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Improvement in production and fruit quality of semi-soft pear by girdling

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ABSTRACT

A study was conducted with the objective to improve fruit quality in semi-soft pear and find out the plant part and stage of growth for girdling. In semi-soft pear cultivar Punjab Beauty under sub-tropics of northern India, considerable increase in fruit retention, fruit productivity, fruit weight, size and colour coordinates was noted with girdling treatments, *viz*., trunk girdling (TG), limb girdling (LG) and sub-limb girdling (SLG) applied at flower initiation (FI), 15 days after flower initiation (15 DAFI) and 30 days after flower initiation (30 DAFI) over control. The fruits with best quality attributes in terms of juice, soluble solids content, SSC/ TA ratio, total sugars and low titratable acidity were observed under limb girling performed at 15 DAFI. Girdling treatments also significantly advanced the physiological fruit maturity over the untreated tree.

Key words: Girdling, pear, fruit yield, fruit quality, fruit maturity.

INTRODUCTION

Pear cultivation is gaining popularity in sub-tropical regions due to the availability of low chilling hard, semi-soft and soft-pear varieties. In India, pear cultivation is mainly restricted to Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Tamil Nadu and Sikkim due to requirement of 250 to 1000 chilling hours. Large sized fruits with good keeping quality and advancement in fruit maturity are the main research concerns to boost semi-soft pear production. The major problems faced by the growers predominantly in soft and semi-soft pear cultivation are related to long juvenile phase, erratic and upright growth and a poor fruit set. Therefore, improvement in fruit set, fruit size, yield, quality and maturity have been achieved with the supply of gibberellins and sucrose at full bloom stage in 'Punjab Beauty' pear (Gill *et al*., 7). Girdling technique is also employed throughout the world to reduce juvenility, promotion of flowering and enhancement of fruit set, fruit size, weight and advancement in maturity, and this is well established in grapevines, olives, peaches, nectarines and 'Patharnakh' pear (Singh *et al*., 13). This technique is used to optimise fruit yield and quality that eventually remobilised carbohydrates reserve to improve source-sink modifications (Chalmers, 3). Sousa *et al*. (14) postulated that girdling performed almost three weeks before the fruit harvest did not significantly influence pear fruit quality. Therefore, it is the major apprehension that girdling should be performed at optimum time so that the competition between shoot growth and fruit development for photosynthesis assimilates must be reduced. In view of girdling advantages anticipated for improvement in fruit quality and yield in low chilling semi-soft pear cultivars, the present study was conducted.

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MATERIALS AND METHODS

Girdling treatments were applied on tree branches/ limbs to find out its effect on fruit yield, quality and maturity in 'Punjab Beauty' semi-soft pear cultivar grafted on *Kainth* (*Pyrus pashia* Buch & Ham) and established at the Fruit Research Farm of the University (Latitude, 30° 91' N; Longitude, 75° 80' and elevation, 247 mean sea level). Eighteen- year-old uniform, healthy trees free from pests and diseases were selected for laying out this experiment in factorial Randomised Block Design. Trunk girdling (T_1), limb girdling (T_2), sub-limb girdling (T_3) and control (No girdling) (T_4) treatments were applied at three different stages, *viz*., S_1 = flower initiation (FI), S_2 = 15 days after flower initiation (15 DAFI) and S_3 = 30 days after flower initiation (30 DAFI). Each treatment cum stage combination was replicated four times. The girdling knife used was of 4 mm thickness. The uniform cultural practices were given to all the trees as per recommendation of Punjab Agricultural University. Trees were applied with 50 kg well rotten farm yard manure, 2 kg superphosphate (16.0% P_2O_5) and 1.5 kg muriate of potash (60% K_2O) during December month. However, nitrogen in the form of 1.0 kg urea (46% N) was splitted into two equal halves, where half of the recommended dose was added in early February, *i.e*., before flowering and remaining half in April month after the fruit set. From each tree, ten fruits at optimum physiological maturity were randomly selected for quality evaluation.

