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EFFECT OF GIRDLING AND ROOT PRUNING ON VEGETATIVE GROWTH, FRUIT METABOLITES AND YIELD OF PEAR GROWN UNDER SUB-TROPICAL CONDITIONS

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ABSTRACT

Excessive vegetative growth in semi-soft pear is a limiting factor for optimum fruit production under sub-tropical conditions of north-western India. Therefore, the present studies were conducted to regulate the vegetative growth and improve fruit yield, quality and associated biochemical parameters of pear cultivar 'Punjab Beauty' by girdling and root pruning techniques. The significant increase in fruit set, retention, yield, total phenolics content, flavonoid content and C:N ratio of bark and spur was registered with root pruning at 60 cm as compared to control and the other treatments viz; trunk girdling, limb girdling, root pruning at 40 cm and sub limb girdling. However, fruits with maximum size, weight, total soluble solids (TSS), TSS/Acid ratio were attained with the trunk girdling. The limb girdling and root pruning at 40 cm also enhanced fruit quality but sub-limb girdling did not create significant impact. The fruits of the root pruned trees exhibited a slower oxidation of the total phenol content by inhibiting the activity of polyphenol oxidase and thus retaining higher total phenolic content as compared to control. Hence, root pruning at 60 cm exhibited promising results for controlling vegetative growth, improving yield and fruit biochemical attributes in pear.

Keywords: Fruit set, Fruit yield, Girdling, Root pruning, Vegetative growth

Pear is one of the oldest and most popular fruits of the temperate region of the world. It can also be successfully cultivated in subtropical regions with a wide range of climatic and soil conditions. Pear occupies a prominent position in horticulture industry of Punjab state of India; the major cultivated pear is the hard cultivar 'Patharnakh', followed by semi-soft cultivar 'Punjab Beauty'. The fruit quality of 'Punjab Beauty' pear is superior to 'Patharnakh' in terms of external appearance and melting in texture; nevertheless, the low bearing habit of 'Punjab Beauty' limits its area expansion at a larger scale. The low bearing translates into lower production which could also be due to low fruit set and its juvenile period happens to be longer. The low fruit set in 'Punjab Beauty' pear may be attributed to the prevailing subtropical conditions which are characterized by abundant heat units during long summer, followed by high rainfall and insufficient accumulation of chill hours during winter (Singh *et al.,* 2016). These factors promote excessive vegetative growth during the growing period leading to insufficient partitioning of assimilates towards fruit bearing. With no control over the prevailing weather conditions, the flowering behavior can be manipulated by altering vegetative growth (Li and Xiao, 2001), root pruning, irrigation, balancing C:N ratio and endogenous hormonal balance during its flowering phase (Davenport, 2009). The main factors affecting flowering and fruit set in fruits are long juvenile phase, fruit load of previous cropping year, interaction between vegetative growth and flowering (Wilkie *et al.,* 2008). Hence, it becomes imperative to restrict excessive vegetative growth to facilitate greater interception of solar radiations for improvement of fruit quality (Rademacher, 2004). The developing shoots, branches and leaves are competitive sinks for photo-assimilates during the initial period of plant growth which negatively affect the reproductive growth. To promote fruit set, yield and quality, management of the vegetative growth must be adopted to optimize the source to sink relationship.

In subtropical pears, girdling has been reported to improve fruit set, size and flowering by reducing vegetative growth (Singh *et al*., 2014). This treatment improves fruit quality by affecting the balance between vegetative and reproductive growth (Sharma *et al.,* 2009). However, girdling must be practiced at an optimum stage to reduce competition for resources between shoot growth and fruit development (Sousa *et al*., 2008). Girdling enhances flowering by increasing carbohydrate level of above the girdle parts and reduces nitrogen supply to the tree (Khandaker *et al.,* 2011). This reduction in nitrogen content leads to the retardation of root growth and the enhancement of flowering, fruit set and fruit quality parameters. Likewise, root pruning is the most primitive method

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for limiting vegetative growth and can promote flower bud initiation and fruiting in pear (Webster, 2006). This method reduces root area, flow of nutrients, water and hormones from roots to shoots and leads to growth retardation. According to Rodriguez-Gamir *et al.*(2010) and Maas (2008), root pruning is an effective tool for controlling vegetative growth, shoot length in trees. It not only assists in dwarfing, but also stimulates the emergence of new roots necessary to sustain growth (Yang *et al*., 2010). The main purpose of root pruning is to alter the existing growth pattern of trees and to alter assimilate partitioning, nutrient distribution and hormonal balance. The combined action of girdling and root pruning treatments can cause concurrent effects on plant growth and fruit quality (Asin *et al*., 2007). Keeping in view the benefits of these horticultural techniques, the present study was undertaken to investigate the effect of girdling and root pruning on fruit set, yield, and biochemical characteristics of 'Punjab Beauty' pear.

