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Effect of Girdling on Yield and Quality of Kiwifruit (*Actinidia deliciosa* Chev.) Raised through Different Propagation Methods

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***Abstract*:** The present investigation entitled "Effect of girdling on yield and quality of kiwifruit (*Actinidia deliciosa* Chev.) raised through different propagation methods was carried out during 2019-20 at Dr. YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh. Ten years old vines of uniform size and vigour, planted at 4.0 m × 6.0 m spacing were selected for the study. There were twelve treatment combinations. The experimental plants were raised through three different modes of propagation *viz.*, *in situ*, grafting and own rooted (cuttings) which were planted in different sections of experimental orchard. Four different girdling levels namely; full (100% girdling), 1/2 (50% girdling), 1/4 (25% girdling) and no girdling were applied to the experimental vines. The grafted kiwifruit vines girdled upto 1/4 (25%) trunk girth by removing 2 mm bark in the last week of March exhibited best performance in terms of improvement in flower and yield parameters namely; number of flowers per shoot, per cent fruit set, number of fruits per shoot, total yield and graded yield.

***Keywords*:** Kiwifruit, Girdling, Propagation, Quality, Yield

The kiwifruit (*Actinidia deliciosa* Chev.) belonging to the family, Actinidiaceae is the most recent fruit crop grown and marketed successfully in the world (Shastri et al 2012) and native to Yangtze River valley of northern China and Zhejiang Province on the coast of eastern China. In the World, the major kiwifruit producing countries are China, Italy, New Zealand and Chile. China is the leading kiwifruit producing country with an annual production of 1.39 million tonnes, followed by Italy with 0.41 million metric tonnes and New Zealand with 0.32 million tonnes (FAO 2020). In India, this fruit is successfully grown in Arunachal Pradesh, Nagaland, Mizoram, Sikkim, Himachal Pradesh and Uttrakhand. The area under kiwifruit in India is reported to be 5,000 ha with the production of 13,000 MT (NHB 2019). Himachal Pradesh produced 254 MT of kiwifruit from an area of 145 ha (Anonymous 2018).

The kiwifruit is propagated either through grafting onto the seedling rootstock or semi-hardwood or hardwood cutting to ensure production of true type plants (Hamdi et al 2006). *In situ* propagation technique ascertain the purity of the variety and gives certainty of quality planting material and also minimizes other problems like transportation, wastage of time and mental stress of the farmers. Cutting is very useful method of propagation for production of kiwifruit and it is more quick and cheap because plants grown on their own roots and eliminate the rootstock for grafting (Baber et al 2018).

Girdling involves removal of a strip of bark from the trunk or major limbs of a fruit tree, thereby blocking the downward translocation of photosynthates and other metabolites through the phloem. Trunk girdling temporarily increases the availability of carbohydrates to the developing fruit through disruption in the source sink relationship (Black et al 2012). Mineral elements namely; nitrogen, phosphorus, potassium, calcium, and magnesium are stored in the leaves through girdling which can break off the phloematic flow. The positive effect of girdling on the fruit size and yield via improvement of photosynthates supply towards developing fruits has been well documented for grape, peach, nectarine, citrus, mango, avocado, olive, and persimmon (Assar et al 2009). The objective of the present study is to elucidate the comparative performance of kiwifruit plants raised through different propagation methods and to elucidate the effect of girdling on the yield and quality of kiwifruit.

MATERIAL AND METHODS

The present investigation entitled "Effect of girdling on yield and quality of kiwifruit (*Actinidia deliciosa* Chev.) raised through different propagation methods" was carried out at Dr Y S Parmar UHF, Nauni, Solan, (HP) during the year 2019-2020. The experiment was conducted at an elevation of 1260 m above mean sea level with latitude of 30º 50' North and longitude of 77º11'30" East. The experiment was conducted on 10 years old vines of kiwifruit cv. Allison. The vines were maintained under uniform cultural practices and planted at a spacing of 4m × 6m. The vines were trained on T- bar system. The experiment was laid out according to Randomized Block

Design with 12 treatment combinations (Table 1). In the present study, the experimental plants were raised through three different modes of propagation *viz*., *in situ*, grafting and own rooted (cuttings) which were planted in different sections of experimental orchard. In all, the experimental vines, four different girdling levels namely; full (100% girdling), 1/2 (50% girdling), 1/4 (25% girdling) and no girdling were applied. Girdling of trunk was done during the last week of March at the base with the help of girdling knife. A 2mm of bark was removed in the form of full (100% girdling), 1/2 (50% girdling) and 1/4 (25% girdling).