Fruit size (length and diameter) was recorded with the help of digital Vernier calipers (Mit., Japan) and fruit weight was recorded with the help of electronic

precision balance. Fruit juice content was determined by weighing the extracted juice. Fruit firmness was measured on opposite sides of each fruit with a hand-held firmness penetrometer (FT-327, USA) using 8 mm stainless steel probe. The external peel colour was determined with Colour Flex spectrophotometer (Hunter Lab Color Flex, Hunter Associates Inc., Reston, VA, USA) expressing *L*, a** and *b** colour values. Soluble solids concentration (SSC) was 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. Total, reducing and non-reducing sugars were estimated using the method suggested by Lane and Eynon (AOAC, 1). Data was analyzed using statistical software SAS 9.3 and the critical difference (CD) at 5% level of probability was worked out for comparing the significant treatment effects.

RESULTS AND DISCUSSION

The fruit set was significantly higher in trunk girdling (T_1) compared to limb girdling (T_2), sub-limb girdling (T_3) and control (T_4) treatments. However, T_2 was statistically significant from T_3 but was at par with the control (T_4) (Table 1). The improvement in fruit set after trunk girdling treatment might be due to the availability of extra assimilates and their redistribution among various sink organs. Primarily fruit set is quantitatively correlated with the carbohydrate availability (Goldschmidt and Huber, 8). Similarly, in apple cultivars 'Ingram' and 'King David', the fruit set was increased by 30 and 90 per cent, respectively with ringing treatments performed at the time of full bloom. Higher fruit retention (81.7%) was observed in T_1 (trunk girdling) followed by 79.5% in T_2 (limb girdling) than the control (73.3%). The girdling treatments performed at various stages (FI, 15 DAFI and 30 DAFI) also significantly improved fruit retention per cent over the control. Maximum fruit retention (79.0%) was noted at stage S_1 followed by S_2 (78.0%) and S_3 (77.0%). At S_1 (FI) stage, the highest retention (83.3%) was noted in trunk girdled trees followed by 80.3 and 78.9% in T_2 and T_3, respectively. Similar trend was also observed in other stages S_2 and S_3. These results are in corroboration with the findings of Looney (10) who reported that increase in auxins content in the girdled region is due to inhibition of their basipetal movement and that considerably reduced the fruit abscission.

Trunk girdling done at 30 DAFI took minimum 79 days to heal perfectly followed by limb girdling (82.4 days) at the same stage (Table 1). Girdling applied at flower initiation (FI) had taken maximum time (92 days) to get entire heal. The initiation of healing occurs with the formation of callus-bridge across the girdled ring and this is needed to avoid permanent tree injury (Fernandez-Escobar *et al.*, 6). Kumar (9) also did not find any detrimental effect of girdling in peach and satisfactory healing had observed in all girdled portions.

Girdling performed on pear trees had improved fruit size (length × breadth) over the control (Table 2), being maximum (6.98 cm × 5.84 cm) in T_2 followed by T_3 (6.77 × 5.70 cm) and minimum (6.13 × 5.25 cm) in T_4 (control). Among different stages, highest fruit size of 6.60 cm (L) and 5.57 cm (B) was observed in S_1 followed by S_2. The fruit weight of 154.0 g was found to be the highest in T_2 (LG) followed by 148.3 g in T_3

Table 1. Effect of girdling on fruit set and retention of semi-soft pear and days taken for girdle healing.

Treatment	Fruit set (%)	Fruit retention (%)				Time taken to heal (days)			
	S_1	Stage			Mean	Stage			Mean
		S_1	S_2	S_3		S_1	S_2	S_3	
T_1 (TG)	6.17[a]	83.3	82.0	80.0	81.7[a]	88.4	77.7	77.0	79.0[a]
T_2 (LG)	4.90[b]	80.3	79.2	79.0	79.5[b]	92.1	81.5	73.6	82.4[b]
T_3 (SLG)	3.87[c]	78.9	77.4	75.8	77.4[c]	97.0	85.3	77.5	86.6[c]
T_4 (C)	5.40[b]	73.3	73.4	73.1	73.3[d]	--	--	--	
Mean	5.08	79.0[a]	78.0[b]	77.0[c]		92.5[c]	81.5[b]	74.0[a]	
LSD ($p \leq 0.05$)									
Treatment (T)	0.66		0.95				1.11		
Stage (S)	-		0.82				1.10		
T × S	-		NS				NS		

TG = Trunk girdling, LG = Limb girdling, SLG = Sub-limb girdling, C = Control, S1 = Flower initiation, S2 = 15 days after flower initiation, S3 = 30 days after flower initiation, NS = Non significant

Table 2. Effect of girdling on fruit size, weight and yield of semi-soft pear.