MATERIALS AND METHODS

Plant material, growth conditions and experimental design

The present investigation was conducted on twelve years old pear cultivar 'Punjab Beauty', grafted on 'Kainth' (*Pyrus pashia* Buch and Ham) with plant height ranged from 6.0 – 6.5 m and spaced at 6.0 m × 6.0 m in a square system at the Fruit Research Farm, Department of Fruit Science, Punjab Agricultural University, Ludhiana (Latitude, 30º 91′ N; Longitude, 75º 80′ and elevation 247 mean sea level) during the years 2018 and 2019. All pear trees were trained to a modified central leader system and given light annual pruning by removing dead wood and intermingled shoots. The soil of the experimental plot was deep, well-drained Hagerstown silt loam (mixed mesic, Typic Hapludalf) on 1–2% slope with 2.5–3.0% organic matter. Pest and disease control was performed according to the standard management of the region. Two root pruning, three girdling treatments and an untreated control were arranged in a Randomized Block Design with four replicates in each treatment and maintaining single tree unit per replication, making the total number of treatments as six and total trees as twenty-four.

Root pruning and girdling

Two root pruning treatments on pear trees (i) 40 cm away from the trunk at 40 cm depth, and (ii) 60 cm away from the trunk at 40 cm depth in a circumference pattern were performed in the last week of December with the help of a sharp spade during both the years of investigation. Three girdling treatments were performed in the second week of March during both the years of study which comprised girdling of (a) trunk (b) limb and (c) sub-limb done 2 mm deep, 4 mm wide and at 20-25 cm above the uniform soil level. The plants were maintained keeping uniform cultural practices as per the recommendation of Punjab Agricultural University. The grafted bud union was 15 cm above from the ground level and was 50 cm away from the first branch. To avoid the effect of neighboring trees on root pruning treatment, a furrow of 40 cm depth was dig out at 3 m away from the root pruned trees before root pruning treatment.

The effect of different treatments on vegetative growth was observed in terms of shoot length of current year emerged shoots. For measuring shoot length, two primary branches per tree were tagged during the dormant period in December. On these branches, the length of 10 current year emerged shoots was recorded at the end of the growing season and expressed in cm. The similar tagged primary branches were used to observe shoot length for the following growing year.

The fruit set and retention parameters were recorded from the flower bud formation stage till the completion of fruit set and counting the number of fruits retained on the tagged branches. A total of 160 flowers (40 flowers/plant) were tagged to compute the fruit set per cent and retention in each replicate of all the treatments. The fruit set and retention percentage were calculated by using formula:

$$\text{Fruit set (\%)} = \frac{\text{(Number of developing fruitlets) x100}}{\text{Total number of flowers}}$$

$$\text{Fruit retention (\%)} = \frac{\text{(Number of fruits at harvest) x100}}{\text{Number of fruitlets at peanut stage}}$$

At harvest, the total number of fruits per tree was counted and then the total yield (kg/tree) was calculated.

To record the physical and chemical parameters, fruits from each treatment were picked at maturity stage (firmness 57-62 N) during third week of July. The fruit size (fruit length and diameter) and average weight was recorded in a sample of 20 randomly picked fruits. Fruit size was recorded with digital Vernier calipers (Mitutoyo, Japan) and fruit weight was recorded with an electronic precision balance. Fruit firmness was determined by using a stand mounted penetrometer with 8 mm probe (Model no FT-327, QA Supplies LLC, Virginia, USA) on opposite cheeks after removing a slice of peel from the fruit. Total soluble solids (TSS) were determined with digital refractometer (ATAGO, PAL^{-1}, Model 3810, Japan) at room temperature by making subsequent corrections at 20°C. Titratable acidity (TA), in terms of malic acid, was determined by neutralization with 0.1N NaOH till pH raised to 8.1 (AOAC 2019).

The phenol and flavonoid content in pear extracts was determined by following the method described by

Table 1. Effect of girdling and root pruning treatments on vegetative growth of pear cultivar Punjab Beauty

Treatment	Shoot length (cm)	
	2018	2019
Trunk girdling	32.45^{d}	29.17^{bc}
Limb girdling	33.78^{c}	30.85^{bc}
Sub-limb girdling	34.67^{b}	31.67^{b}
Root pruning at 40 cm from trunk	33.56^{c}	30.65^{bc}
Root pruning at 60 cm from trunk	30.45^{e}	28.56^{c}
Control	37.98^{a}	39.54^{a}

Different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test.

