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Effects of Double Girdling Applications on Fruit Yield, Pomological Characteristics and Leaf Carbohydrates of Some Lemon Cultivars

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In present study, the effects of double girdling on fruit yield, pomological characteristics and carbohydrate content of leaves in 'Interdonato, Kibris and M. Mehmet' lemon cultivars were investigated. It was found that the double girdling applications provided 2 times more fruit yield than their controls without disturbing the fruit quality. No significant effect was found on reducing sugar, sucrose, total sugar and starch contents of leaves of girdling in the lemon cultivars except for some periods. It was found that while high level of total carbohydrates in January was not enough on its own to get high yield, double girdling application had a positive effect on the yield by rising the level of total carbohydrates especially in July.

Key Words: Lemon, Carbohydrates, Girdling, Fruit yield, Pomological characteristics.

INTRODUCTION

Girdling consists of removal of a ring of bark from the trunk or scaffold branches. Girdling has been shown to cause accumulation of carbohydrates and particularly starch in tree organs above the girdle[1-4]. It is known that effects of girdling application time and form on citrus tree performance are different. At the full-bloom or at the end of blossoming, girdling improves fruit set and yield[1,4-15]. Also, the girdling applications 1-2 years prior to removal trees can carry out to provide high yield on the trunk in half close and high density planted trees orchard. Autumn girdling enhances differentiation into flower buds[16-20]. Summer girdling increases fruit size[4,18,21-24]. It is also reported that girdling effects the fruit quality and ripening date[1,4,8,17,18,25-30].

The double girdling form have higher healing percentage of girdling than single one. In a previous study, it was found that the single girdling limited vegetative growth significantly which resulted with in high yield in same year, but decreased the yield in the following year in clementine mandarin. Whereas double girdling increased the fruit yield during 3 years because of the faster healing on double girdled trees. The healing percentage of girdling was 85-100 % in double girdled trees and 70-90 % in single ones in January[31].

Synthesis, conversion each other and using of reducing sugar, total sugar, sucrose and starch are different at the vegetative growth, anthesis and dormancy periods of trees. The fruit load, vegetative growing rate, age of trees and climatic factors affect also these carbohydrates[32-36]. Girdling also alters the source-sink relationship of carbohydrates[2,8,37,38].

In this study, the effects of double girdled treatments on the trunk conducted at the end of blossoming on fruit yield, fruit characteristics and carbohydrates in leaves of 'Interdonato, Kibris and Molla Mehmet' lemon cultivars were investigated.

EXPERIMENTAL

All the trees included in this study were 9 years old Interdonato, Kibris and Molla Mehmet lemon (*Citrus limon* (L.) Burm.) cultivars which were grafted on sour orange (*Citrus aurantium* L.) stock. The girdles were carried out with the U-shaped girdling knife. The girdles of double girdling were taken at 15 cm below the scaffold branches junction level and 5 cm above it with about 5 mm width around the bark of the trunk.

The experiment was set up according to randomized plot design with 6 replications and carried out in three successive years. The characters that were investigated are as below:

Fruit yield and fruit characteristics: Fruit yield (kg/tree), cumulative yield (kg/tree), fruit weight (g), fruit length (mm), fruit width (mm), rind thickness (mm), the number of seeds, fruit juice (%), total soluble solid content (TTS), % of titratable acidity (TA) and TTS/TA.

Carbohydrates analyses: Carbohydrates analyses were carried out on leaves collected in early July of the first year and the second year, late January of the second year and the third year.

Anthron method for total sugar and starch analyses and dinitrophenol method for reducing sugar analyses were used[31].

Statistical analyses were done according to randomized plots design with 6 replications.

RESULTS AND DISCUSSION

Effects of the applications on the amount of fruit yields: The girdling at the end of blossoming is known to result in higher yields[1,6,8,10,18,23]. However, the fruit yield values obtained by girdling in this study were very high in 2 successive years.

The effects of applications on fruit yield were given in Table-1. It can be seen from the table that increasing of the fruit yield at all of the cultivars was considered specially in the first year. The differences between trees with double girdling and control trees in terms of fruit yield were statistically important in all cultivars. Girdling applications increased the yield per tree about 2 or 3 times more than control.

