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Effect of canopy management on growth, yield and nut quality of pistachio under high-altitude dry temperate conditions of Kinnaur

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Abstract

A field experiment was conducted during 2025 at RHRTS Sharbo, Kinnaur, Himachal Pradesh (2,190 m amsl) to evaluate the effect of systematic canopy management on growth, yield and nut quality of 23-year-old Kerman pistachio (*Pistacia vera* L.) trees under high-altitude dry temperate conditions. The experiment was laid out in Randomized Block Design with two treatments and three replications. Treatments comprised T₁ – systematic modified central leader training + dormant-season pruning (heading-back and thinning cuts) and T₂ – unpruned control (strong apical dominance since planting). Results revealed that canopy management significantly improved vegetative growth and physical nut quality. T₁ recorded significantly higher shoot extension (62.16 vs 53.75 cm), individual fruit weight (1.491 vs 1.400 g), nut weight per fruit (0.990 vs 0.896 g) and shell weight per fruit (0.663 vs 0.556 g). Nut length advanced from 20.05 mm (borderline medium-large) in control to 22.11 mm (large commercial grade) in pruned trees. Total fruit weight per tree remained comparable, while blank nut incidence was statistically similar (~39%). The improvement in nut size and shell development under T₁ was attributed to release of apical dominance, better light interception, enhanced assimilate partitioning and improved calcium transport in the opened canopy. The results indicate that systematic canopy management is an effective strategy for enhancing market quality and profitability of pistachio under Kinnaur conditions.

Keywords: *Pistacia vera*, canopy management, dormant pruning, training, nut quality, blank nuts, Kinnaur Himalayas, alternate bearing

1. Introduction

Pistachio (*Pistacia vera* L.) is a high-value nut crop with significant potential for commercial cultivation in the dry temperate valleys of Kinnaur, Himachal Pradesh (2,100–2,500 m amsl). The crop is valued for its nutrient-dense kernels rich in unsaturated fatty acids, protein, vitamins and antioxidants, contributing to human health and nutritional security (Okay *et al.*, 2010)^[4]. In India, systematic research on pistachio was initiated at Regional Horticultural Research & Training Station (RHRTS), Sharbo, Kinnaur, with introduction of Kerman (female) and Peters (male) cultivars. Despite favourable agro-climate analogous to the crop's native Central Asian habitat, productivity and quality in traditional orchards remain suboptimal due to neglect of canopy management.

Pistachio exhibits strong apical dominance and bears laterally on one-year-old wood. Unmanaged trees develop dense peripheral canopies with shaded, barren interiors, leading to poor light interception, reduced photosynthesis, migration of fruiting wood outward, and high incidence of blank (unfilled) nuts caused by assimilate competition during the critical July nut-fill period (Ferguson *et al.*, 2005)^[2]. Alternate bearing is further exacerbated by premature abscission of flower buds distal to heavy fruit clusters. These physiological constraints are particularly pronounced in long-neglected orchards of Kinnaur, resulting in irregular yields and produce that often falls in lower market grades.

Previous studies have demonstrated the benefits of pruning and training in pistachio. Okay *et al.* (2010)^[4] reported significant interactive effects of pruning methods and N/P fertilization on nut weight, splitting and empty nut rates, with apical bud management plus traditional pruning giving

superior results. Küden *et al.* (1995) ^[3] observed that autumn and winter pruning improved shoot vigour, induced beneficial self-thinning, reduced fruit bud drop and helped achieve more regular cropping. Aktug Tahtaci *et al.* (2016) ^[1] found modified central leader and closed open-centre training systems optimised yield and nut weight in ‘Siirt’ pistachio. However, location-specific quantitative data on the response of mature Kerman pistachio to systematic canopy management under high-altitude Himalayan dry temperate conditions are limited. Therefore, the present investigation was undertaken to study the effect of systematic modified central leader training combined with dormant-season pruning versus unpruned control on vegetative growth, yield parameters and physical nut quality of 23-year-old Kerman pistachio trees at RHRTS Sharbo, Kinnaur, during the first year of intervention (2025). The findings are expected to provide evidence-based recommendations for improving market competitiveness and sustainability of pistachio cultivation in the Indian Himalayas.