Sethi *et al.* (2013). The activity of polyphenol oxidase in pear fruit was determined by using the Garcia-Palazon*et al*.(2004) method with little modification.

Dried and ground healthy bark samples were subsequently used to determine the total carbohydrate and nitrogen content. The total carbohydrates content in bark and spur were estimated as per method described by Dubois *et al.*(1956). Nitrogen content was analyzed by using Kel Plus Nitrogen Estimation System (Pelican Equipments, India) on dry weight basis. The C:N ratio was calculated by dividing total carbohydrate content to the nitrogen content. The data from the two years was analyzed statistically by using ANOVA, software SAS (Version 9.3 for Windows). Statistical significance was determined at p≤ 0.05. When the analysis was statistically significant, Tukey's HSD test was performed. A correlation test using Pearson's correlation coefficient was conducted to evaluate the associations among all the attributes.

RESULTS AND DISCUSSION

Shoot length

The girdling and root pruning reduced the shoot length of the pear trees when compared to control (Table 1). Significantly higher reduction in shoot length during both years was attained with root pruning at 60 cm (30.45 cm and 28.56 cm, respectively) closely followed by trunk girdling. The limb girdling and root pruning at 40 cm also reduced shoot length, even if non-significantly. These two treatments were similar in reducing shoot length. Wang *et al.* (2014) performed root pruning and compared the effect of pruned and non-pruned treatments on pear cultivar 'Conference' and reported maximum reduction in vegetative growth from root pruning treatment. Root pruning causes the growth to be partitioned in favor of the roots resulting in reduced shoot length. It was suggested by Budiarto *et al*.(2019) that root pruning could decrease resource uptake or create a plant hormone imbalance which could adversely affect shoot growth in citrus.

Fruit set, retention and yield parameters

The effect of different girdling and root pruning treatments on fruit set, retention and yield during 2018 and 2019 presented in Table 2 indicates that all the yield contributing attributes (fruit set and fruit retention) were higher in the treated trees when compared to control. Among the different treatments tried, root pruning at 60 cm significantly increased the fruit set during the year 2018 (9.19%) and 2019 (9.03%) when compared to control. Also, there was a significant difference in fruit set attained by trunk girdling and root pruning at 60 cm treatments. The fruit

Table 2. Effect of girdling and root pruning treatments on fruit set, fruit retention and yield of pear cultivar Punjab Beauty

Treatment	Fruits set (%)		Fruit retention (%)		Yield (kg/tree)	
	2018	2019	2018	2019	2018	2019
Trunk girdling	7.43^{b}	9.83^{a}	76.80^{c}	83.62^{a}	56.03^{b}	58.24^{b}
Limb girdling	6.89^{bc}	7.64^{cd}	76.07^{c}	80.91^{a}	49.41^{c}	52.17^{c}
Sub-limb girdling	6.72^{bc}	7.36^{cd}	69.24^{d}	70.37^{c}	44.90^{d}	48.01^{d}
Root pruning at 40 cm from trunk	8.76^{a}	8.33^{bc}	79.74^{b}	77.18^{b}	44.20^{d}	46.77^{e}
Root pruning at 60 cm from trunk	9.19^{a}	9.03^{ab}	81.78^{a}	82.96^{a}	58.64^{a}	60.58^{a}
Control	6.09^{c}	6.36^{d}	65.85^{e}	66.83^{d}	40.61^{e}	45.61^{f}

Different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test.

Table 3a. Effect of girdling and root pruning treatments on fruit length and diameter of pear cultivar Punjab Beauty

Treatments	Fruit length (mm)		Fruit diameter (mm)	
	2018	2019	2018	2019
Trunk girdling	80.01[a]	81.60[a]	64.71[a]	62.26[a]
Limb girdling	77.14[b]	79.93[b]	64.47[b]	58.53[b]
Sub-limb girdling	74.58[c]	78.93[c]	62.70[c]	59.66[b]
Root pruning at 40 cm from trunk	72.62[d]	71.20[e]	59.20[f]	55.86[cd]
Root pruning at 60 cm from trunk	72.75[d]	71.33[e]	60.10[e]	54.26[d]
Control	73.08[d]	76.63[d]	60.39[d]	56.03[c]

Different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test.

retention was significantly higher with root pruning at 60 cm and it was 81.78% and 82.96% during 2018 and 2019, respectively. Furthermore, trunk girdling, limb girdling and root pruning at 40 cm also increased fruit retention significantly compared to the control and the other treatments.

