

Effect of Canopy Training Systems on Yield Performance of Chinese Jujube (*Ziziphus Jujuba* Mill.) Cultivars Grafted on *Ziziphus Acidojujuba* Rootstock

 Fazliddin B. Turobov

Research Institute of Plant Genetic Resources, National Center for Knowledge and Innovation in Agriculture, Tashkent, Uzbekistan

 Norboy Sh. Kayumov

Andijan Scientific Experimental Station, Research Institute of Plant Genetic Resources, Andijan, Uzbekistan

Baxrom E. Izbasarov

Scientific-Production Center for Cultivation and Processing of Medicinal Plants, Uzbekistan

 Abdurauf A. Dolimov

Research Institute of Plant Genetic Resources, National Center for Knowledge and Innovation in Agriculture, Tashkent, Uzbekistan

Received: 28 Mar 2026 | Received Revised Version: 16 Apr 2026 | Accepted: 05 May 2026 | Published: 31 May 2026

Volume 08 Issue 05 2026 | Crossref DOI: 10.37547/tajabe/Volume08Issue05-13

Abstract

Canopy architecture is an important orchard-management factor affecting light distribution, fruiting surface, and yield efficiency in Chinese jujube. This study evaluated the effects of four canopy training systems on the yield of four Chinese jujube cultivars - Zanzhuangdazao, Junzao, Xiangzao, and Linyilizao - grafted on Ziziphus acidojujuba rootstock. Trees planted in 2018 at 4.0 x 3.0 m spacing were assessed during 2023-2025 under four training treatments: free-growing control, open-center (vase), sparse-tier, and bush form. Yield was recorded as kg tree⁻¹ and converted to t ha⁻¹. Across cultivars, the sparse-tier system consistently produced the highest three-year mean yield. Averaged over the four cultivars, field yield reached 12.80 t ha⁻¹ under sparse-tier training compared with 9.93 t ha⁻¹ in the free-growing control, corresponding to a 29.0% increase. The open-center system also improved productivity, averaging 11.03 t ha⁻¹ (+11.1% versus control), whereas the bush form averaged 9.43 t ha⁻¹ (-5.0%). Cultivar-specific responses were strongest in Linyilizao, where sparse-tier training increased the three-year mean field yield from 8.69 to 12.08 t ha⁻¹ (about 39%). Zanzhuangdazao showed the highest absolute productivity, reaching 13.66-13.70 t ha⁻¹ under sparse-tier training. The results demonstrate that canopy training substantially modifies yield performance in Chinese jujube and that sparse-tier architecture provides the most stable yield advantage across the evaluated cultivars. These findings support cultivar-aware canopy management as a practical strategy for improving orchard productivity in grafted jujube plantings.

Keywords: Chinese jujube; *Ziziphus jujuba*; *Ziziphus acidojujuba*; canopy architecture; pruning; training system; sparse-tier; open-center; yield.

© 2026 Fazliddin B. Turobov, Norboy Sh. Kayumov, Baxrom E. Izbasarov, & Abdurauf A. Dolimov. Abdumurod. This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0). The authors retain copyright and allow others to share, adapt, or redistribute the work with proper attribution.

Cite This Article: Fazliddin B. Turobov, Norboy Sh. Kayumov, Baxrom E. Izbasarov, & Abdurauf A. Dolimov. (2026). Effect of Canopy Training Systems on Yield Performance of Chinese Jujube (*Ziziphus Jujuba* Mill.) Cultivars Grafted on *Ziziphus Acidojujuba* Rootstock. The American Journal of Agriculture and Biomedical Engineering, 8(05), 78–84. <https://doi.org/10.37547/tajabe/Volume08Issue05-13>

1. Introduction

Chinese jujube (*Ziziphus jujuba* Mill.) is one of the oldest cultivated fruit trees and is increasingly valued for its adaptation to arid and semi-arid environments, early bearing, low input requirements, and high nutritional and economic value. Modern jujube production systems increasingly rely on deliberate canopy management to improve light interception, regulate vegetative growth, facilitate orchard operations, and stabilize fruit production [1].

