



Effect of root pruning and trunk girdling on morphological, yield and fruit quality attributes in ‘YaLi’ pear (*Pyrus* spp.) trained on the Cordon system

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Received: 19 June 2025; Accepted: 20 January 2026

ABSTRACT

The study was carried out in 2022 and 2023 at Punjab Agricultural University, Ludhiana, Punjab to assess the effect of root pruning (RP), trunk girdling (TG) and RP + TG treatments in ‘YaLi’ pear (*Pyrus* spp. L.) cultivar trained on Cordon system for vegetative growth, fruit yield and quality attributes. The pooled data revealed significant reduction in annual shoot length, shoot diameter, internodal length, leaf area index, number of water sprouts/plant and pruned wood weight in the plants subjected to trunk girdling, root pruning and RP + TG treatments than the control (untreated plants). Leaf relative water content, total chlorophyll (SPAD) and macro nutrients content were reduced in all treatments except the control. The C:N ratio was substantially enhanced with TG and RP + TG compared to RP and the control. The reduction in net photosynthesis, stomatal conductance, intercellular CO₂ concentration, rate of transpiration and higher plant photosynthetically active radiation (PAR), fruit yield efficiency and antioxidant activities were observed in the plants with girdling and root pruning treatments over the control. It was intended that the combination of root pruning + trunk girdling techniques is potential, valuable, low cost and eco-friendly to control tree growth and substantially improve return bloom, fruit yield and quality attributes of pear orchards under high density plantation.

Keywords: Antioxidant activity, Canopy management, C:N ratio, Fruit yield, Photosynthetic efficiency

Punjab province situated in sub-tropics of India holds significant potential for pear (*Pyrus* spp. L.) cultivation and area is expanding annually due to hardy nature, nutraceutical properties, good remunerative returns and more demand of fruits during festival seasons. Punjab Agricultural University (PAU), Ludhiana has recommended low-chilling Asian pear cultivars for the general cultivation and fruits are classified as hard, semi soft and soft that needs <300 chilling units. ‘YaLi’ pear cultivar is gaining popularity in the region due to its juicy, fine-grained texture, mild tartness and relatively soft flesh that generally matures in July. Growth regulation is a critical aspect for pear canopy management, as excessive vegetative vigour can reduce light penetration, fruit yield, quality attributes and enhances pruning expenditure (Wang *et al.* 2014). Under sub-tropics, pear is trained by a modified leader system and are pruned regularly to develop compact tree canopy with more reproductive spurs and maintaining a balance between shoots-roots ratio. Skilled labour is required to prune diseased, criss-crossed, excessive vegetative growth and to sustain well-developed fruiting branches. It is observed that root pruning and girdling treatments

are comparatively less labour-intensive and offer effective alternatives to control tree vigour without negotiating with reproductive structures. Root pruning restricts water and nutrients uptake, indirectly limiting shoot elongation, while girdling temporarily blocks phloem flow, enhancing carbohydrates accumulation above the girdled portion (Sharma *et al.* 2024). The efficacy of both techniques is influenced by time of application and intensity; however, optimal results are obtained when applied almost a few weeks before full bloom (Uselis *et al.* 2020). Although these practices significantly reduce vegetative growth and enhance flowering and fruiting in various fruit crops (Sharma *et al.* 2024) but their adoption is limited due to lack of mechanisation and standard protocols. Therefore, the present study was carried out with the objectives to evaluate the individual and combined effect of root pruning and trunk girdling on vegetative growth dynamics, photosynthetic efficiency, intra-canopy light distribution, fruit set, yield and fruit quality in ‘YaLi’ pear trained on the Cordon trellis system.

MATERIALS AND METHODS

The study was carried out during 2022 and 2023 at Punjab Agricultural University, Ludhiana (30.90° N, 75.80° E; at an elevation of 247 m amsl), Punjab on 11-year old

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plants of pear cv. ‘YaLi’ grafted on *Pyrus pashia* (Kainth) rootstock and trained on the Cordon system. The plants were spaced at 2 m × 3 m accommodating about 3,333 plants/ha. The study involved root pruning (RP), trunk girdling (TG), combinations of root pruning and trunk girdling (RP + TG) treatments and an untreated control (C), laid out in completely randomised block design (CRBD) with five replications. All the treatments were applied at the onset of spring season. Root pruning was carried only during 2022; by chopping the roots 45 cm from the trunk at a depth of 30 cm. Trunk girdling was performed by removing a 4 mm thick ring of bark circumferentially at a height of 20 cm above the ground level during 2022, and was carried out at the distance of 5 cm above the previous girdling site in the successive year (Fig. 1).