The fruit yield of pear cultivar 'Punjab Beauty' was significantly affected with various girdling and pruning treatments during both the years of experiment. As compared to untreated plants, a significant higher fruit yield during the year 2018 (58.64 kg/tree) and 2019 (60.58 kg/tree) was recorded with the root pruning at 60 cm treatment over control (40.61 and 45.61 kg/tree). This was closely followed by the trunk girdling and limb girdling, while root pruning at 40 cm and sub limb girdling did not exhibit significant differences when compared with other treatments as well as control. Results of the present study regarding high fruit set due to root pruning at 60 cm corroborates with the earlier findings of Jana (2016) and Raja *et al.*(2018) in Asian and Chinese sand pear, respectively. They suggested that root pruning stimulated root regeneration, its activity and cytokinin production resulting in enhanced sink activity.

Fruit physical properties

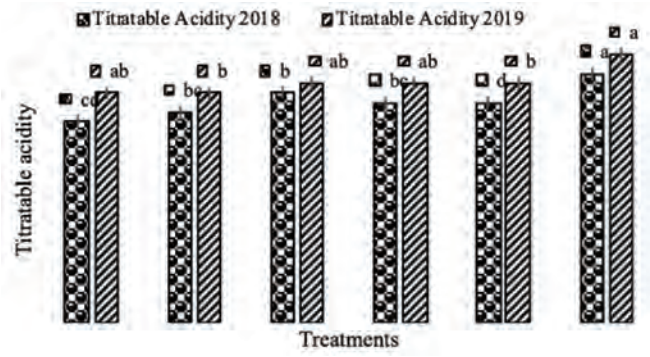
Fruit size, weight and fruit firmness

The fruit size (length and diameter) varied significantly in response to the girdling and root pruning treatments (Table 3a). The girdling treatments increased the length and diameter of pear fruits as compared to the control as well as root pruning treatments. On the basis of two years of the study, significantly higher fruit length (80.01 mm) and diameter (64.71 mm) was registered with trunk girdling treatment than the control and the rest of the treatments. Singh *et al.* (2016) reported that the increased fruit size due to girdling in pear cultivar 'Punjab Beauty' was possibly due to translocation of assimilates towards the developing fruits. It is established that girdling creates interruption of phloem transport and increases the supply of assimilates to the area above the girdled portion. Similar trend was followed by fruit weight, where girdling treatments exhibited significant increase, while the root pruning treatments reduced fruit weight when compared with the control. The maximum fruit weight in 2018 (170.09 g) as well as in 2019 (171.52 g) was observed in the trunk girdling treatment. An increase in fruit weight due to girdling may be because of increased availability of photosynthates and less competition among the developing fruits (Meitei *et al.,* 2013).

The effect of different girdling and root pruning treatments on fruit firmness during 2018 and 2019 is presented in Table 3b. As compared to control, various girdling and root pruning treatments reduced the firmness of pear fruits. Among the different treatments applied, the minimum fruit firmness was recorded in trunk girdling (52.54 N and 51.38 N) followed by limb girdling treatment (53.42 and 51.16 N) during the years 2018 and 2019, respectively. However, root pruning did not have a significant effect on the fruit firmness. While, the maximum fruit firmness 59.53 N and 58.86 N was recorded in control during 2018 and 2019, respectively. The present results showed the conformity with the findings of Kaur *et al.* (2019) and Lata *et al*. (2014) who reported that girdling decreased fruit firmness in peach cultivar 'Shan-i-Punjab' and plum cultivar 'Satluj purple', respectively.

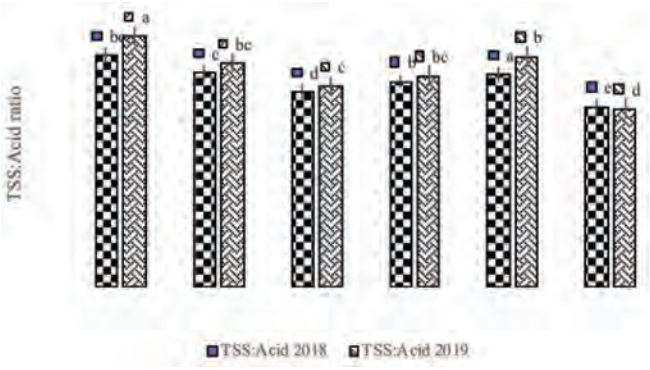
Fruit biochemical traits

A perusal of the two years data with respect to the juice quality attributes viz; TA, TSS and TSS:Acid ratio (Fig. 1, 2a and 2b) of pear fruit reveals a significant variation in these parameters with the different treatments applied. In 2018, the application of trunk girdling resulted in significantly high TSS (10.04º Brix) as compared to control (9.38 º Brix) and the other treatments. Likewise, trunk girdling significantly reduced the fruit TA (0.25%) compared to control and other treatments but it was similar to limb girdling. The TSS/ Acid ratio differed significantly with different treatments, it being maximum with trunk girdling (40.16 and 43.53) followed by root pruning at 60 cm (36.85 and 39.96) and minimum in control (31.26 and 30.91) during 2018



Vertical bars represent the standard error of the mean of four replicates and different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test. TG-Trunk girdling, LG- limb girdling, SLG-sub-limb girdling, RP 40-root pruning at 40 cm from trunk, RP 60 cm- root pruning at 60 cm from trunk.