Tree form is especially important in jujube because its growth and fruiting habit differs from that of many temperate fruit trees. Orchard systems may use free-growing, central-leader, open-center, spindle, small-canopy, or tiered forms depending on cultivar vigor, planting density, climate, and management objectives. Open-center training is a common conventional system, whereas compact and tiered architectures are increasingly used to improve canopy distribution and labor efficiency [2]. Research in Chinese jujube has shown that canopy structure affects the spatial distribution of fruiting shoots, light environment, fruit quality, and yield formation [3,4].

Pruning can also alter water consumption and resource allocation. Field studies in semi-arid jujube plantations have demonstrated that canopy size and pruning intensity influence transpiration, soil-water use, water-use efficiency, and crop yield [5,6]. Thus, canopy training should not be considered only as a structural operation; it is an agronomic tool that changes the balance between vegetative growth and reproductive productivity.

For Central Asian jujube production, cultivar-specific evidence on long-term yield responses to training systems remains limited. A recent study on the same four cultivars reported consistent differences in annual shoot growth among free-growing, open-center, sparse-tier, and bush forms, with sparse-tier training producing the strongest vegetative response [7]. However, yield performance must be evaluated separately because excessive vegetative growth does not always translate directly into higher orchard productivity.

The objective of this study was therefore to compare the

effect of four canopy training systems on the yield of Zanzhuangdazao, Junzao, Xiangzao, and Linyilizao Chinese jujube cultivars grafted on *Ziziphus acidojujuba* rootstock over three consecutive production years (2023–2025), and to identify the most productive canopy architecture for practical orchard management.

2. Methods

2.1. Plant material and orchard design

The experiment used four Chinese jujube cultivars: Zanzhuangdazao, Junzao, Xiangzao, and Linyilizao. All cultivars were grown on *Ziziphus acidojujuba* rootstock. The orchard was established in 2018 at a spacing of 4.0 x 3.0 m. Yield observations analyzed in the present study were collected during the 2023, 2024, and 2025 seasons from the established experimental orchard.

2.2. Canopy training treatments

Four canopy training treatments were compared: (1) free-growing trees used as the control; (2) open-center (vase) training, in which the canopy center is kept open and structural branches are distributed around the trunk; (3) sparse-tier training, in which main scaffold branches are arranged in separated tiers to create a structured canopy; and (4) bush-form training, in which a lower, multi-axis canopy is maintained. These treatments correspond directly to the four variants reported in the original dataset.

2.3. Yield assessment and statistical indicators

Yield was recorded for each treatment as fruit yield per tree (kg tree⁻¹) and field yield (t ha⁻¹). Three-year means were calculated from the 2023–2025 observations. The original dataset also reported LSD0.05 and coefficient of variation (CV, %) values by cultivar and year; these statistics were retained as supporting evidence of experimental variability. Because the source file did not provide the full ANOVA design or replication structure, no additional inferential tests were reconstructed beyond the reported LSD0.05 and CV statistics. Percentage change relative to the free-growing control was calculated as [(training-system mean - control mean) / control mean] x 100.



Figure 1. General view of the canopy-training experiment in Chinese jujube cultivars grafted on *Ziziphus acidojuba* rootstock.

3. Results and Discussion

3.1. Three-year yield response of cultivars to canopy training

Canopy training had a clear and repeatable effect on yield in all four cultivars. The sparse-tier system produced the highest three-year mean yield in every cultivar, while the

open-center system ranked second in most cases. The free-growing control was intermediate, whereas the bush form generally produced the lowest or near-lowest yield. This consistent ranking indicates that canopy architecture strongly influenced the efficiency with which tree growth was converted into harvestable fruit production.

Table 1. Three-year mean yield of Chinese jujube cultivars under different canopy training systems (2023-2025).