The data on morphometric attributes, viz. annual shoot length, shoot diameter, number of water sprouts, internodal length and pruned wood weight was recorded during the end of growing season (dormant season). For estimation of leaf area index (LAI), the CI-110 Plant Canopy Imager (CID Bio Science, Inc., USA) was used. Relative water content (RWC%) was determined as per Sharma *et al.* (2025a). Chlorophyll content was estimated from the mature pear leaves with SPAD chlorophyll meter (Model: SPAD-502 plus chlorophyll meter, Spectrum technologies, USA). Leaf N, P and K were calculated using the procedure outlined by Singh *et al.* (2015). For calculation of C/N, the carbohydrates

content was analysed using anthrone reagent method (AOAC 2000). Portable photosynthesis system (Model: CI-340, CID Bio-Science, USA) was used to record net photosynthesis rate (Pn), stomatal conductance (C), intercellular CO₂ (Ci), transpiration rate (E) and photosynthetically active radiation (PAR) at monthly intervals from April to July.

Fruit set (%) was recorded after petal fall at pea stage with respect to the total number of flowers/shoot. Fruits were harvested at physiological maturity and yield was estimated by multiplying average fruit weight of ten fruits with number of fruits/plant and number of plants/ha. Yield efficiency was calculated in terms of kg/cm² of tree TCSA (Trunk cross-sectional area). Return bloom was determined by counting the number of flowering clusters/m of shoot length (FCPMS) at the time of full bloom in successive years 2023 and 2024 (Stopar 2009). Average fruit weight was determined using a digital weighing balance (Model: EK6100i, A&D, Japan). Fruits weighing >120 g were classified as ‘A’ grade and their proportion in percentage was calculated to assess the number of fruits distributed. Fruit firmness was determined using a stand mount fruit penetrometer (Model FT-327, USA). Total soluble solids (TSS), titratable acidity, fruit juice (%), total sugars and reducing sugars in fruit pulp were estimated by the procedure of AOAC (2000). Fruit ascorbic acid, total phenols, flavonoids, DPPH and FRAP were determined using the protocols followed by Sharma *et al.* (2025a).

Analysis of variance (ANOVA) was carried out using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). Treatment differences were evaluated using the least significant difference (LSD) test at a significance level of $p \leq 0.05$. Data are presented as mean values ± standard error (SE).

RESULTS AND DISCUSSION

It is clear from pooled data that root pruning, trunk girdling and root pruning + trunk girdling treatments (RP + TG) significantly reduced plant vigour (Table 1). Annual shoot length ranged from 153.5 cm in RP + TG to 159.1 cm in TG treatment, while control had the highest (170.1 cm). Minimum shoot diameter (1.24 cm) was registered in plants subjected to RP + TG treatment and maximum (1.45 cm) in untreated plants. RP + TG treated plants had produced about 23.6% fewer water sprouts/plant with a value of 12.3 in comparison to the control (16.1). Shoot internodal length of 3.84, 4.06 and 4.15 cm was observed in RP + TG, RP and TG treatments, respectively while control registered the highest (4.35 cm). During bud break, the carbohydrates stored in the roots are mobilised to support metabolic activities required for shoot emergence and vegetative growth as the plant transitions from dormancy to active growth. However, root pruning removes a significant portion of stored assimilates, prompting plants to restore the root-to-shoot equilibrium by reallocating stored carbohydrates toward root healing and new root development, thereby reducing vegetative shoot growth (Wang *et al.* 2014). Girdling practices promote the accumulation of carbohydrates above the girdled portion,



Fig. 1 Root pruning and girdling treatments in pear plants trained on Cordon system.