TABLE-1
EFFECTS ON FRUIT YIELD OF DOUBLE GIRDLING APPLICATIONS AT LEMON CULTIVARS IN THE FIRST YEAR AND THE SECOND YEAR

Applications	Yield (kg/tree) The first year	Yield (kg/tree) The second year	Cumulative yield (kg/tree)
Interd-C	20.06 a[z]	19.40 a	39.46 a
Interd-DG	39.20 b	37.40 b	76.60 b
Significance level[y]	*	**	**
LSD	11.23	11.00	15.26
Kibris-C	66.86 a	69.83 a	136.69 a
Kibris-DG	166.64 b	102.46 b	269.10 b
Significance level	**	**	**
LSD	57.36	29.35	40.98
M.Meh-C	49.75 a	101.80	151.55 a
M.Meh-DG	159.71 b	100.20	259.91 b
Significance level	**	NS.	**
LSD	35.01	-	31.04

[z]:Values within the columns followed by unlike letters are significantly different by LSD test.
[y]:significance level: *Significant difference at 0.05, **Significant difference at 0.01.
NS.: Not significant. C: Control; DG: Double girdling.

Similar results were also obtained in the second year. Double girdling applications on Interdonato and Kibris cultivars doubled the yield in a comparison to control trees. On the other hand, girdled Molla Mehmet trees provided 3 times more fruit yield in the first year, control trees also gave the similar amount of fruit yield in the second year.

The applications of double girdling were compared with their controls in terms of cumulative yield. It was found that the girdling applications had nearly 2 times more cumulative yield than the controls in all of cultivars. Interd-C and Interd-DG, Kibris-C and Kibris-DG, M.Mehmet-C and M.Mehmet-DG had 30.46 kg and 76.60 kg, 136.69 kg and 269.10 kg, 151.55 kg and 256.91 kg cumulative yields respectively (Table-1).

Effects of the applications on pomological characteristics: As presented in Table-2, in the first year, no statistically important differences were found for pomological characteristics except fruit weight, fruit length, no. of seeds and total soluble solid contents in Interdonato cultivar and fruit weight in Kibris cultivar. Fruits of greater weight were provided at the trees with double girdling applications in Interdonato and Kibris cultivars. Similar result was obtained for fruit length in Interdonato cultivar. The trees having double girdling applications had longer fruit. On the other hand, double girdling application provided less no. of seeds than control in Interdonato cultivar. Fruits with higher juice content were obtained at the trees girdled (Table-2). Similarly, the differences between girdling and control applications in terms of only juice percentage at Interdonato and Kibris cultivars were statistically important in the second year (Table-3). The Interdonato trees with girdling caused

TABLE-2
EFFECTS ON POMOLOGICAL CHARACTERISTICS OF DOUBLE GIRDLING APPLICATION AT LEMON CULTIVARS IN THE FIRST YEAR

Applications	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Rind thick. (mm)	No. of seeds	Juice (%)	TA (%)	TTS (%)	TSS/TA ratio
Interd-C	150.2 a[z]	5.91	8.88 a	3.63	12.61 b	36.65	6.19	8.03 b	1.30
Interd-DG	168.2 b	6.31	9.36 b	3.69	8.72 a	35.78	6.10	7.60 a	1.24
S.L[y]	*	NS.	*	NS.	*	NS.	NS.	**	NS.
LSD	14.68		0.42	-	3.30	-	-	0.37	-
Kibris-C	119.56a	5.85	7.42	4.27	14.09	29.29	7.41	8.77	1.18
Kibris-DG	140.35b	6.10	7.71	4.20	13.68	31.12	7.53	8.69	1.15
S. L.	**	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.
LSD	16.55	-	-	-	-	-	-	-	-
M.Meh-C	105.7	5.54	6.57	5.15	15.72	29.88	7.46	8.10	1.09
M.Meh-DG	102.4	5.44	6.58	5.04	17.47	27.35	7.88	8.10	1.03
S. L	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.

[z]:Values within the columns followed by unlike letters are significantly different by LSD test.
[y]:S.L.(Significance level): *Significant difference at 0.05, **Significant difference at 0.01.
NS.: Not significant.