Cultivar	Training system	Yield (kg tree-1)	Yield (t ha-1)	Change vs control (%)
Zanhuangdazao	Free-growing control	13.3	11.08	Control
Zanhuangdazao	Open-center (vase)	14.3	11.94	+7.8
Zanhuangdazao	Sparse-tier	16.4	13.66	+23.3
Zanhuangdazao	Bush form	13.0	10.80	-2.5
Junzao	Free-growing control	12.3	10.24	Control
Junzao	Open-center (vase)	13.7	11.44	+11.6
Junzao	Sparse-tier	15.5	12.91	+26.0
Junzao	Bush form	11.4	9.52	-7.0
Xiangzao	Free-growing control	11.6	9.69	Control
Xiangzao	Open-center (vase)	12.6	10.52	+8.6
Xiangzao	Sparse-tier	15.0	12.52	+29.2
Xiangzao	Bush form	10.6	8.83	-8.9
Linyilizao	Free-growing control	10.4	8.69	Control
Linyilizao	Open-center (vase)	12.3	10.27	+18.2
Linyilizao	Sparse-tier	14.5	12.08	+39.0
Linyilizao	Bush form	10.3	8.55	-1.6

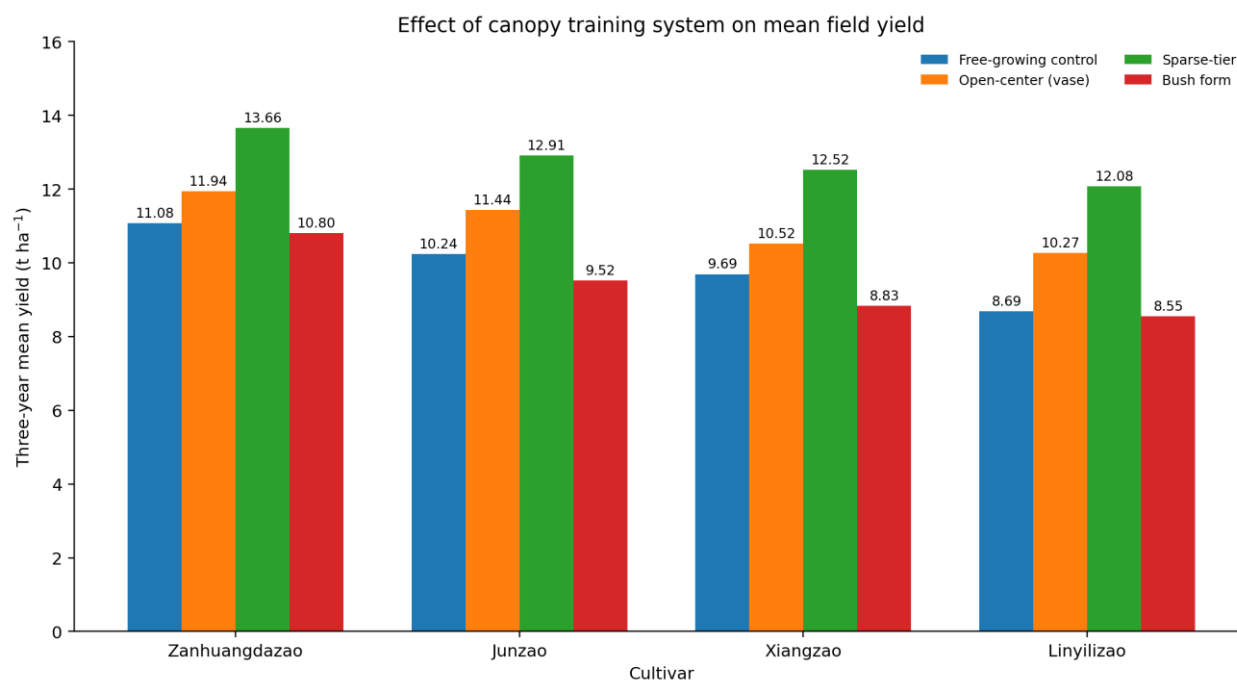


Figure 2. Three-year mean field yield of four Chinese jujube cultivars under different canopy training systems.

3.2. Cultivar-specific responses

Zanhuangdazao was the highest-yielding cultivar in absolute terms. Its three-year mean field yield increased from about 11.08 t ha⁻¹ in the free-growing control to 11.91 t ha⁻¹ under open-center training and 13.66-13.70 t ha⁻¹ under sparse-tier training. The sparse-tier advantage was approximately 23% relative to the control. The bush form did not provide a stable advantage, averaging about 10.8 t ha⁻¹.