Table 1 Effect of root pruning and trunk girdling on vegetative growth dynamics and physiological attributes of 'YaLi' pear trained on Cordon system

Treatments	Annual shoot length (cm)	Shoot diameter (cm)	Number of water sprouts	Internodal length (cm)	Pruned wood weight (kg/tree)	LAI
RP	157.3 ± 2.53 ^b	1.31 ± 0.03 ^{bc}	13.2 ± 0.57 ^b	4.06 ± 0.08 ^b	2.17 ± 0.08 ^b	0.423 ± 0.015 ^{bc}
TG	159.1 ± 3.00 ^b	1.36 ± 0.03 ^{ab}	13.9 ± 0.68 ^{ab}	4.15 ± 0.06 ^b	2.22 ± 0.09 ^{ab}	0.468 ± 0.016 ^{ab}
RP + TG	153.5 ± 2.95 ^b	1.24 ± 0.02 ^c	12.3 ± 0.62 ^b	3.84 ± 0.06 ^b	1.96 ± 0.06 ^b	0.409 ± 0.010 ^c
C	170.1 ± 2.78 ^a	1.45 ± 0.03 ^a	16.1 ± 0.56 ^a	4.35 ± 0.05 ^a	2.55 ± 0.10 ^a	0.502 ± 0.007 ^a
Treatments	RWC (%)	Total Chl (SPAD)	Leaf C/N	Leaf N (%)	Leaf P (%)	Leaf K (%)
RP	92.8 ± 1.22 ^b	44.9 ± 0.66 ^b	3.29 ± 0.08 ^c	2.37 ± 0.04 ^{ab}	0.179 ± 0.001 ^{ab}	1.24 ± 0.02 ^b
TG	93.5 ± 0.62 ^{ab}	45.8 ± 0.73 ^{ab}	3.88 ± 0.11 ^a	2.38 ± 0.04 ^{ab}	0.180 ± 0.001 ^a	1.25 ± 0.02 ^b
RP + TG	91.3 ± 0.77 ^b	43.3 ± 0.50 ^b	3.58 ± 0.07 ^b	2.29 ± 0.03 ^b	0.175 ± 0.001 ^b	1.19 ± 0.02 ^b
C	95.4 ± 0.84 ^a	47.7 ± 0.70 ^a	3.50 ± 0.04 ^{bc}	2.45 ± 0.03 ^a	0.183 ± 0.001 ^a	1.34 ± 0.04 ^a

Values are mean ± standard deviation (n = 5). Different letters between columns indicate a significant difference ($p \leq 0.05$) according to the Least Significant Difference (LSD) test. LAI, Leaf area index; RWC, Relative water content; C/N, Carbohydrate to nitrogen ratio; N, Nitrogen; P, Phosphorus; K, Potassium; Total Chl, Total chlorophyll; RP, Root pruning; TG, Trunk girdling; C, Control.

which favours growth of reproductive organs over vegetative growth (Sharma *et al.* 2025b). The reduction in vegetative growth in treated plants significantly reduced the pruned wood weight by 12.9, 14.9 and 23.1% and leaf area index by 6.7, 15.7 and 19.9% in TG, RP and RP + TG treatments, respectively compared to the control.

Relative leaf water content and chlorophyll content decreased under various root pruning and girdling treatments being the lowest in RP + TG followed by RP and TG treatments (Table 1). However, the TG treatment had shown statistically non-significant results with the control. Root pruning and girdling reduced relative water content (RWC) and chlorophyll levels by disrupting root-shoots signalling and phloem transport, respectively. Root pruning restricts water uptake and induces partial stomatal closure, reducing transpiration and photosynthetic efficiency (Ning *et al.* 2021), while girdling leads to leaf carbohydrate accumulation which may impair chlorophyll synthesis. The C/N among different treatments was in the order of TG > RP + TG > C > RP. Trunk-girdled plants exhibited about 9.8% higher C:N ratio compared to the control and about 15.2% than RP treatment. In root pruned plants, leaf carbohydrate levels declined due to their mobilisation toward regenerating roots. In contrast, girdling or their combination with root pruning led to carbohydrate accumulation above the girdled portion by blocking downward translocation and thereby increasing the C:N ratio. Maximum reduction in leaf N, P and K contents was observed in RP + TG treatment comparison to the control. This reduction is primarily due to impaired root function, which limits nutrients uptake and cytokinin production essential for nutrients mobilisation. In girdled trees, nutrient decline was linked to disruption in auxin-cytokinin transportation and increased allocation of nutrient to developing fruits above the girdled zone (Urban *et al.* 2004).