Fig. 1. Effect of girdling and root pruning treatments on fruit titratable acidity per cent of pear cultivar Punjab Beauty

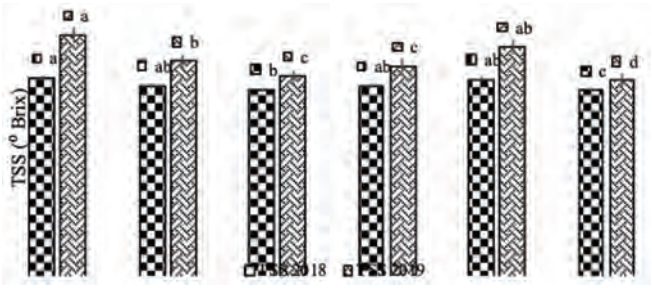


Vertical bars represent the standard error of the mean of four replicates and different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test. TG-Trunk girdling, LG- limb girdling, SLG-sub-limb girdling, RP 40-root pruning at 40 cm from trunk, RP 60 cm- root pruning at 60 cm from trunk.

Fig. 2b. Effect of girdling and root pruning treatments on TSS: acid ratio of fruits of pear cultivar Punjab Beauty

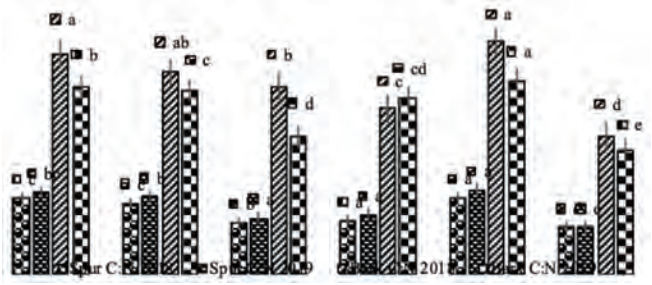
and 2019, respectively. The root pruning treatment also registered significant increase in TSS in the present study which is in line with the prior studies of Carra *et al.* (2017) on Asian pear cultivar 'Shinseiki'. They were of the view that root pruning reduced translocation of water to the fruit at the ripening stage which resulted in an increase in TSS content. An increase in TSS:Acid ratio with the girdling and root pruning treatment has also been reported earlier by Kaur *et al*.(2019) in peach cultivar 'Shan-i-Punjab'.

The effect of girdling and root pruning treatments on the total phenol and total flavonoid content as well as the PPO activity of pear cultivar 'Punjab Beauty' is presented in Table 4. A significantly high phenol content during the year 2018 (31.29 mg GAE/100g FW) and 2019 (31.56 mg GAE/100g FW) was recorded



Vertical bars represent the standard error of the mean of four replicates and different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test. TG-Trunk girdling, LG- limb girdling, SLG-sub-limb girdling, RP 40-root pruning at 40 cm from trunk, RP 60 cm- root pruning at 60 cm from trunk.

Fig. 2a. Effect of girdling and root pruning treatments on TSS content of fruits of pear cultivar Punjab Beauty



Vertical bars represent the standard error of the mean of four replicates and different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test. TG-Trunk girdling, LG- limb girdling, SLG-sub-limb girdling, RP 40-root pruning at 40 cm from trunk, RP 60 cm- root pruning at 60 cm from trunk.

Fig. 3. Effect of girdling and root pruning treatments on bark and spur C:N ratio of pear cultivar Punjab Beauty

with the root pruning at 60 cm treatment than the rest of the treatments. This was closely followed by the trunk girdling treatment. Similarly, non-significant high flavonoid content during 2018 (35.82 mg GAE/100g FW) and 2019 (36.11 mg GAE/100g FW) was registered with the root pruning at 60 cm and it was followed by trunk girdling treatment during both years. The girdling and root pruning treatments significantly reduced the PPO activity as compared to control. Root pruning at 60 cm, resulted in minimum PPO activity during 2018 and 2019. Phenolics are secondary plant metabolites and play an important role in plant defense mechanisms against biotic and abiotic stresses and root pruning triggered the synthesis of phenolic compounds by inducing stress to the plants at the time of harvesting as reported by Asrey *et al.*(2013) in mango cultivar 'Amrapali' and Umar *et al.* (2019) in 'Kinnow' orange. An increase in the fruit flavonoid content in the girdling and root pruning treatments has been also observed in the present study. The flavonoids have diverse