Junzao responded strongly to structured canopy management. The three-year mean field yield increased from 10.25 t ha⁻¹ in the control to 11.41 t ha⁻¹ in the open-center treatment and 12.91 t ha⁻¹ in the sparse-tier treatment. Thus, sparse-tier training improved yield by about 26%, whereas the bush form reduced mean yield to approximately 9.50 t ha⁻¹.

Xiangzao showed a similar pattern. The control averaged about 9.66-9.70 t ha⁻¹, the open-center system approximately 10.50 t ha⁻¹, and the sparse-tier treatment approximately 12.52 t ha⁻¹. This represents a yield

advantage of nearly 30% over free-growing trees. The bush-form treatment remained below the control, at about 8.83 t ha⁻¹.

Linyilizao showed the largest relative response to canopy structure. Its mean field yield increased from 8.69 t ha⁻¹ under free growth to 10.27 t ha⁻¹ with open-center training and 12.08 t ha⁻¹ with sparse-tier training. The sparse-tier system therefore increased productivity by approximately 39% relative to the control. The bush form remained essentially at the control level or slightly below it (about 8.58 t ha⁻¹).

3.3. Yield dynamics across years

Yield increased from 2023 to 2025 in all treatments, reflecting orchard maturation and increasing productive capacity. Importantly, however, the ranking of training systems remained stable: sparse-tier trees produced the highest mean field yield in each year, followed by open-center trees, while bush-form trees generally remained below the control. This stability suggests that the response was not restricted to a single favorable season.

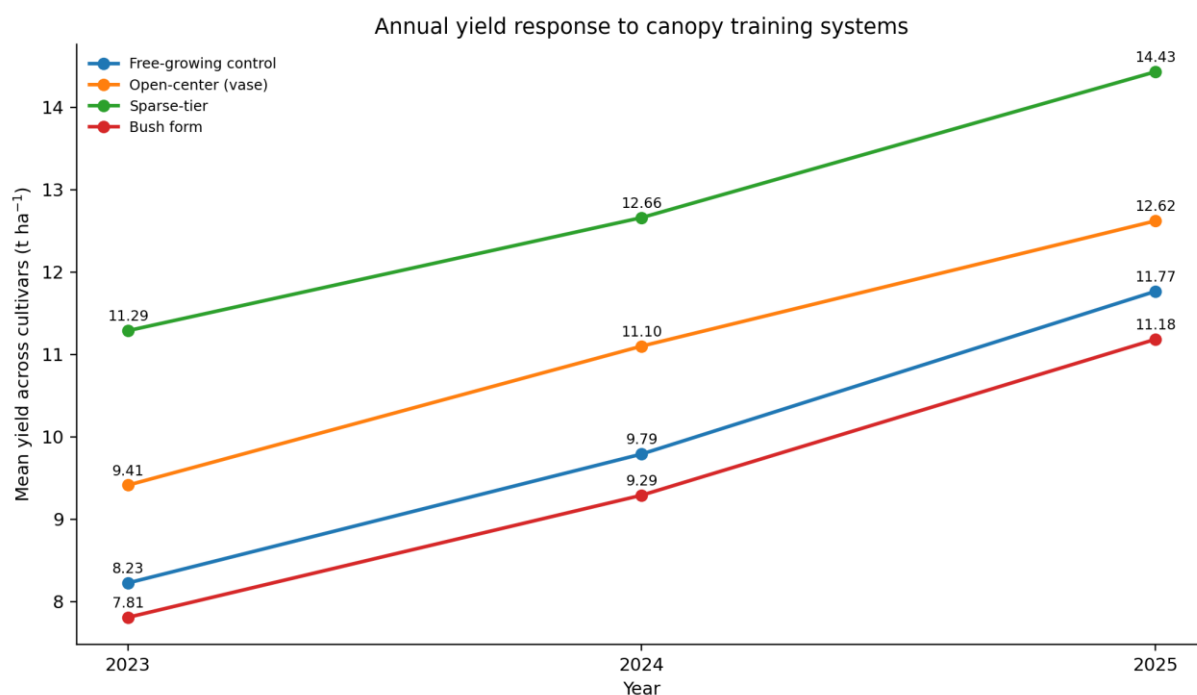


Figure 3. Annual mean field yield across four cultivars under four canopy training systems (2023-2025).