A significant impact of root pruning and girdling was reported on the photosynthetic efficiency of the treated plants

(Fig. 2). RP + TG treatment decreased the net photosynthesis (Pn) by 11.9, 11.1, 9.4 and 9.3% and stomatal conductance by 8.3, 11.2, 11.2 and 8.9% for April, May, June and July months, respectively compared to the control. The maximum reduction of intercellular CO₂ level was registered in RP + TG treatment to the tune of 115.3 µmol/mol in April, 130.3 µmol/mol in May, 143.4 µmol/mol in June and 119.5 µmol/mol in July. Transpiration rate was found lowest to the tune of 1.08, 1.61, 2.12 and 1.71 mmol/m²/sec in April, May, June and July, respectively in plants subjected to RP + TG treatment, whereas the untreated control had the highest values of 1.23, 1.85, 2.35 and 1.85 mmol/m²/sec, respectively. The photosynthetically active radiation (PAR) was positively influenced by different treatments being the highest in RP + TG with the values of 390.7, 263.8, 167.4 and 104.2 µmol/m²/sec during April to July, respectively over untreated the control. Girdling and root pruning significantly altered the photosynthetic system, resulting in reduction of net photosynthesis, stomatal conductance and transpiration rate. The effects are probably due to end-product inhibition caused by sink limitation and stress-induced accumulation of ABA leading to stomatal closure (Iglesias *et al.* 2002). The decline in intercellular CO₂ concentration observed in this study aligned with reduced stomatal conductance and net photosynthesis, as also reported in apples by Zhou and Quebedeaux (2003). In root-pruned trees, limited water uptake and root-shoot signalling (Zhao *et al.* 2007) substantially contributed to stomatal closure, further reducing CO₂ diffusion and transpiration. The increase in PAR can be attributed to reduction in canopy density in both girdled and root pruned trees.

Plants subjected to different treatments exhibited a considerable improvement in fruit yield and quality related attributes compared to the control in pear cultivar 'YaLi' (Table 2). TG treatment had the highest fruit set of 9.74% which was statistically at par with RP (9.54%). However, fruit retention was observed maximum in RP + TG treatment

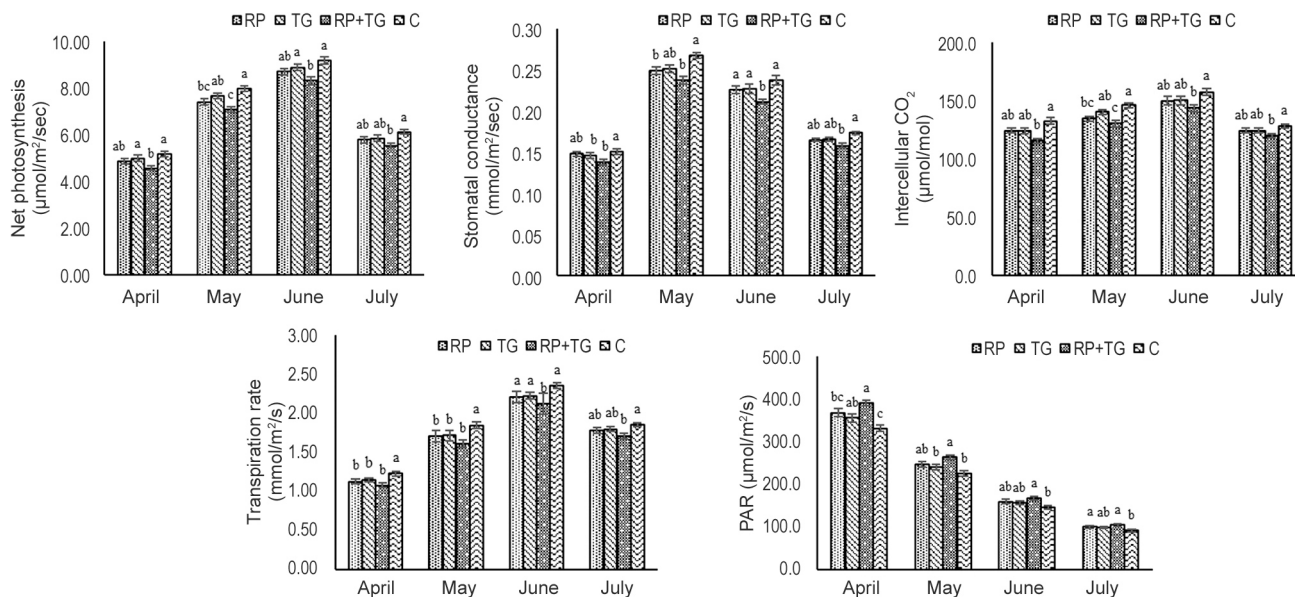


Fig. 2 Effect of root pruning and trunk girdling on photosynthetic efficiency in ‘YaLi’ pear plants trained on Cordon system. RP, Root pruning; TG, Trunk girdling; C, Control; PAR, Photosynthetically active radiation.