TABLE-3
EFFECTS ON POMOLOGICAL CHARACTERISTICS OF DOUBLE GIRDLING APPLICATIONS AT LEMON CULTIVARS IN THE SECOND YEAR

Applications	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)	Rind thick. (mm)	No. of seeds	Juice (%)	TA (%)	TTS (%)	TSS/TA ratio
Interd-C	161.1	6.07	8.16	3.47	13.99	37.78 a[z]	6.51	7.56	1.17
Interd-DG	173.0	6.21	8.46	3.51	10.06	32.53 b	6.73	7.56	1.12
S.L.[y]	NS.	NS.	NS.	NS.	NS.	*	NS.	NS.	NS.
LSD	-	-	-	-	-	4.73	-	-	-
Kibris-C	166.2	6.35	8.16	4.70	7.38	31.33 a	7.18	7.48	1.09
Kibris-DG	159.4	6.25	8.05	5.16	8.53	36.44 b	6.76	7.80	1.16
S.L.	NS.	NS.	NS.	NS.	NS.	*	NS.	NS.	NS.
LSD	-	-	-	-	-	4.79	-	-	-
M.Meh-C	120.2	5.82	7.45	4.72	8.76	28.30	7.07	7.70	1.09
M.Meh-DG	120.4	5.95	7.38	5.41	11.36	25.82	7.46	7.96	1.07
S.L.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.

[z]:Values within the columns followed by unlike letters are significantly different by LSD test.
[y]:S.L.(Significance level): *Significant difference at 0.05, NS.: Not significant.

to lower juice percentage (32.53 %) than their control trees (37.78 %), whereas girdled Kibris trees (36.44 %) produced the higher percentage of fruit juice than the control trees (31.33 %). However, the differences between double girdling and control in terms of other external fruit quality were not significant except juice in the second year. Also, many researchers stated that the girdling affected some fruit characteristics such as fruit weight, no of seed, TTS, TTS/TA and fruit juice[5,8,29,30].

Effects of the applications on the levels of carbohydrates in plant leaves: Total sugar, reducing sugar, sucrose, starch and total carbohydrates in leaves are shown in Table-4. No statistical differences were found for total sugar, reducing sugar and sucrose at all of cultivars in early July of the first year and late January of the second year. However, it was found that differences between double girdling applications and their controls in terms of starch and total carbohydrates were statistically important only in early July of the first year. Double girdling applications in Interdonato, Kibris and M.Mehmet cultivars had higher starch levels (10.61, 8.42 and 7.57 %) than their controls (7.41, 5.24 and 5.25 %). Similarly, double girdling applications in these cultivars provided higher total carbohydrates (15.58, 13.96 and 13.48 %, respectively) than their controls (12.18, 10.14 and 11.00 %).

TABLE-4
EFFECTS ON CARBOHYDRATES OF DOUBLE GIRDLING APPLICATIONS AT LEMON CULTIVARS IN EARLY JULY OF THE FIRST YEAR AND LATE JANUARY OF THE SECOND YEAR (%)

Applications	Total sugar		Reducing sugar		Sucrose		Starch		Total carbohydrates	
	July Year 1	Jan. Year 2	July Year 1	Jan. Year 2	July Year 1	Jan. Year 2	July Year 1	Jan. Year 2	July Year 1	Jan. Year 2
Interd-C	4.77	7.94	3.41	1.79	1.29	5.84	7.41 a[z]	3.17	12.18 a	11.10
Interd-DG	4.97	8.75	3.52	1.52	1.38	6.87	10.61b	2.58	15.58b	10.32
S.L.[y]	NS.	NS.	NS.	NS.	NS.	NS.	**	NS.	*	NS.
LSD	-	-	-	-	-	-	2.49	-	2.09	-
Kibris-C	5.30	9.15	3.00	1.62	2.19	7.53	5.24 a	3.99	10.14 a	13.15
Kibris-DG	5.54	9.07	3.14	2.06	2.28	6.84	8.42 b	3.38	13.96b	12.45
S.L.	NS.	NS.	NS.	NS.	NS.	NS.	*	NS.	*	NS.
LSD	-	-	-	-	-	-	2.70	-	1.90	-
M.Meh-C	5.75	9.62	2.86	2.61	2.75	6.73	5.25 a	1.01	11.00 a	10.62
M.Meh-DG	5.91	9.22	3.04	2.17	2.73	6.97	7.57 b	1.56	13.48b	10.38
S.L.	NS.	NS.	NS.	NS.	NS.	NS.	*	NS.	*	NS.
LSD	-	-	-	-	-	-	2.12	-	1.46	-

[z]:Values within the columns followed by unlike letters are significantly different by LSD test.
[y]:S.L.(Significance level): *Significant difference at 0.05, **Significant difference at 0.01, NS.: Not significant. C: Control; DG: Double girdling.