Treatment	Length (cm)				Breadth (cm)				Weight (g)				Yield (kg/ tree)			
	Stage			Mean	Stage			Mean	Stage			Mean	Stage			Mean
	S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3	
T_1 (TG)	6.57	6.33	6.16	6.35^c	5.44	5.33	5.29	5.35^c	143.3	143.0	137.5	141.3^c	76.0	74.4	71.4	74.0^c
T_2 (LG)	6.85	7.12	6.97	6.98^a	5.83	5.93	5.77	5.84^a	150.9	157.3	153.8	154.0^a	83.9	91.9	87.0	87.6^a
T_3 (SLG)	6.87	6.74	6.69	6.77^b	5.77	5.74	5.60	5.70^b	151.4	148.4	145.1	148.3^b	84.4	80.0	77.9	80.8^b
T_4 (C)	6.09	6.17	6.12	6.13^d	5.22	5.24	5.28	5.25^d	135.2	134.8	137.1	135.7^d	69.2	67.7	69.8	68.9^d
Mean	6.60^a	6.59^{ab}	6.48^c		5.57^a	5.56^{ab}	5.48^c		145.2^{ab}	145.9^a	143.4^c		78.4^{ab}	78.5^a	76.5^c	
LSD ($p \leq 0.05$)																
Treatment (T)	0.17				0.07				1.75				2.02			
Stage (S)	0.09				0.03				1.52				1.75			
T × S	NS				NS				3.04				3.50			

TG = Trunk girdling, LG = Limb girdling, SLG = Sub-limb girdling, C = Control, S_1 = Flower initiation, S_2 = 15 days after flower initiation, S_3 = 30 days after flower initiation, NS = Non significant

(SLG) and minimum (135.7 g) in T_4 (control) but all the girdling treatments were statistically diverse from the control. These results are in agreement with the findings of Sousa *et al.* (14) who reported that girdling procedure of 3 mm thickness applied at petal fall stage to significantly improve fruit size in pear cv. Rocha.

Significantly higher fruit yield (87.6 kg/ tree) was noted in limb girdled trees (T_2) followed by sub-limb girdling (T_3) (80.8 kg/ tree) and trunk girdling (T_1) (74.0 kg/ tree) over the minimum (68.9 kg/ tree) in control (T_4) (Table 2). Impact of girdling practices performed at stages on fruit yield was also statistically significant and it was the highest (78.5 kg/ tree) in S_2 followed by S_1 (78.4 kg/ tree) and S_3 (76.5 kg/ tree). However, S_1 stage was at par with S_2 but significantly different from S_3 stage. The highest fruit yield at different stages was recorded in T_3 at FI, T_2 at both 15 and 30 DAFI stages. The interactions were significant and maximum (91.9 kg/ tree) in T_2S_2 over the other treatment combinations. The increase in fruit yield as a result of girdling treatments is attributed to the substantial improvement in fruit retention and fruit size as evident from Table 1. These results are in agreement with the findings of Raffo *et al.* (11) that trunk girdling was practiced on 'Bartlett' pear to control the tree vigour for the enhancement of fruit yield and size. The trees girdled at sub-limb position had drastically lower fruit firmness than the control. However, T_1, T_2 and T_3 treatments were statistically at par with each other. These results are not in agreement with the observations of Sartori *et al.* (12) that various girdling treatments did not affect fruit firmness in peach cultivar Sentinela.

Trees girdled at sub-limb position had resulted in highest values of '*L**' (58.17), '*b**' (25.52) and '*a**' (-4.15) followed by limb girdling treatment (57.35, 25.19 and -5.00, respectively). Girdling performed on 30 DAFI, effectively improved fruit colour coordinates for '*L**', '*b**' and '*a**' as compared to other stages (Table 3). Higher '*L**' values denotes more lightness in fruit colour, whereas higher '*b**' values showed that fruits had more yellowish tinge as compared to control and '*-a**' values indicated the extent of green colour. Overall, the mean values of '*L**' '*a**' and '*b**' coordinates in each girdling treatment performed at different stages were higher in comparison to the control. The colour development affected by girdling treatments might be due to accumulation of higher carbohydrates above the girdled portion, which acts as a precursor for colouring pigments.