Table 3b. Effect of girdling and root pruning treatments on fruit weight and firmness of pear cultivar Punjab Beauty

Treatments	Fruit weight (g)		Fruit firmness (N)	
	2018	2019	2018	2019
Trunk girdling	170.09^{a}	171.52^{a}	52.54^{c}	51.38^{cd}
Limb girdling	166.05^{b}	170.46^{b}	53.42^{c}	51.16^{d}
Sub-limb girdling	150.92^{c}	156.93^{c}	58.50^{ab}	57.65^{ab}
Root pruning at 40 cm from trunk	139.04^{f}	142.81^{f}	58.28^{ab}	57.47^{ab}
Root pruning at 60 cm from trunk	142.36^{e}	147.87^{e}	57.74^{b}	55.46^{abc}
Control	147.42^{d}	151.96^{d}	59.53^{a}	58.86^{a}

Different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test.

beneficial biochemical and antioxidant effects (Donald and Cristobal 2000) and impact color and taste in fruits (Pietta 2000). The increase in flavanols with girdling has also been reported in grapes (Brar *et al.*2008) and wax jambu (Khandaker *et al.,* 2011).

Bark and spur C: N ratio

The bark and spur C:N ratio were higher in the root pruned trees than the girdling treatment and control (Fig. 3). Among the different treatments tried, root pruning at 60 cm increased the spur and bark C:N ratio significantly during the years 2018 (28.46 and 86.07) and 2019 (31.29 and 71.57), respectively. Similarly, both the spur and bark C:N ratio was also in the limb girdling (26.38 and 74.68) in 2018 and (28.74 and 67.98) in 2019 and root pruning at 40 cm trees as compared to control which was due to the higher total carbohydrates and lower nitrogen content. An increase in the bark and spur C:N ratio due to the root pruning and girdling treatment in the present studies is in consonance with the findings of Raja *et al.*(2018) in the Chinese sand pear. They reported maximum C: N ratio in the root pruned trees followed by trunk girdling trees. They were of the opinion that an increase in carbohydrate and nitrogen content from girdling and root pruning treatments was possibly due to blockage of translocation of carbohydrates towards the lower side and their accumulation in the upper parts of the girdled portion.

Correlation analysis

The spur C:N ratio was negatively associated with fruit length and diameter, leading to reduced pear fruit weight. Total phenol and flavonoid content exhibited a negative correlation with activity of Polyphenol oxidase. Pearson's correlation coefficient of PPO with phenol (r = −0.16) and flavonoid content (r = -0.42) revealed negative association. The root pruning treatments triggered the synthesis of phenolic compounds by inducing stress to the plants and initiating preferential biochemical and antioxidant effects leading to consumer desirable color and taste to the fruits as reported by Umar *et al.* (2019) in Kinnow. A negative correlation between shoot length, fruit set and yield suggest that excessive vegetative growth affected the fruit set adversely which led to reduced fruit yield. In the present study, the root pruning and girdling treatments reduced the vegetative growth and improved the fruit set and yield in pear plants. The maximum fruit set percent and yield depends on the availability of photo-assimilates in the developing

Table 4. Effect of girdling and root pruning treatments on total phenolic, total flavonoid content and polyphenol oxidase (PPO) activity of pear cultivar Punjab Beauty

Treatments	Total Phenolic Content (mg GAE/100g pulp)		Total Flavonoid Content (mg CE/100g pulp)		Polyphenol Oxidase (unit min^{-1} g^{-1} fresh weight)	
	2018	2019	2018	2019	2018	2019
Trunk girdling	30.52^{ab}	30.72^{b}	35.81^{ab}	36.07^{a}	15.95^{de}	13.55^{d}
Limb girdling	28.34^{cd}	28.95^{d}	35.47^{c}	35.88^{ab}	16.44^{cd}	17.33^{bc}
Sub-limb girdling	28.11^{d}	28.71^{d}	35.17^{c}	35.72^{ab}	19.86^{ab}	21.22^{a}
Root pruning at 40 cm from trunk	29.47^{bc}	29.68^{c}	35.56^{bc}	35.67^{ab}	18.12^{bc}	19.12^{ab}
Root pruning at 60 cm from trunk	31.29^{a}	31.56^{a}	35.82^{a}	36.11^{a}	12.58^{e}	14.44^{cd}
Control	22.31^{e}	24.64^{e}	34.65^{d}	35.43^{b}	21.67^{a}	22.36^{a}

Different letters in the column represent significant difference at P ≤ 0.05 level by Tukey's HSD test.