2. Materials and Methods

2.1 Experimental Site and Climate

The field experiment was conducted during 2025 at the Regional Horticultural Research & Training Station (RHRTS), Sharbo, Reckong Peo, Kinnaur, Himachal Pradesh, India (31°32’N, 78°15’E; 2,190 m above mean sea level). The site represents a typical high-altitude dry temperate ecosystem with warm dry summers, cold snowy winters and irrigation from glacial melt via traditional kuhl channels. Soil is slightly alkaline, low in organic matter and well-drained. Weather during the critical nut development period (April–August 2025) was recorded from the RHRTS Automatic Weather Station. Mean temperatures ranged from 15.8 °C (April) to 26.7 °C (June), with maxima reaching 29.8–32.2 °C, providing adequate heat accumulation for shell hardening and kernel filling. Rainfall was minimal during May–August, with a brief western disturbance in early April. Diurnal RH showed near-saturated mornings and low evening values (6–42%), conditions highly favourable for wind pollination and reduced disease pressure.

2.2 Plant Material and Experimental Details

Twenty-three-year-old Kerman (female) pistachio trees (planted 2001–02, sourced from Tucson, Arizona) with Peters pollinisers were selected. Trees were spaced at 5 × 5 m and received uniform cultural practices including kuhl irrigation, NPK fertilisation and plant protection. The experiment was laid out in Randomized Block Design with two treatments and three replications.

Treatment Details

T₁ – Systematic canopy management: Modified central leader training + annual dormant-season pruning (April, pre-bud burst). Pruning included heading-back cuts on vigorous terminal shoots (retaining 10–12 buds on smaller shoots or 12–14 buds on vigorous shoots, targeting the middle productive zone), thinning

cuts to remove suckers, water sprouts, dead/diseased/crossing branches and ‘broom heads’, and directional training of branches at ≥45° angles for light interception and structural strength. Canopy removal was limited to 10–15%. T₂ – Control: Trees left unpruned since planting, exhibiting strong apical dominance, peripheral fruiting, shaded barren interiors and excessive hanging wood.

2.3 Observations Recorded

Five representative shoots/plants were randomly selected from each net plot for biometric observations. Final yield and quality observations were recorded on plot and sample basis.

2.3.1 Growth Parameters

Shoot extension growth (cm): Measured on tagged current-season shoots at harvest; average of ten shoots per tree expressed in centimetres.

2.3.2 Yield Parameters

Total fruit weight per tree (g), number of fruits per tree, and individual fruit weight (g) were recorded. Five random samples of 50 fruits per treatment were used for component weights and dimensions.

2.3.3 Nut Quality Attributes

Hull (epicarp + mesocarp), nut (shell + kernel), shell (endocarp) and kernel weights per fruit (g) were determined by separation and electronic balance. Physical dimensions (fruit and nut length/breadth, mm) were measured with digital vernier calliper. Blank nut percentage was determined by cut-test on random samples of 200 nuts per treatment. All observations followed standard procedures.

2.4 Statistical Analysis

Data were subjected to statistical analysis of variance (ANOVA) appropriate for Randomized Block Design as described by Panse and Sukhatme (1985) ^[5]. Treatment means were compared using critical difference (CD) at P=0.05. Percentage differences were calculated for interpretation of practical significance.

3. Results and Discussion

3.1 Growth Parameters

Systematic canopy management (T₁) significantly stimulated vegetative vigour. Shoot extension growth reached 62.16 cm in pruned trees compared to 53.75 cm in the unpruned control (Table 1), representing a 15.6% increase. Heading-back cuts effectively released apical dominance, redirecting carbohydrates and auxin toward lateral buds and promoting robust new shoot growth – the primary zone for next season’s inflorescence differentiation. The improvement is consistent with the findings of Küden *et al.* (1995) ^[3] who reported better shoot development following winter pruning in pistachio.

