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Grafting Height Effects on Lateral Branching, Shoot Angles and Growth of Some Fruit Species Saplings

Hüseyin KARLIDAĞ, Gültünay EREN, Fırat Ege KARAAT, Tuncay KAN

***Abstract* – In order to enhance quality aspects of fruit saplings, four grafting heights (15, 30, 45 and 60 cm above ground) were applied in a study conducted in 2013. Apple (*Malus* x *domestica* Borkh.) cultivars 'Pink Lady' and 'Stark Crimson' were grafted on 'MM106' rootstock, pear (*Pyrus communis* L.) cultivars 'Deveci' and 'Tosca' and quince (*Cydonia vulgaris* L.) cultivar 'Eşme' were grafted on 'BA29' rootstock, sweet cherry (*Prunus avium* L.) cultivar '0900 Ziraat' was grafted on 'Maxma 14' rootstock. Seven growth parameters including sapling height, stem diameter, branching height, shoot number, shoot length, shoot diameter and shoot angle were observed in 2014. According to the results, increasing grafting heights significantly increased sapling height, branching height and number of lateral shoots in all cultivars. Consequently, it was concluded that 45 and 60 cm grafting heights promote lateral shoot formation and growth, so have the potential to be used in production of quality saplings needed for sustainable agriculture and organic systems.**

***Keywords* – Grafting Height, Branching, Growth, Sapling Quality.**

I. Introduction

Plants particularly horticulture section are used by people for food, either as edible products, or for culinary ingredients, for medicinal use or ornamental and aesthetic purposes. They are genetically very diverse group and play a major role in modern society end economy. Fruits and vegetables are an important component of traditional food, but are also central to healthy diets of modern urban population [1, 2, 3, 4].

The main goal of agricultural production is to obtain the highest possible profits. In order to reach this goal larger trees are found more suitable to be grown in traditional orchards since they produce more fruits per tree when compared to dwarfed trees. For that reason, nurseries have produced unbranched saplings called "whips" which is optimum to train trees to a larger habitus [5]. On the other hand, modern fruit growing approach offers to setup orchards with rather dwarfed trees. This way, even though fruit yield decreases per tree, it increases per unit area because of the possibility of denser plantation. Additionally, this approach brings the advantages of higher fruit quality, easier and cheaper cultivation especially for harvest and higher yield at earlier tree age. The quality of the sapling plays a key role to achieve the advantages of those especially early fruit bearing, so nurseries have to adapt their production according to those needs. For this purpose, the most important point to pay attention in production of high quality saplings which are needed by modern fruit growers is that the saplings have to be well-branched instead of unbranched "whips" type of traditional nurseries. The number of lateral branches has a significant importance on desired tree architecture. Besides, the height of lateral branches, position and the angle with the stem are important factors on fertility and early fruit bearing of fruit trees [6, 7, 8]. Although the cultural techniques such as scoring, twisting, deblading, sanding, debudding, notching have been tried to encourage lateral shoot formation, they are usually found unsatisfying [5, 9, 10, 11, 12, 13]. On the other hand, even if chemical stimulation with different growth promoting regulators can positively affect lateral shoot formation of some species, their effects are mostly found insufficient as well [13]. This method is also not suitable for organic production. For all those reasons, as a simple cultural technique to promote lateral shoot formation, modulation of grafting height was used in previous studies and found successful [14]. In this study, the effects of different grafting heights were observed on saplings of apple (*Malus* x *domestica* Borkh.), pear (*Pyrus communis* L.), quince (*Cydonia vulgaris* L.), and sweet cherry (*Prunus avium* L.) cultivars. Thus, the performances of well-branched saplings which are required by modern fruit growers were evaluated.