Leaf area index was calculated as the ratio of the leaf surface (one side only) of a plant to the ground area occupied by the plant (Chen and Cihlar 1995). Leaf area measured in the field using LP-80 PAR/LAI ceptometer in the month of July to first week of August. The girth of experimental kiwifruit vines was measured in cm above the ground level by using measuring tape before start of the experiment and then at the end of growing period. The carbohydrate contents of leaf and shoot were determined as per the method described by Thimmaiah (2006). Carbohydrate content was estimated by drying samples and weighing 100 mg then crushed in pestle and mortar, and taken in boiling tube. It was then hydrolyzed by keeping it on boiling water bath for 3 hours with an addition of 5 ml of 2.5 N HCL. The sample solution was cooled to room temperature. After cooling, it was neutralized by adding solid sodium carbonate until effervescence ceased. Then, the final volume was made to 100 ml by adding distilled water and centrifuged. One ml of supernatant was taken in the test tube for analysis and 4 ml of the anthrone reagent was added to it and mixed well by vortexing. The mixture was heated for 8 minutes in boiling water bath. The contents were cooled rapidly and the intensity of green to dark green colour was measured at 630 nm using UV-VIS spectrophotometer. The yield of fruits under each treatment was determined on the basis of weight of crop load removed from each vine at the time of harvest and expressed as kilogram per vine (kg/vine).The fruits harvested from vines were categorized into three grades on the basis of fruit weight. These grades were A grade (> 80 g), B grade (50-80 g) and C grade (< 50 g). The per cent of different grade fruits per vine was calculated by using the following formula:

$$\text{Per cent yield of grade 'X'} = \frac{\text{Yield of grade X (kg/vine)}}{\text{Total yield (kg/vine)}} \times 100$$

Where, 'X' = Grade A or B or C

The fruit samples were collected for physico-chemical analysis when the fruits had attained optimum maturity (TSS > 6.5%). The size of fruit was measured in terms of fruit length and fruit breadth and expressed in millimeters. The total soluble solids content in fruit were determined by Erma hand Refractometer (0-32^0 Brix). The total soluble solids were expressed as per cent. Total sugars and ascorbic acid were estimated by using the standard methods (AOAC 1984). The sugar acid ratio was calculated by dividing per cent total sugars by per cent titratable acidity.

Leaf sampling was done in the second fortnight of August, according to guidelines of Cresswell (1989). From each experimental vine, 30 healthy leaves along with petioles were collected from middle of 5-6 months old new shoots in all the directions. After sampling, leaves were gently washed in running tap water to remove the dirt, soil particles, spray residues and then the leaves were washed with distilled

Table 1. Effect of girdling on the vegetative growth parameters of kiwifruit raised through different propagation methods

Treatment code	Treatment details	Leaf area index	Per cent increase in trunk girth	Number of shoots/cane	Shoot carbohydrate content (%)
T_1	*In situ* + full girdling	2.59	7.12	4.55	2.92
T_2	*In situ* + 1/2 girdling	2.78	7.29	4.75	2.86
T_3	*In situ* + 1/4 girdling	3.11	7.81	5.06	2.65
T_4	*In situ* without girdling	3.90	7.73	5.60	2.33
T_5	Grafted + full girdling	2.61	7.81	4.63	3.25
T_6	Grafted + 1/2 girdling	2.90	8.00	4.96	3.99
T_7	Grafted + 1/4 girdling	3.49	8.16	5.21	4.22
T_8	Grafted without girdling	3.98	8.38	5.66	2.01
T_9	Own rooted + full girdling	2.63	8.58	4.60	4.02
T_{10}	Own rooted + 1/2 girdling	2.97	9.26	4.68	2.86
T_{11}	Own rooted + 1/4 girdling	3.76	9.70	5.50	3.24
T_{12}	Own rooted without girdling	4.10	8.53	5.88	1.94
CD (p=0.05)		0.12	0.54	NS	0.35