The percentage of juice content was maximum (57.7%) in control and minimum in T_1 (53.6%) whereas, T_2 and T_4 as well as T_1 and T_3 were statistically non-significant (Table 4). Trees girdled at 15 DAFI had higher juice content of 56.0 per cent than stage FI (55.6 %) and 30 DAFI (55.1 %) where S_1 and S_2 were statistically at par with each other but S_2 was significantly different from S_3. Limb girdling treatments produced fruits with higher soluble solids content, *i.e.*, 11.8% followed by 11.5% in sub-limb girdled and minimum (10.6%) in control. Whereas, T_2 treatment was statistically at par with T_1 and T_3 but all these differ significantly from control. Girdling performed at S_2 stage recorded significantly maximum (11.5%) SSC followed by 11.4% at stage S_1. The fruits with highest (11.7%) SSC was produced at the stage S_1 in T_3 (SLG) followed by 11.6 per cent in T_2 (LG) and 11.5 per cent in T_1 (TG). At stage S_2, T_2 resulted in highest (12.1%) juice SSC, which was followed by both T_3 and T_1 (11.5%). Stage S_3 also followed same trend as noted in stage S_2. Arakawa *et al*. (2) also reported a significant increase in SSC due to girdling in apple fruits.

The lowest (0.23%) juice titratable acid content was recorded in limb girdling followed by 0.25 per

Table 3. Effect of girdling on fruit firmness and peel colour of semi-soft pear.

Treatment	Firmness (lbs/cm^2)				Colour coordinates											
					*L**				*a**				*b**			
	Stage			Mean	Stage			Mean	Stage			Mean	Stage			Mean
	S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3	
T_1 (TG)	6.25	6.46	5.62	6.11^{abc}	56.26	55.96	57.92	56.71	-5.35	-5.17	-5.00	-5.17	24.67	24.63	25.82	25.04^{ab}
T_2 (LG)	5.73	6.05	5.67	5.82^{ab}	57.50	56.65	57.91	57.35	-5.52	-4.83	-4.65	-5.00	25.08	24.75	25.74	25.19^{ab}
T_3 (SLG)	5.71	5.10	5.82	5.54^{a}	57.77	59.57	57.19	58.17	-4.83	-4.58	-4.06	-4.15	25.30	26.36	24.92	25.52^{a}
T_4 (C)	7.10	7.50	7.88	7.49^{c}	54.93	54.63	53.82	54.46	-5.05	-5.21	-5.64	-5.30	23.84	23.75	23.35	23.64^{c}
Mean	6.20	6.28	6.25		56.61	56.70	56.71		-5.18	-4.94	-4.84		24.72	24.87	24.95	
LSD (p ≤ 0.05)																
Treatment (T)	1.47				NS				NS				1.28			
Stage (S)	NS				NS				NS				NS			
T × S	NS				NS				NS				NS			

'*L**' is lightness coefficient, '*-a**' describes the 'greenness' and '*+b**' the 'yellowness'

Table 4. Effect of girdling on juice per cent and chemical attributes in semi-soft pear.

Treatment	Juice (%)				SSC (%)				Titratable acidity (TA) (%)				SSC/TA ratio			
	Stage			Mean	Stage			Mean	Stage			Mean	Stage			Mean
	S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3	
T_1 (TG)	54.3	54.0	52.5	53.6^{c}	11.5	11.5	11.3	11.4^{abc}	0.26	0.25	0.25	0.25^{b}	44.0	45.9	45.0	45.0^{bc}
T_2 (LG)	55.1	57.3	56.0	56.1^{ab}	11.6	12.1	11.8	11.8^{a}	0.24	0.23	0.23	0.23^{a}	48.5	52.6	51.4	50.8^{a}
T_3 (SLG)	55.6	54.7	54.6	55.0^{bc}	11.7	11.5	11.3	11.5^{ab}	0.24	0.25	0.26	0.25^{b}	48.9	46.0	43.6	46.2^{b}
T_4 (C)	57.5	58.0	57.5	57.7^{a}	10.8	10.8	10.1	10.6^{d}	0.25	0.26	0.30	0.27^{c}	43.0	41.7	33.6	39.4^{d}
Mean	55.6^{ab}	56.0^{a}	55.1^{b}		11.4^{ab}	11.5^{a}	11.1^{c}		0.25	0.25	0.26		46.1	46.6	43.4	
LSD (p ≤ 0.05)																
Treatment (T)	2.44				0.60				0.01				3.06			
Stage (S)	0.65				0.11				NS				NS			
T × S	NS				NS				NS				NS			