II. Materials and Methods

The study was conducted on two apple, two pear, one quince and one sweet cherry cultivars grafted on different clonal rootstocks. Apple cultivars 'Pink Lady' and 'Stark Crimson' were grafted on 'MM106' rootstock, pear cultivars 'Deveci' and 'Tosca', quince cultivar 'Eşme' were grafted on 'BA29' rootstock and sweet cherry cultivar '0900 Ziraat' was grafted on 'Maxma 14' rootstock. Four different grafting height (15, 30, 45 and 60 cm above ground) treatments were applied to each cultivar. Each treatment included three replicates with ten plants. Thus, totally one hundred and twenty grafted plants were obtained from each cultivar. Grafting processes were accomplished in the first week of September 2013 with T-budding technique.

Drip irrigation system was used for irrigation. Drip irrigation system is also used for fertigation. There were no nutritional deficiencies and drought stress symptoms observed during the study. Weed control were done before plantation and when required after plantation. Pests and diseases were managed properly.

The parameters of sapling heights (cm), sapling stem diameters (mm) measured 5 cm above the budding union, branching heights measured at the beginning of the first branch from ground level (cm), lateral shoot numbers per sapling, shoot lengths (cm), diameters (mm) of lateral shoots and angles (o) between lateral shoots and sapling stems measured with protractor. The results were collected in 2014 and interpreted with analysis of variance (ANOVA). Duncan's multiple range tests were used for separation of means.

RESULTS AND DISCUSSION

The influences of four grafting heights on various sapling quality parameters were evaluated in different cultivars of apple, pear, quince and sweet cherry. The results showed that different grafting heights had significant effects on all of the parameters evaluated in each species and cultivar. In respect to the apple cultivars the most significant differences were found in branching heights. Increasing grafting heights caused increases in branching heights. The saplings of both apple cultivars which were grafted from 60 cm height showed highest branching (66.43 cm in 'Pink Lady' and 69.58 cm in 'Stark Crimson'). When stem diameter and shoot length were not influenced with grafting height in 'Pink Lady', they were increased by increasing grafting heights in 'Stark Crimson'. The highest stem diameter and shoot length were 2.23 cm and 99.44 cm, respectively and they were obtained from 60 cm grafting height in 'Stark Crimson'. Opposite to stem diameter and shoot length parameters, shoot angle was increased by increasing grafting heights in 'Pink Lady' while not affected in 'Stark Crimson'. The highest shoot angle was 54.95 degrees and observed on the saplings grafted from 60 cm in 'Pink Lady'. The effects of grafting height on sapling height, shoot number and shoot diameter were in a similar way in both apple cultivars. The highest sapling height, shoot number and shoot diameter values were 203.31 cm, 8.44 and 0.70 cm in 'Pink Lady' and 202.39, 2.64 and 1.04 cm in 'Stark Crimson', respectively and all of those were obtained from 60 cm grafting height (table I).

In terms of the pear cultivars, the effects of different grafting heights for sapling height, branching height and shoot angle parameters were found to be similar. The highest values for those parameters were obtained from 60 cm grafting height and the values were 258.45 cm, 63.60 cm, 46.94 degrees for 'Deveci' and 265.19 cm, 73.17 cm, 52.25 degrees for 'Tosca', respectively. The results of shoot number were also increased with increasing grafting heights but the highest number (9.21) was attained from 45 cm grafting height in 'Deveci' while 60 cm grafting height gave the highest shoot number (5.02) in 'Tosca'. Even though shoot length and shoot diameter were not significantly affected by grafting height in 'Tosca', they were increased with increasing grafting heights and 45 cm grafting height gave the highest values (51.35 cm and 0.63) in 'Deveci'. The impact of the grafting height on stem diameter were found to be opposite between the cultivars. While 45 cm grafting height showed the highest stem diameter (2.32 cm) in 'Deveci', the highest stem diameter (2.19 cm) was obtained from 15 cm grafting height in 'Tosca' (table I).