water. The washed leaves were put in brown paper bags. The samples were dried in an oven at 60 ± 5°C for nearly 48 hours until reaching at constant dry weight. After drying, samples were ground and sieved to obtain finely ground samples. The samples were analyzed for macro nutrients. For nitrogen estimation, 0.5g dried samples were taken in Kjeldahl flask and digested in 10 ml of concentrated H_2SO_4 in the presence of 1 g digestion accelerator which was prepared by mixing 2.5 g SeO2, 100 g K_2SO_4 and 20 g of $CuSO_4.5H_2O$. In case of phosphorus and potassium one gram of dried leaf sample was digested with 10 ml Di-acid mixture prepared by mixing nitric acid and per chloric acid in a ratio of 4:1 (v/v) (Jackson 1973). The data obtained from these observations were appropriately computed, tabulated and analyzed by applying Randomized Block Design (RBD) as given by (Panse and Sukhatme 2000). The level of significance was tested for different variable at 5 per cent level of significance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Vegetative growth paramerters: The leaf area index (LAI) was significantly influenced by different levels of girdling in kiwifruit vines, raised through different propagation methods (Table 1). The highest leaf area index (4.10) was noticed in the ungirdled own rooted vines which was statistically at par with ungirdled grafted vines whereas, the lowest leaf area index (2.59) was in fully girdled *in situ* vines. The possible reason for reduction in leaf area index with full girdling might be due to the low photosynthetic rate. The results of present study are supported by earlier findings of Richardson et al (2021) who reported that the girdling might create imbalance in the source-sink ratios, transpiration rates and structural properties of the leaves. The decline in photosynthetic rate was also achieved by a decline in photosynthetic capacity under full girdling (Asao and Ryan 2015). Cheng et al (2008) reported that the decrease in the photosynthesis rate after girdling is mainly caused by closing of the stomatal aperture and reduction in RuBP activity per leaf area.

The highest (9.70%) increase in trunk girth was in own rooted vines subjected to 1/4 girdling treatment which was statistically at par with 1/2 girdled own rooted vines. The lowest increase in vine girth (7.12%) was in fully girdled grafted vines. The highest carbohydrate content (4.22%) was observed in shoots of 1/4 girdled grafted vines which was statistically at par with 1/2 girdled grafted and fully girdled own rooted exhibiting 3.99 per cent and 4.02 per cent shoot carbohydrate contents, respectively. The lowest shoot carbohydrate content (1.94%) was observed in ungirdled own rooted vines shown in (Table 1). Girdling expressed a significant accumulation of carbohydrate contents in bearing shoots.

Yield parameters: The highest yield (43.29 kg/vine) was recorded in 1/4 girdled grafted vines which was statistically at par with 1/2 girdled grafted vines. Whereas, the lowest yield (30.38 kg/vine) was recorded in ungirdled own rooted vines depicted in Table 2. The highest proportion of grade 'A' fruits had significantly improved with all the girdling treatments, but more noticeable effect was observed in 1/4 girdled grafted vines which yielded highest proportion (24.24 kg/vine) of 'A' grade fruits, contributing 56 per cent towards total yield. This treatment was closely followed by treatment 1/2 girdled grafted and 1/4 girdled own rooted. The lowest (9.31 kg/vine)

Table 2. Effect of girdling on yield and physical characteristics of kiwifruit raised through different propagation methods

Treatment code	Fruit yield (kg/vine)	Graded yield (kg/vine)			Fruit size (mm)		Fruit weight (g)
		A	B	C	Length	Diameter	
T_1	32.11	9.31	11.24	11.56	61.98	42.27	68.52
T_2	34.10	11.94	9.89	12.28	65.90	41.88	67.36
T_3	36.29	14.15	11.98	10.16	62.46	41.78	67.75
T_4	32.54	13.99	10.09	8.46	65.64	41.39	65.04
T_5	40.05	17.82	12.96	9.72	63.65	42.35	68.86
T_6	42.00	20.58	11.76	9.66	66.58	42.50	68.75
T_7	43.29	24.24	12.99	6.06	66.87	42.87	68.98
T_8	32.49	17.54	8.77	6.17	63.25	41.14	67.62
T_9	31.33	16.60	8.15	6.58	62.62	41.16	63.45
T_{10}	31.65	16.46	7.91	7.28	64.79	41.88	67.36
T_{11}	36.70	18.72	8.81	9.18	65.90	42.28	67.75
T_{12}	30.38	15.19	8.51	6.68	60.46	40.10	61.52
CD (p=0.05)	1.85	0.44	0.52	0.17	1.30	1.06	1.53