TG = Trunk girdling, LG = Limb girdling, SLG = Sub-limb girdling, c = Control, S_1 = Flower initiation, S_2 = 15 days after flower initiation, S_3 = 30 days after flower initiation, NS = Non significant

cent in trunk and sub-limb girdling as compared to maximum in control (Table 4). The girdling treatments notably increased assimilate supply to the fruits and substantially advanced fruit maturity and reduced juice acid contents. These results were in line with the findings of Chanana and Gill (5), who found that girdling + thinning treatments applied 15 days after full bloom in peach cultivar Florda Prince decreased acidity by as compared to the control.

Limb girdling resulted in highest juice SSC/TA ratio *i.e.*, 50.8 followed by 46.2 in SLG and minimum (39.4) in the control (Table 4). Fruits with the highest total sugars, reducing sugars and non-reducing sugar were observed in T_2 (LG) in comparison to other girdling treatments. However, among various girdling stages statistically higher mean total sugars was recorded at S_2 stage as compared other two stages. The results corroborated the findings of Chanana and Beri (4) who found that juice sugar components were increased due to girdling intervention. Fruit maturity was advanced by 6 to 8 days in girdled 'Punjab Beauty' soft pear trees and maximum earliness of 8 days was recorded in sub-limb girdling followed by 7 days in limb girdling over the control (Table 5). Girdling performed on 15 DAFI (S_2) and 30 DAFI (S_3) were statistically different from each other but S_2 was at par with S_1. The fruits under T_3S_2 and T_1S_3 matured earlier, *i.e.*, 131.4 and 131.7 days, respectively. The advancement in fruit maturity through elimination of sink competition in girdled trees is attributed to translocation of accumulated photosynthetic assimilates towards the developing fruits.

In conclusion, based on various girdled tree parts at different stages, limb girdling performed after 15 DAFI was the best for enhancing fruit yield

Table 5. Effect of girdling on fruit sugar concentrations and maturity of semi-soft pear.

Treatment	Total sugars (%)				Reducing sugars (%)				Non-reducing sugars (%)				Maturity (days)			
	Stage			Mean	Stage			Mean	Stage			Mean	Stage			Mean
	S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3		S_1	S_2	S_3	
T_1 (TG)	7.44	7.43	6.73	7.19^{b}	5.55	6.22	4.77	5.51^{bc}	1.80	1.15	1.86	1.60^{b}	134.4	136.8	131.7	134.3^{b}
T_2 (LG)	7.90	8.61	8.21	8.24^{a}	5.75	5.72	5.77	5.75^{a}	2.04	2.60	2.32	2.32^{a}	133.2	133.9	132.7	133.2^{a}
T_3 (SLG)	8.03	7.78	7.73	7.84^{ab}	5.59	5.66	5.70	5.65^{ab}	2.32	2.01	1.93	2.09^{ab}	132.9	131.4	133.4	132.6^{a}
T_4 (C)	6.44	6.43	6.46	6.45^{c}	5.33	5.44	5.3	5.36^{c}	1.05	0.94	1.10	1.03^{c}	139.9	140.2	140.4	140.2^{c}
Mean	7.45^{a}	7.56^{a}	7.28^{b}		5.55^{b}	5.76^{a}	5.38^{c}		1.80^{a}	1.69^{b}	1.80^{a}		135.1^{ab}	135.6^{b}	134.3^{a}	
LSD ($p \leq 0.05$)																
Treatment (T)	0.71				0.19				0.52				0.92			
Stage (S)	0.15				0.05				0.09				0.80			
T × S	NS				NS				NS				1.60			

TG = Trunk girdling, LG = Limb girdling, SLG = Sub-limb girdling, c = Control, S_1 = Flower initiation, S_2 = 15 days after flower initiation, S_3 = 30 days after flower initiation, NS = Non significant

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