which in turn enhanced fruit yield (4.0 Mt/ha) and yield efficiency (0.031 kg/cm²). This might be attributed to better fruit retention due to the movement of photosynthates towards developing fruits instead of vegetative growth. Return bloom in different treatments was in the order of RP + TG > RP > TG > C and it was enhanced by 15.3% in RP + TG compared to the control. The enhancement in return bloom in treated plants may be due to reduction in vegetative growth which enhances light penetration into tree canopy and the movement of carbohydrates towards the reproductive buds. It has been found that shading from excessive shoot growth has a negative effect on flower bud induction and the quality of the return bloom (Miller and Tworkoski 2003). Highest fruit weight (133.7 g) and proportion of ‘A grade’

fruit production to the tune of 67.2% was reported in RP + TG treatment and the control plants had minimum values of 117.9 g and 54.5%, respectively due to translocation of photosynthates towards developing fruits.

Minimum titratable acid content was registered in RP + TG (0.215%) and fruit juice content of 81.8% in plants subjected to RP treatment; the reduction in fruit juice content in both treatments might be attributed to reduction in water translocation in plants with girdling and root pruning treatments. Fruits harvested from trunk girdled plants registered highest fruit firmness followed by RP + TG and C whereas minimum in RP treatment. The reduction in fruit firmness might be due to reduction in uptake of nutrients such as Ca involved in maintaining membrane

Table 2 Effect of root pruning and trunk girdling treatments on fruit yield and quality related attributes of ‘YaLi’ pear cultivar trained on Cordon system

Treatments	Fruit set (%)	Yield (Mt/ha)	Return bloom (FCPMS)	Yield efficiency (kg/cm ²)	Fruit weight (g)	FND (% ‘A’ grade fruits)
RP	9.54 ± 0.16 ^a	3.30 ± 0.18 ^b	2.16 ± 0.05 ^{ab}	0.026 ± 0.0011 ^{ab}	123.1 ± 2.56 ^{bc}	58.7 ± 1.54 ^{bc}
TG	9.74 ± 0.13 ^a	3.35 ± 0.16 ^{ab}	2.14 ± 0.06 ^{bc}	0.026 ± 0.0012 ^{ab}	129.4 ± 2.04 ^{ab}	63.2 ± 1.92 ^{ab}
RP + TG	9.43 ± 0.13 ^b	4.00 ± 0.13 ^a	2.35 ± 0.03 ^a	0.031 ± 0.0013 ^a	133.7 ± 2.19 ^a	67.2 ± 1.82 ^a
C	8.97 ± 0.11 ^b	2.74 ± 0.16 ^b	1.99 ± 0.05 ^c	0.023 ± 0.0008 ^b	117.9 ± 2.87 ^c	54.5 ± 1.89 ^c
Treatments	Titratable acidity (%)	Fruit firmness (lbs)	Fruit juice content (%)	TSS (°B)	Total sugars (%)	Reducing sugars (%)
RP	0.226 ± 0.002 ^{ab}	10.4 ± 0.11 ^b	81.4 ± 0.51 ^b	11.7 ± 0.21 ^a	9.07 ± 0.16 ^b	5.69 ± 0.12 ^a
TG	0.229 ± 0.003 ^a	11.0 ± 0.08 ^a	84.1 ± 0.43 ^a	11.7 ± 0.18 ^a	9.59 ± 0.11 ^a	5.78 ± 0.13 ^a
RP + TG	0.215 ± 0.003 ^b	10.9 ± 0.07 ^a	81.8 ± 0.44 ^b	12.2 ± 0.23 ^a	9.89 ± 0.12 ^a	5.92 ± 0.16 ^a
C	0.238 ± 0.003 ^a	10.8 ± 0.11 ^a	81.5 ± 0.67 ^b	10.5 ± 0.22 ^b	8.80 ± 0.19 ^b	5.00 ± 0.15 ^b

Values are mean ± standard deviation (n = 5). Different letters between columns indicate a significant difference (p ≤ 0.05) according to the Least Significant Difference (LSD) test. FCPMS, Flower clusters/m shoot; FND, Fruit number distribution; TSS, Total soluble solids; RP, Root pruning; TG, Trunk girdling; C, Control.