yield of 'A' grade fruits was observed with fully girdled *in situ* treatment, which was significantly lower than all other treatments. Highest proportion of 'B' grade fruits (12.99 kg/vine) comprising 30 per cent of the total yield was observed in treatment grafted plants with 1/4 girdling. The minimum yield of 'B' grade fruits (7.91 kg/vine) was recorded in 1/2 girdled own rooted vines. The yield of 'C' grade fruits was reduced significantly with different treatments of girdling. The highest 'C' grade fruits (12.28 kg/vine) contributing 36 per cent of total fruit yield were obtained in 1/2 girdled *in situ*. The lowest yield of 'C' grade fruits (6.06 kg/vine) was with 1/4 girdled grafted treatment. The data on different grade fruits are presented in (Table 2). The results of present study are supported by the earlier findings of Rivas et al (2006) who reported that girdling increased the yield by 28 per cent in 'Fortune' mandarin and 'Clausellina' Satsuma mandarin. Fayek et al (2011) on Le Conte pear found that girdling significantly increased yield comparing with the control. Girdling disrupts basipetal transport in the phloem, which results in the removal of apical dominance and an increase in root-derived cytokinins.

Fruit quality parameters: Different levels of girdling in kiwifruit vines raised through different propagation methods significantly influenced the fruit quality parameters (Table 2. The highest fruit length (66.87 mm) and diameter (42.87 mm) were in the 1/4 girdled grafted vines. whereas, the lowest fruit length (60.46 mm) and diameter (40.10 mm) was with ungirdled own rooted vines, the better solute uptakes and more formation of carbohydrates lead to improve fruit size. The results are also in accordance with Khandaker et al (2011). The highest fruit weight (68.98g) was in 1/4 girdled grafted vines, which was statistically at par with *in situ* + full girdling, *in situ* + 1/2 girdling, grafted + full girdling), grafted + 1/2 girdling), grafted without girdling, and own rooted + 1/4 girdling. However, the lowest fruit weight (61.52g) was observed in ungirdled own rooted vines. The significant increase in fruit weight in girdled vines is attributed to the more assimilates and more availability of carbohydrates to the fruits as a result of which the fruits gained more fruit weight. Kabeel et al (2018) also observed that girdling treatment significantly enhanced the fruit weight in comparison to control.The highest (16.03%) TSS was recorded in 1/4 girdled grafted vines which was found to be statistically at par with (15.30%) 1/2 girdled grafted vines (Table 3). The results of the present study are in accordance with the findings of Hockema and Echeverria (2000). This may be due to the increased photosynthetic rate provided by higher leaf fruit ratio and girdling (Lata et al 2010). The highest titratable acidity (1.55%) was recorded in ungirdled *in situ* vines and the lowest (1.23%) was recorded in 1/4 girdled own rooted vines. The improvement in fruit quality in terms of high TSS and low acidity in the present study could be attributed to accumulation of more carbohydrates above the girdled ring and reduction in inter-fruit competition for water, minerals and other assimilates. The results are in accordance with the findings of Eliwa (2003) and Lata et al (2010). The highest (76.92 mg/100g fruit) ascorbic acid was in 1/4 girdled in fruits from ungirdled own rooted vines which was found to be statistically similar with treatments of fully girdled *in situ* , ungirdled *in situ* , ungirdled grafted vine and fully girdled own

Table 3. Effect of girdling on the chemical characteristics of kiwifruit raised through different propagation methods