On the other hand, the differences between double girdling and control in respect of total sugar and reducing sugar in Interdonato and M. Mehmet cultivars in early July of the second year were statistically important (Table-5). Interdonato trees which were treated with girdling gave higher total sugar (5.80 %) and reducing sugar (1.33 %) than control trees with no applications (5.20 and 0.96 %, respectively), whereas trees of M. Mehmet with double girdling application had lower total sugar (3.57 %) and reducing sugar (0.29 %) than their controls (4.59 and 0.48 %, respectively).

TABLE-5
EFFECTS ON CARBOHYDRATES OF DOUBLE GIRDLING APPLICATIONS AT LEMON CULTIVARS IN EARLY JULY OF THE SECOND YEAR AND LATE JANUARY OF THE THIRD YEAR (%)

Applications	Total sugar		Reducing sugar		Sucrose		Starch		Total carbohydrates	
	July Year 2	Jan. Year 3	July Year 2	Jan. Year 3	July Year 2	Jan. Year 3	July Year 2	Jan. Year 3	July Year 2	Jan. Year 3
Interd-C	5.20 a [z]	4.63	0.96 a	2.94	4.03	1.61	6.76	5.53	11.96	10.16
Interd-DG	5.80 b	5.18	1.33 b	3.03	4.25	2.05	6.76	6.06	12.56	11.23
S.L. [y]	**	NS.	*	NS.	NS.	NS.	NS.	NS.	NS.	NS.
LSD	0.44	-	0.30	-	-	-	-	-	-	-
Kibris-C	3.84	4.72	0.28	2.60	3.37	2.07	5.81	5.07	9.65	9.79
Kibris-DG	4.00	5.76	0.42	3.03	3.41	2.59	7.22	5.44	11.21	11.20
S.L.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.
LSD	-	-	-	-	-	-	-	-	-	-
M.Meh-C	4.59 b	7.07	0.48 b	4.11	3.90	2.81	6.80	4.80 a	11.40	11.88 a
M.Meh-DG	3.57 a	6.34	0.29 a	3.62	3.35	2.59	6.91	8.82 b	10.48	15.17b
S.L.	*	NS.	*	NS.	NS.	NS.	NS.	**	NS.	*
LSD	0.91	-	0.17	-	-	-	-	3.27	-	2.66

[z]:Values within the columns followed by unlike letters are significantly different by LSD test.
[y]:S.L.(significance level):*Significant difference at 0.05, **Significant difference at 0.01, N.S.: Not significant, C: Control; DG: Double girdling.

In the late January of the third year, the differences between double girdling and control in terms of starch and total carbohydrates were found statistically important only in M. Mehmet cultivar (Table-5). Double girdling application provided higher starch (8.82 %) and total carbohydrates (15.17 %) than their controls (4.80 and 11.88 %, respectively).

Generally, lower total sugar and higher starch in early July were detected. On the contrary, in late January, total sugar in leaves was higher, whereas starch level were lower. Similarly, Some researchers stated that total sugar levels in leaves of lemon and navel orange was maximum in winter months and minimum in summer months, whereas starch content was opposite[34]. The similar results were obtained for Kaula and Nagpuri mandarins and Clementine mandarin by different researchers[31,32].

REFERENCES

1. L.N. Lewis and C.D. McCarty, in ed.: W. Reuther, Pruning and Girdling of Citrus, The Citrus Industry II, Univ. of Calif. Div. Agr. Sci., Berkeley, California, pp. 211-229 (1973).
2. I. Wallerstein, R. Goren and S.P. Monselise, *J. Hort. Sci.*, **48**, 75 (1973).
3. J.H. Ossthuizen and R. Morse, *CSFRI Information Bull.*, **202**, 12 (1992).
4. E.E. Goldschimidt and K.E. Koch, in eds.: E. Zamski and A.A. Schaffer, Citrus, Photoassimilate Distribution in Plants and Crops, Marcel Dekker Inc. New York (1996).
5. A.H. Krezdorn, Factors Affecting the Unfruitfullness of Tangelos, Ann. Rep. Fla. Agr. Exp. Sta., p. 270 (1960).
6. A.H. Krezdorn and W.J. Wiltbank, Annual Girdling of Orlando Tangelos over an Eight Year Period, Proc. Fla. State Hort. Soc., pp. 29-35 (1968).