According to the results of quince cultivar 'Eşme' it can be indicated that sapling height, branching height, shoot number and shoot angle were increased while stem diameter was decreased with increasing grafting heights. The highest branching height, shoot number and shoot angle values (68.47 cm, 3.35, 55.04 degrees, respectively) were obtained from 60 cm grafting height and the highest saplings (279.78 cm) were attained on 45 cm grafting height whereas the highest stem diameter value (2.40 cm) was observed on the saplings grafted from 15 cm height. Shoot length and shoot diameter parameters were not significantly affected by different grafting heights in 'Eşme' cultivar (table I).

Increasing grafting heights positively affected sapling height, stem diameter, branching height and shoot number but did not significantly affected shoot length, shoot diameter and shoot angle in sweet cherry cultivar '0900 Ziraat'. While the highest sapling height and stem diameter (266.67 cm and 2.43 cm, respectively) were obtained from the grafting height of 45 cm, the highest branching height and shoot number values (73.73 cm and 3.87, respectively) were observed on the saplings grafted from 60 cm height in '0900 Ziraat' cultivar (table I).

The results of sapling height obtained from apple and pear cultivars were opposite to most of the previous reports [15, 16, 17, 18, 19]. The differences may be caused from cultivars. Hence, [20] showed that heights of 'Vance Delicious' cultivar apple trees increased significantly when they were grafted from 15 cm above ground level when compared to 7.5 cm. Similarly, [21] reported that apple trees of 'Auksis' cultivar budded at 30 cm were found to be taller than those budded at 10 or 20 cm from the ground. For cherry, various results have been reported so far. According to the majority of these results grafting height does not have a significant effect on dwarfing [22]. On the other hand, [23] reported increased tree vigour with higher grafting in sour cherry.

In this present study, the results of shoot length and shoot diameter of apple and pear cultivars were found to be different to majority of the previous reports indicated inverse correlation with growth and grafting height [15, 17, 18, 19]. On the other hand, [24] reported that the linear and radial growth of the scion occurred greater with 15 cm and 25 cm grafting heights compared to a 10 cm grafting height in 'Redspur' apple. The findings on shoot length and shoot diameter of sweet cherry were similar to results of previous studies as most of them reported non-significant effects of grafting heights [25, 26].

Since the effects of grafting height on tree growth and the mechanism of branching have not been proved, there are different explanations about these issues. Common opinion is that the hormonal balance especially between auxins and cytokinins may be responsible for these effects in grafted trees. [27] suggested that the effect might be the result of the longer rootstock portion (shank) exposed to the sun. They suggested that auxins might be involved in the scion growth reduction and auxin transport may be reduced and decomposition is greater in the rootstock bark that was exposed to sun. However, auxins have no direct effects on lateral bud growth because auxins produced in shoot tips are not transported to lateral buds [28, 29, 30]. On the other hand, cytokinins have direct effects on lateral bud growth since cytokinins produced in shoot nodes are transported directly to the lateral buds and cytokinin levels increase significantly in growing lateral buds [28, 29, 30, 31]. The grafting union can reduce the transport of some substances such as hormones (e.g., auxins) from scion to rootstock or vice versa [32]. Depending on this effect, higher levels of cytokinin production may occur in longer rootstock trunks. Consequently, the amounts of cytokinin transported from rootstock to scion may be greater, and higher levels of cytokinin in the scion shoot can promote lateral bud growth [14]. Indeed, number of lateral shoots increased with increasing grafting height.

III. Conclusion

According to results of the present study it can be concluded that grafting height is an effective cultural technique to promote lateral shoot formation which is very important in high quality saplings. The results suggest that tree growth and number of lateral shoots are increased with 45 cm and 60 cm grafting heights in the species and cultivars included in the present study. For this reason, these grafting heights might be used to develop quality of the saplings by promoting growth and lateral branching. Consequently, it can positively affect production of high quality saplings which are required for fruit production in sustainable and organic agricultural systems.