Table 5. Pearson's correlation coefficient among selected fruit traits of pear trees treated with girdling and root pruning treatments

Fruit Traits	FS	FR	Yield	FL	FD	FW	Bark C:N Ratio	Spur C:N Ratio	Phenols	Flavonoids	PPO	SL
FS	1											
FR	0.453	1										
Yield	0.795	0.377	1									
FL	0.198	0.611	-0.188	1								
FD	0.296	0.619	-0.047	0.966	1							
FW	0.115	0.730	-0.011	0.901	0.817	1						
Bark C:N	0.502	0.266	0.582	0.049	0.287	-0.156	1					
Spur C:N	0.569	0.040	0.764	-0.343	-0.019	-0.482	0.847	1				
Phenols	0.726	0.424	0.793	0.070	0.290	-0.065	0.940	0.885	1			
Flavonoids	0.580	0.065	0.310	0.422	0.564	0.100	0.553	0.494	0.581	1		
PPO	0.328	-0.176	0.099	0.073	-0.003	0.026	-0.370	-0.48	-0.166	-0.428	1	
SL	-0.182	-0.651	-0.419	0.072	0.068	-0.211	-0.177	-0.101	-0.278	0.538	0.552	1

FS fruit set; FR fruit retention; FL fruit length; FD fruit diameter, FW fruit weight; PPO Polyphenol oxidase; SL shoot length.

flowers; and the positive correlation between bark and spur C:N ratio with fruit set per cent in the present study validated that root pruning and girdling increased the carbohydrate status of bark and spur to enhance fruit set per cent and yield in pear cultivar 'Punjab Beauty'.

Optimizing vigour reduction and its associated benefits in fruit crops can be achieved by integrating agro-horticultural techniques. In the present study, the application of root pruning at 60 cm from the trunk and trunk girdling emerged as an effective treatment for improving fruit yield and quality of pear cultivar 'Punjab Beauty'. Among all the tested treatments of root pruning and girdling, root pruning at 60 cm from the trunk reduced vegetative growth, enhanced fruit quality and yield through improvement of fruit set and fruit retention percent, efficiently. The root pruning at 60 cm from the trunk further improved biochemical attributes of pear fruit viz; TSS, phenol and flavonoid content, bark and spur carbohydrates, whereas, reduced fruit titratable acidity and polyphenol oxidase. In the present study, root pruning and girdling emerge as efficient agro-horticultural techniques for the management of vegetative and reproductive growth of pear and the improvement of yield and fruit quality.

Authors' contribution

Conceptualization of research work and designing of experiments (NK, PPS); Execution of field/lab experiments and data collection (AP); Analysis of data and interpretation (AP, NK, PPS, KG); Preparation of manuscript (AP, NK, PPS, KG).

LITERATURE CITED

AOAC 2019. *Official methods of analysis of the association of analytical chemists*. 21st edn. Inc. Virginia, USA.

Asin L, Alegre S and Montserrat R 2007. Effect of paclobutrazol, prohexadione-Ca, deficit irrigation, summer pruning and root pruning on shoot growth, yield and return bloom in a Blanquilla pear orchard. *Sci Hortic* **113**: 142-48.

Asrey R, Patel V B, Barman K and Pal R K 2013. Pruning affects fruit yield and postharvest quality in mango (*Mangifera indica* L.) cv. Amrapali. *Fruits* **68**:367-80.

Brar H S, Singh Z, Swinny E and Ian C 2008. Girdling and grapevine leaf roll associated viruses affect berry weight, colour development and accumulation of anthocyanins in 'Crimson Seedless' grapes during maturation and ripening. *Plant Sci* **175:** 885–97.

Budiarto R, Poerwanto R, Santosa E and Efendi D 2019.A Review of Root Pruning to Regulate Citrus Growth. *J Trop Crop Sci* **6:** 1-7.

Carra B, Fachinello J C, Abreu E S, Pasa M S, Spagnol D, Giovanaz M A and Silva C P 2017.Control of the vegetative growth of 'Shinseiki' pear trees by prohexadione calcium and root pruning. *Pesqagropec bras Brasília* **52:** 177-185.

Davenport T L 2009. Reproductive physiology. In: Litz RE (Ed) The Mango: Botany Production and Uses, 2nd edition. CAB International, Wallingford, UK, pp. 97-169.

Donald R and Cristobal M 2000. Aktifitas Antioksidan Flavonoid. Oregon State University.

Dubois M, Gilles K A, Hamilton J K, Rebers P A and Smith F 1956 Calorimetric method for determination of sugars and related substances. *Anal Chem* **28:**350- 56.

