yield of the Linyilizao jujube cultivar grown on the Melkoplodniy kisliy 1 rootstock was analyzed by year, yield increased in the open-center (vase-shaped) and sparse-tiered systems relative to the control, whereas yield in the bush-shaped form was lower than the control.

In 2023, the free-growing (control) treatment produced 6.9 kg per tree and 8.6 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 8.2 kg and 10.2 t/ha, which were 1.3 kg or 18.8%, and 1.6 t/ha or 18.6% higher than the

control, respectively. In the sparse-tiered training system, yield reached 10.2 kg per tree and 12.7 t/ha, exceeding the control by 3.3 kg or 47.8%, and 4.1 t/ha or 47.7%, respectively. In the bush-shaped treatment, yield was 7.4 kg per tree and 9.2 t/ha; the source text states a difference of 0.5 kg or 7.2%, and 0.6 t/ha or 7.0% relative to the control.

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In 2024, the free-growing (control) treatment produced 9.0 kg per tree and 11.2 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 10.3 kg and 12.8 t/ha, which were 1.3 kg or 14.4%, and 1.6 t/ha or 14.3% higher than the control, respectively. In the sparse-tiered training system, yield reached 12.8 kg per tree and 16.0 t/ha, exceeding the control by 3.8 kg or 42.2%, and 4.8 t/ha or 42.9%, respectively. In the bush-shaped treatment, yield was 8.5 kg per tree and 10.6 t/ha; the source text states a difference of 0.5 kg or 5.6%, and 0.6 t/ha or 5.4% relative to the control.

In 2025, the free-growing (control) treatment produced 11.5 kg per tree and 14.3 t/ha. In the open-center (vase-shaped) treatment, the corresponding values were 12.7 kg and 15.8 t/ha, which were 1.2 kg or 10.4%, and 1.5 t/ha or 10.5% higher than the control, respectively. In the sparse-tiered training system, yield reached 14.5 kg per tree and 18.1 t/ha, exceeding the control by 3.0 kg or 26.1%, and 3.8 t/ha or 26.6%, respectively. In the bush-shaped treatment, yield was 10.5 kg per tree and 13.1 t/ha; the source text states a difference of 1.0 kg or 8.7%, and 1.2 t/ha or 8.4% relative to the control.

According to the three-year average results, the control treatment produced 9.1 kg per tree and 11.3 t/ha. In the open-center (vase-shaped) treatment, these indicators were 10.4 kg and 13.0 t/ha, respectively, and the source text reports differences of 14.3% and 15.0% relative to the control. The sparse-tiered training system showed the highest result, with 12.5 kg per tree and 15.6 t/ha; the source text reports increases of 37.4% and 38.1%, respectively. For the bush-shaped treatment, the source text reports differences of 8.8% and 11.0% relative to the control.

Conclusion. According to the study results, canopy training method was associated with changes in yield indicators in four jujube cultivars grown on the Melkoplodniy kisliy 1 rootstock. The sparse-tiered training system generally produced the highest yield indicators, while the open-center (vase-shaped) system also exceeded the control in the studied cultivars. The bush-shaped form showed values close to or lower than the control in most cases. These results indicate that canopy training is an important agrotechnical factor in realizing the yield potential of jujube cultivars.

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