Table 3 Effect of root pruning and trunk girdling on fruit antioxidant capacity in pear plants trained on Cordon system

Treatments	Ascorbic acid (mg/kg FW)	Fruit phenols (mg GAE/g FW)	Fruit flavonoids (mg QE/g FW)	Fruit DPPH (%)	Fruit FRAP (mg Fe ²⁺ /g)
RP	60.8 ± 0.75 ^{ab}	2.99 ± 0.06 ^{ab}	1.89 ± 0.04 ^{ab}	44.5 ± 0.78 ^{ab}	1.54 ± 0.04 ^{ab}
TG	59.5 ± 0.79 ^{ab}	2.92 ± 0.08 ^{bc}	1.88 ± 0.03 ^{ab}	43.4 ± 0.82 ^a	1.49 ± 0.04 ^b
RP + TG	62.6 ± 0.91 ^a	3.13 ± 0.04 ^a	2.02 ± 0.03 ^a	46.3 ± 0.69 ^a	1.63 ± 0.03 ^a
C	57.9 ± 0.81 ^b	2.79 ± 0.05 ^c	1.76 ± 0.05 ^b	41.0 ± 0.82 ^b	1.43 ± 0.02 ^b

Values are mean ± standard deviation (n = 5). Different letters between columns indicate a significant difference ($p \leq 0.05$) according to the Least Significant Difference (LSD) test. DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, Ferric reducing antioxidant power; GAE, Gallic acid equivalent; RP, Root pruning; TG, Trunk girdling; C, Control.

integrity (Singh *et al.* 2015). Maximum fruit TSS (12.2°B), total sugars (9.89%) and reducing sugar (5.92%) content were observed in RP + TG treatment and minimum in the control to the tune of 10.5°B, 8.80% and 5.0%, respectively. The elevated levels of ethylene under the stress conditions induced by girdling and root pruning treatments might have promoted the conversion of starch to sugars and reduced the translocation of water towards ripening fruit resulting in higher TSS content (Yang *et al.* 2012). In present study, girdling and root pruning acted as a mechanical stress and the plants elevated fruit sugar levels under stress and to enhance desiccation tolerance and protect the developing fruit (Naser *et al.* 2010).

Further, the pooled data of two consecutive years revealed that there was an increase in the level of secondary metabolites and antioxidant potential in the fruits harvested from treated plants in comparison to the control (Table 3). Maximum ascorbic acid, phenols and flavonoids were registered in RP + TG treatment to the tune of 62.6 mg/kg FW, 3.13 mg GAE/g FW and 2.02 mg QE/g FW, respectively. Ascorbic acid acts as an antioxidant under stress and helps to combat oxidative damage. Similar improvement in quality parameters have been also reported in plum after girdling (Piccolo *et al.* 2021). Elevated phenolics and flavonoids might result from stress induced activation of phenylalanine ammonia lyase enzymes involved in phenol biosynthesis (Khandaker *et al.* 2012). The higher DPPH and FRAP free radical scavenging activity in treated plants was primarily attributed to the accumulation of these antioxidant compounds.

The present study revealed that root pruning and trunk girdling treatments were effective approaches for controlling vegetative growth and enhancing fruit yield and quality of 'YaLi' pear trained on Cordon system. By modulating resource allocation through induced physiological stress, these horticultural manipulations reduce excessive vegetative growth and improve light distribution in tree canopy. Despite a provisional decline in photosynthetic efficiency, a notable improvement was observed in productivity and fruit quality parameters. Higher bioactive compounds (ascorbic acid, phenolics and flavonoid content) depicted the role of moderate stresses in enhancing fruit biochemical properties. Therefore, the combination of root pruning + trunk girdling treatment significantly managed plant canopy and enhanced

fruit yield and quality attributes under high density pear plantation. The practice can be studied in other cultivars and growing conditions to further validate its efficacy and expand its practical relevance.

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