3.4. Overall productivity and horticultural interpretation

When data from all cultivars were pooled, the free-growing control averaged 9.93 t ha⁻¹. Open-center training increased this value to 11.03 t ha⁻¹ (+11.1%),

while sparse-tier training produced 12.80 t ha⁻¹ (+29.0%). In contrast, the bush form averaged 9.43 t ha⁻¹, approximately 5% below the control. The magnitude and consistency of the sparse-tier response indicate that a structured tiered canopy can improve fruit-bearing efficiency across genetically different jujube cultivars.

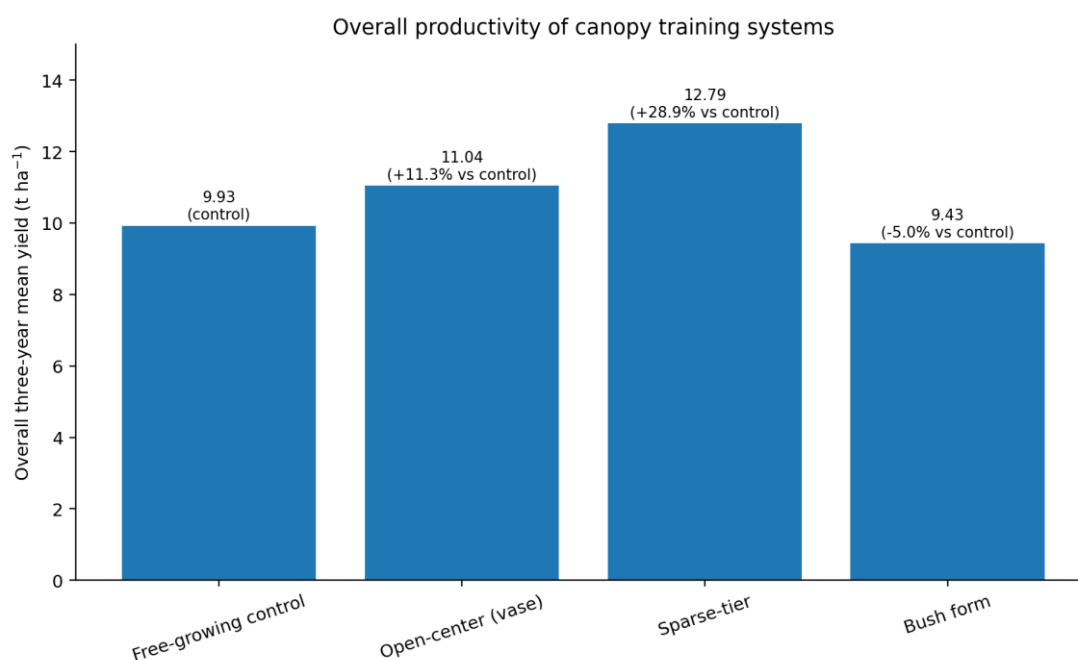


Figure 4. Overall three-year mean field yield of canopy training systems averaged across four cultivars. Percentages show the change relative to the free-growing control.

These results agree with broader jujube research showing that canopy architecture and pruning can improve the distribution of productive shoots, regulate canopy microclimate, and alter the balance between water use and crop production [3,5,6]. The sparse-tier form likely benefits yield by combining an organized scaffold structure with sufficient canopy openness to support light penetration and productive shoot development. This interpretation is also consistent with the previously reported vegetative-growth response of the same cultivar set, in which sparse-tier training produced the greatest mean shoot growth [7]. Nevertheless, the present yield data show that the value of canopy management should be judged primarily by fruit productivity rather than vegetative vigor alone.