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Authors' Profiles

Hüseyin Karlıdağ
Professor and faculty member of İnönü University, Faculty of Agriculture, Department of Horticulture in Malatya/TURKEY.
E-mail: huseyin.karlidag@inonu.edu.tr (Corresponding author)

Gültünay Eren
Academic Instructor and member of İnönü University, Battalgazi Vocational School in Malatya/TURKEY.
E-mail: gultunay.eren@inonu.edu.tr

Fırat Ege Karaat
Research Assistant and faculty member of İnönü University, Faculty of Agriculture, Department of Horticulture in Malatya/TURKEY. E-mail: ege.karaat@inonu.edu.tr

Tuncay Kan
Assistant Professor and faculty member of İnönü University, Faculty of Agriculture, Department of Horticulture in Malatya/TURKEY.
E-mail: tuncay.kan@inonu.edu.tr

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Table 1. The results of the effects of different grafting heights

Grafting Height	Sapling Height	Stem Diameter	Branching Height	Shoot Number	Shoot Length	Shoot Diameter	Shoot Angle
			Pink Lady				
	***		*	*		***	*
15	181.14 b	2.29 a	25.72 d	4.75 c	52.35 a	0.58 b	46.22 c
30	203.86 ab	2.20 a	37.39 c	7.14 b	53.55 a	0.63 ab	50.24 b
45	215.43 a	2.27 a	53.00 b	8.08 a	58.01 a	0.65 ab	50.59 b
60	203.31 ab	2.36 a	66.43 a	8.44 a	57.16 a	0.70 a	54.95 a
			Stark Crimson				
	**		*	*	*	**	
15	182.64 b	1.94 b	25.11 d	0.82 d	65.89 b	0.78 b	46.19 a
30	180.83 b	2.16 ab	38.00 c	1.19 c	65.33 b	0.85 b	29.10 a
45	179.02 b	2.07 ab	52.28 b	1.97 b	79.87 b	1.04 a	44.42 a
60	202.39 a	2.23 a	69.58 a	2.64 a	99.44 a	1.04 a	48.34 a
			Deveci				
	*	*	*	**	*	**	*
15	216.27 c	2.06 bc	29.65 c	5.20 b	33.44 c	0.48 c	30.74 d
30	241.75 b	1.95 c	33.85 c	8.64 a	40.35 b	0.54 b	37.10 c
45	252.33 ab	2.32 a	49.80 b	9.21 a	51.35 a	0.63 a	43.38 b
60	258.45 a	2.08 b	63.60 a	7.68 a	39.59 b	0.59 a	46.94 a
			Tosca				
	*	***	*	*			
15	223.73 b	2.19 a	28.73 d	3.69 c	48.40 a	0.59 a	47.00 b
30	220.27 b	2.02 ab	43.37 c	3.79 c	52.12 a	0.60 a	49.13 ab
45	226.87 b	1.95 b	57.13 b	4.40 b	45.27 a	0.56 a	51.27 ab
60	265.19 a	2.06 ab	73.17 a	5.02 a	45.47 a	0.57 a	52.25 a
			Eşme				
	*	*	*	*			*
15	246.10 c	2.40 a	22.00 c	1.23 c	94.39 a	0.81 a	40.30 c
30	270.72 b	2.22 b	44.97 b	1.93 b	111.65 a	0.91 a	40.57 c
45	279.78 a	2.31 b	50.92 b	3.13 a	85.25 a	0.82 a	48.77 b
60	266.22 b	2.29 b	68.47 a	3.35 a	93.81 a	0.79 a	55.04 a
			0900 Ziraat				
	**	*	*	*			
15	242.04 b	2.23 b	42.17 d	0.40 c	55.94 a	0.65 a	40.22 a
30	232.77 b	2.04 c	52.17 c	1.27 b	45.02 a	0.53 a	40.19 a
45	266.67 a	2.43 a	66.72 b	3.67 a	62.86 a	0.68 a	40.61 a
60	229.33 b	2.08 bc	73.73 a	3.87 a	53.22 a	0.66 a	40.83 a

*: $P \leq 0.1$; **: $P \leq 0.05$; ***: $P \leq 0.10$