7. A.H. Krezdorn and A.A. Powell, *Am. Soc. Hort. Sci.*, **13**, 149 (1969).
8. P. Damigella, E. Tribulato and G. Continella, *Tecnica Agricola*, **25**, 508 (1970).
9. G. Cutuli, Influenza dell Acido Gibberellico Sulla Maturaziene dei Frutti de Limone Risultati di un Oandriennio di Prove. Annali Dell' Istituto Sperimentale Per l'Agrumicultura, ¾, 67-77 (1971).
10. R. Goren and S.P. Monselise, *J. Hort. Sci.*, **46**, 435 (1971).
11. A. Vanderweyen and A. Eifali, *Awamia*, **39**, 55 (1971).
12. S.P. Monselise, E.E. Goldschimidt and A. Golomb, *Proc. Int. Soc. Citriculture*, **1**, 686 (1982).
13. J.H. De Lang, O. Skarup and A.P. Vincent, *Sci. Hort.*, **2**, 285 (1974).
14. P. Brosh and S.P. Monselise, *Sci. Hort.*, **7**, 369 (1977).
15. A.D. Shamel and C.S. Pomeroy, *The California Citrograph*, **44**, 80 (1994).
16. R. Hochburg, S.P. Monselise and J. Costot, *Hort. Sci.*, **12**, 228 (1977).
17. A. Cohen, *Proc. Int. Soc. Citriculture*, 196 (1981).
18. A. Cohen, *J. Hort. Sci.*, **59**, 119 (1984).
19. E.E. Goldschimidt, N. Aschkenazi, Y. Herzano, A.A. Schaffer and S.P. Monselise, *Sci. Hort.*, **26**, 159 (1985).
20. H. Inoue and Y. Ikoma, *J. Japanese Soc. Hort. Sci.*, **60**, 285 (1991).
21. M. Fishler, E.E. Goldschimidt and S.P. Monselise, *J. Am. Soc. Hortic. Sci.*, **108**, 218 (1983).
22. Y. Erner, *Israel J. Bot.*, **37**, 173 (1988).
23. M. Agusti, V. Almela and J. Pons, *J. Horticult. Sci.*, **67**, 203 (1992).
24. O. Tuzcu, M. Kaplankiran and T. Yesiloglu, Effects of Girdling Applications on Fruit Yield and Fruit Size in Clementine Mandarin. Proc. Int. Soc. Citriculture, pp. 735-739 (1992).
25. B.S. Chundawat and G.S. Randhawa, *Indian J. Hort.*, **29**, 277 (1972).
26. A. Vanderweyen, *Awamia*, **40**, 9 (1972).
27. A. Cohen, *Proc. Int. Soc. Citriculture*, 178 (1977).
28. S. Iwahori, R. Matsumoto and J.T. Oohata, *Bull. Fac. Agric., Kagoshima Univ.*, **27**, 1 (1977).
29. Y.H. Peng and E. Rabe, *J. Horticult. Sci.*, **71**, 581 (1996).
30. T. Yesiloglu, *J. Fac. Agric., Akdeniz Univ.*, **12**, 37 (1999).
31. T. Yesiloglu, O. Tuzcu, M. Kaplankiran and M. Özsan, *Doga-Turk. J. Agric. Forest.*, **16**, 252 (1992).
32. P.L. Kar and G.S. Randhawa, *Indian J. Hort.*, **25**, 85 (1968).
33. W.W. Jones, T.W. Embleton, E.L. Barnhart and C.B. Cree, *Hilgardia*, **42**, 441 (1974).
34. W.K. Jr. Dugger and R.L. Palmer, Seasonal Changes in Lemon Leaf Carbohydrates, Proc. 1st. Int. Citrus Symposium, Vol. 1, pp. 339-343 (1969).
35. M. Savamura, F. Hashinaga and Y. Osajima, *Nippon Nogei Kagaku Kaishi*, **47**, 571 (1973).
36. E.E. Goldschmidt and A. Golomb, *J. Am. Soc. Hort. Sci.*, **10**, 206 (1982).
37. R.H. Hilgeman, J.A. Dunlap and G.C. Sharples, *Proc. Am. Soc. Hort. Sci.*, **90**, 110 (1967).
38. A.C. Purvis and G. Yelenosky, *Plant Physiol.*, **73**, 877 (1983).

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