The weaker performance of the bush form suggests that a low, multi-axis canopy does not necessarily improve production under the conditions represented by this dataset. Depending on cultivar, a bush architecture may increase canopy density, shading, or competition among structural axes, thereby limiting the proportion of assimilates allocated to fruit production. Further studies should combine yield measurements with canopy light distribution, leaf area index, fruit quality, pruning labor, and water-use measurements to determine the physiological basis of the observed yield differences.

4. Conclusion

Canopy training significantly influenced the productivity of Chinese jujube cultivars grafted on *Ziziphus acidujubus* rootstock during 2023-2025. Among the four systems evaluated, sparse-tier training consistently produced the highest yield in Zanhuangdazao, Junzao, Xiangzao, and Linyilizao. Averaged across cultivars, sparse-tier training increased three-year mean field yield by approximately 29% compared with the free-growing control, while open-center training improved yield by about 11%. Bush-form training did not provide a stable productivity advantage and averaged below the control. The strongest cultivar-specific response was observed in Linyilizao, whereas Zanhuangdazao showed the highest absolute productivity. These results identify sparse-tier canopy architecture as the most promising of the tested systems for improving jujube orchard yield. Future experiments should document full experimental replication and extend evaluation to fruit quality, canopy microclimate, water-use efficiency, and labor requirements to support production-scale recommendations.

References

1. Liu M.J., Wang M., Liu P., Zhao J., Zhao Z.H., Dai L., Li X.S., Liu Z.G. The historical and current research progress on jujube - a superfruit for the future. *Horticulture Research*. 2020;7:119. doi:10.1038/s41438-020-00346-5.
2. Sarkhosh A., Huff D. Jujube as a Florida Fruit Crop. UF/IFAS Extension, University of Florida. HS1477. Accessed 2026.
3. Wang Z., Zhang Q., Shan G., Lu F., Zhou G. The distribution of yield and comparison of fruit quality of the small and sparse canopy shape of Chinese jujube. *Chinese Agricultural Science Bulletin*. 2013;29(16):167-170. doi:10.11924/j.issn.1000-6850.2012-3773.
4. Wang W., Wang J., Chen Q., Zheng Q. Parameter determination and modeling of central leader tree shape for high quality and high yield production of *Ziziphus jujuba* 'Huizao'. *Acta Horticulturae Sinica*. 2024;51(4):832-846. doi:10.16420/j.issn.0513-353x.2023-0131.
5. Ma L., Wang X., Gao Z., Wang Y., Nie Z., Liu X. Canopy pruning as a strategy for saving water in a dry land jujube plantation in a loess hilly region of China. *Agricultural Water Management*. 2019. doi:10.1016/j.agwat.2018.12.007.
6. Effects of pruning and mulching measures on annual soil moisture, yield, and water use efficiency in jujube (*Ziziphus jujuba* Mill.) plantations. *Global Ecology and Conservation*. 2018;15:e00406. doi:10.1016/j.gecco.2018.e00406.
7. Turobov F.B. The effect of canopy training systems on annual shoot growth of Chinese jujube (*Ziziphus jujuba* Mill.) cultivars. *Agrobusiness, Science and Technology*. 2026;4(8).
8. Nikumbhe P., Meghwal P.R., Meena O.P., Pramendra, Meena H.M. Performance of Apple ber on different training systems in hot arid condition. *Journal of Horticultural Sciences*. 2023;18(1). doi:10.24154/jhs.v18i1.2147.
9. Fu L., Al-Mallahi A., Peng J., Sun S., Feng Y., Li R., He D., Cui Y. Harvesting technologies for Chinese jujube fruits: A review. *Engineering in Agriculture, Environment and Food*. 2017;10(3):171-177. doi:10.1016/j.eaef.2017.01.003.
10. Shi R., Wang H., Deng W., Zhang X., Liu Y., Huang J., Han G. Effects of different tree forms and grass mulching on microclimate in *Ziziphus jujuba* orchards in the plain regions of southern Xinjiang,

China. Chinese Journal of Applied Ecology.
2025;36(4):1127-1134. doi:10.13287/j.1001-
9332.202504.015.