Table 1: Effect of canopy management on vegetative growth and yield parameters of Kerman pistachio

Treatment	Shoot extension (cm)	No. of fruits/tree	Fruit wt/fruit (g)	Total fruit wt/tree (g)	Harvest index (%)
T ₁ – Systematic pruning & training	62.16	1738	1.491	2405	39.8
T ₂ – Control (unpruned)	53.75	1943	1.400	2422	38.9
SEm±	1.82	48.6	0.028	42.3	0.72
CD (P=0.05)	5.41	144.5	0.083	NS	NS

NS = Non-significant

3.2 Yield Parameters

Total fruit weight per tree was nearly identical between treatments (2,405 g in T₁ vs 2,422 g in T₂). However, pruned trees carried

10.5% fewer fruits (1,738 vs 1,943), resulting in 6.55% heavier individual fruits (1.491 vs 1.400 g). This classic crop-load moderation effect demonstrates that pruning redistributed

assimilates among fewer fruits, enhancing per-fruit resource availability without sacrificing total biomass yield in the first year. Similar trade-offs between fruit number and size have been reported in pruning studies on pistachio (Okay *et al.*, 2010) ^[4]. Harvest index remained statistically comparable, indicating efficient partitioning in both treatments.

3.3 Nut Quality Attributes

Canopy management produced marked improvements in nut quality components (Table 2). Hull weight per fruit increased by 9.2%, nut (shell + kernel) weight per fruit by 10.5% and shell weight per fruit by a substantial 19.3% in T₁. The pronounced shell response suggests enhanced calcium and assimilate transport to developing endocarps under improved light regimes and reduced intra-fruit competition within the more open canopy. Physical dimensions followed the same positive trend (Table 3). Nut length rose from 20.05 mm to 22.11 mm (+10.3%) and nut

breadth from 10.96 mm to 11.91 mm (+8.7%). Critically, pruned-tree nuts crossed the commercial threshold into the ‘large’ grade category (nut length >22 mm), whereas control nuts remained borderline ‘medium-large’. This shift has substantial implications for farm-gate price realisation.

Blank nut incidence was 39.58% in pruned trees versus 38.83% in control, a marginal and non-significant difference in this first year of intervention. The high baseline blank percentage is characteristic of long-neglected, apically dominant canopies under alternate-bearing pressure and is consistent with the physiological mechanism described by Ferguson *et al.* ^[2], wherein heavy crop loads during nut fill trigger distal bud abscission and limit assimilate supply. Full expression of blank-nut reduction through renewed productive wood and moderated crop load per branch is anticipated from the second year onward, as documented by Küden *et al.* (1995) ^[3].

Table 2: Effect of canopy management on nut quality components (g fruit⁻¹) of Kerman pistachio

Treatment	Hull wt	Nut wt	Shell wt	Kernel wt	% Shell
T ₁ – Systematic pruning & training	0.392	0.990	0.663	0.436	44.48
T ₂ – Control (unpruned)	0.359	0.896	0.556	0.485	39.71
<i>SEm</i> ±	0.012	0.022	0.018	0.015	1.25
CD (P=0.05)	0.036	0.065	0.053	NS	3.72

Table 3: Effect of canopy management on physical dimensions (mm) and blank nut incidence of Kerman pistachio

Treatment	Fruit length	Nut length	Nut breadth	Blank nuts (%)	Market grade
T ₁ – Systematic pruning & training	24.10	22.11	11.91	39.58	Large
T ₂ – Control (unpruned)	23.08	20.05	10.96	38.83	Medium-large
<i>SEm</i> ±	0.28	0.31	0.19	1.15	-
CD (P=0.05)	0.83	0.92	0.56	NS	-

The higher shell proportion and larger dimensions under T₁ are of direct commercial significance because pistachio is predominantly marketed in-shell. Improved light penetration and canopy ventilation also favour better calcium transport and reduced humidity-related disorders, aligning with the physiological principles outlined by Ferguson *et al.* 2005 ^[2] and the pruning responses documented by Okay *et al.* (2010) ^[4] and Küden *et al.* (1998) ^[3].

4. Conclusion

Systematic canopy management through modified central leader training and light annual dormant-season pruning (10–15% canopy removal) significantly enhanced vegetative growth and physical nut quality of Kerman pistachio under high-altitude dry temperate conditions of Kinnaur. Pruned trees produced nuts in the ‘large’ commercial grade with heavier shells and superior dimensions compared to the borderline medium-large grade of unpruned trees, while maintaining comparable total yield in the first year. The practice is recommended for adoption in Kinnaur orchards to improve market price realisation and long-term sustainability. Multi-year evaluation is warranted to quantify impacts on alternate bearing and blank nut reduction.

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