Garcia-Palazon A, Suthanthagai W, Kajda P and Zabetakis L 2004. The effects of high hydrostatic pressure on β-glucosidase, peroxidase and polyphenoloxidase in red raspberry (*Rubus idaeus*) and strawberry (*Fragaria* × *ananassa*). *Food Chem* **88:** 7-10.

Jana B 2016. Effect of Pruning, strapping, dormancy breaking chemical and irrigation on Asian Pear (*Pyrus pyrifolia*L.) grown under Eastern Plateau of India. *Int J Curr Microbiol App Sci* **5:** 783-91.

Kaur R, Kaur G and Singh A 2019. Impact of chemical thinning with branch girdling on fruit yield and quality of peach (*Prunus persica* L. Batsch) cv. Shan-i-Punjab. *J PharmacognPhytochemSP* **1:** 577-81.

Khandaker M M, Hossain A S, Osman N and Boyce A N 2011. Application of girdling for improved fruit retention, yield and fruit quality in *Syzygiumsama-rangense* under field conditions. *Int J Agric Biol* **13:** 18–24.

Lata S, Kaur H and Bandana 2014. Effect of girdling and thinning on fruit maturity and quality of Satluj Purple plum. *Asian J Adv Basic Sci* **2 (3):** 28-32.

Li C B and Xiao Y 2001. Girdling increases yield of Nuomici litchi. In: Huang H and Menzel C (Eds). Acta Hortic, *International Symposium on litchi, longan and other sapindaceae fruit* **558:**233-35.

Maas F 2008. Strategies to control tree vigour and optimize fruit production in 'Conference' pears. *Acta Hortic* **800:** 139-46.

Meitei S B, Patel R K, Deka B C, Deshmukh N A and Singh A 2013. Effect of chemical thinning on yield and quality of peach cv. *Flordasun. Afr J Agric Res* **8:** 3558-65.

Pietta P G 2000. Flavonoids as antioxidants. *J Nat Prod,***63:** 1035–1042.

Raja R H S, Wani M S, Mushtaq R, Bhat Z A, Malik A R and Javid K 2018. Effect on vegetative growth and reproductive development of Chinese sand pear (*Pyrus pyrifolia*) treated with various growth controlling strategies. *J PharmacognPhytochem* **7:**18-24.

Rademacher W 2004. Chemical regulation of shoot growth in fruit trees. *Acta Hortic* **653:** 29-32.

Rodríguez-Gamir J, Intrigliolo D S, Primmomillo E and Forner-Giner M A 2010. Relationships between xylem anatomy, root hydraulic conductivity, leaf/root ratio and transpiration in citrus trees on different rootstocks. *Physiol Plant* **139:** 159-69.

Sethi S, Singh S, Rudra S G and Kaur C 2013. Protocols for analysis of antioxidants and functional quality in food (Part-I). Indian Agricultural Research Institute, New Delhi; (TB-ICN:112).

Sharma S, Rehalia A S and Sharma S D 2009. Vegetative growth restriction in pome and stone fruits — A review. *Agric Rev* **30:** 13-23.

Singh D, Singh N P, Dhillon W S, and Gill P P S 2016. Improvement in production and fruit quality of semi-soft pear by girdling. *Indian J Hort* **73:** 339-43.

Singh D, Dhillon W S, Singh N P and Gill P P S 2014. Impact of girdling on quality and maturity of patharnakh pear. *Indian J Hort* **71:** 335 – 39.

Sousa R M, Calouro F and Oliveira C M 2008.Influence of trunk girdling on growth and fruit production of 'Rocha'/ BA29. *Acta Hortic* **800:** 319-24.

Umar M, Ahmad S, Tul-Ain Haider S and Naz S 2019. Effect of pruning to improve yield and fruit quality of 'Kinnow' Mandarin plants under high density plantation. *J Hortic Sci Technol* **2:** 85-89.

Wang Y, Travers S, Bertelsen M G, Thorupkristensen K, Petersen K K and Liu F 2014. Effect of root pruning and irrigation regimes on pear tree: growth, yield and yield components. *Hortic Sci* **41:** 34-43.

Webster T 2006. Control of growth and cropping of temperate fruit trees. *Chron Horticult,***46:** 20-26.

Wilkie J D, Sedgley M and Olesen T 2008. Regulation of floral initiation in horticultural trees. *J Exp Bot* **59:** 3215–28.

Yang S, Xing S, Liu C and Du Z 2010. Effects of root pruning on the vegetative growth and fruit quality of Zhanhuadongzao trees. *Hortic Sci* **37:** 14-21.