Treatment	TSS (%)	Titratable acidity (%)	Ascorbic acid (mg/100g fruit)	Sugars (%)			Sugar acid ratio
				Total sugars	Reducing sugars	Non-reducing sugars	
T_1	14.53	1.47	70.20	11.62	8.37	3.09	7.90
T_2	14.63	1.37	76.92	11.70	8.42	3.12	8.54
T_3	14.56	1.28	71.29	11.64	8.38	3.10	9.09
T_4	12.76	1.55	70.02	10.20	7.34	2.72	6.58
T_5	14.90	1.45	74.67	11.92	8.58	3.17	8.22
T_6	15.30	1.36	74.65	12.24	8.81	3.26	9.00
T_7	16.03	1.26	76.92	12.82	9.23	3.41	10.17
T_8	14.33	1.51	69.33	11.46	8.25	3.05	7.59
T_9	13.16	1.42	69.58	10.52	7.57	2.80	7.41
T_{10}	13.06	1.30	72.17	10.44	7.52	2.77	8.03
T_{11}	13.13	1.23	73.44	10.50	7.56	2.79	8.54
T_{12}	13.90	1.48	69.07	11.12	8.01	2.95	7.51
CD (p=0.05)	1.07	0.28	1.68	0.63	0.75	0.32	1.10

rooted . The positive relationship between girdled and vitamin C content due to less exposure of plant weight with more nutrients. Ascorbic acid is vulnerable to loss as it oxidizes early in the presence of light, heat, oxygen and nutrients. Koshita et al (2011) and Moqhaddam et al (2018) reported that girdling increases ascorbic acid content of fruits. The highest total sugars content (12.82%) and reducing sugars (9.23%)was obtained from 1/4 girdled grafted (T_7) vines and the lowest total sugars (10.20%) and reducing sugars (7.34%)were recorded in fruits obtained from ungirdled *in situ* vines. The increase in sugars contents of fruits in the girdled vines may be due to the increased photosynthetic rate provided by higher leaf fruit ratio and girdling. The results of this study coincide with Chanana and Gill's (2006) findings in peach and Roussos and Tassis (2011) findings in Mandarin. The effect of the 'Patharnakh' pear to girdling under sub-limb girdling was studied by Singh et al (2014).

The highest non-reducing sugars content (3.41%) was in 1/4 girdled grafted vines and the lowest (2.72%) were recorded in fruits from ungirdled *in situ*. The present results are in agreement with Koshita et al (2011) and Rather et al (2011) in litchi and Ahmad et al (2005) in grape. This might be due to the fact that girdling blocked the translocation of sucrose from the leaves to roots through phloem bundles. The temporarily blockage might have resulted in decreased in starch content of the roots and accumulation of sucrose in the leaves which helped to increase sucrose levels in fruits (Ghadage et al 2019).The sugar acid ratio was significantly influenced by different levels of girdling in kiwifruit vines raised through different propagation methods (Table 3). The highest sugar acid ratio (10.17) was reported in 1/4 girdled grafted vines and the lowest sugar acid ratio (6.58) were recorded with ungirdled *in situ* vines. The improvement in sugar acid ratio may be due to the higher accumulation of carbohydrates achieved by higher number of leaves per fruit and girdling of the plants. The findings of present investigation are in accordance with Yesiloglu et al (2000) who reported that girdling application provided earliness by increasing the total soluble solids/ acidity ratio. Ahmad et al (2005) observed that girdling proved most effective in increasing TSS/acid ratio and reducing sugars was also significantly improved.

Leaf macronutrients (N, P, K): The highest leaf nitrogen content (2.45%) in ungirdled own rooted vines. and, the lowest (2.24%) was in 1/4 girdled *in situ* vines (Table 4). The lowest potassium content (2.13%) was with fully girdled grafted vines. Yilmaz et al (2018) found that girdling reduced Photosystem II and leaf chlorophyll concentration. However, they observed a decrease in nitrogen level in the girdled trees.

Table 4. Effect of girdling on the leaf macro nutrients of kiwifruit raised through different propagation methods

Treatment	Leaf macronutrients status (%)		
	Nitrogen	Phosphorus	Potassium
T_1	2.37	0.26	2.23
T_2	2.36	0.24	2.26
T_3	2.24	0.17	2.25
T_4	2.35	0.21	2.17
T_5	2.43	0.22	2.13
T_6	2.41	0.27	2.36
T_7	2.29	0.25	2.43
T_8	2.26	0.29	2.18
T_9	2.30	0.28	2.24
T_{10}	2.42	0.25	2.34
T_{11}	2.34	0.23	2.35
T_{12}	2.45	0.19	2.44
CD (p=0.05)	0.02	0.02	0.04

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