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Effects of Interstock (M9) Length Grafted onto MM106 Rootstock on Sylleptic Shoot Formation, Growth and Yield in Some Apple Cultivars

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ABSTRACT

In this study, branching effects of interstock lengths (15 and 30 cm) of M9 on MM106 rootstock were tested on Golden Delicious and Granny Smith cultivars. In addition, vegetative growth and cumulative yield were determined between 2003 and 2010. The results showed that increased interstock length significantly decreased sapling and tree growth but increased lateral branching in both cultivars. The tallest trees were in the control (176.5 and 186.5 cm) and the shortest trees were in the 30 cm interstock length (147.5 and 162.6 cm) in Golden Delicious and Granny Smith, respectively. The highest number of lateral shoot was obtained from 30 cm interstock length in Golden Delicious (3.67) and Granny Smith (5.33) while there was no lateral shoot formation in the control. The highest cumulative yield was obtained from 30 cm interstock length as 21.77 kg tree⁻¹ in Golden Delicious and 19.18 kg tree⁻¹ in Granny Smith. The results suggested that M9 as an interstock have the potential to induce growth reduction, branching and early fruit bearing especially in sustainable and organic fruit production systems in apple.

Keywords: Dwarf interstock; Feathering; Golden Delicious; Granny Smith; Tree height; Yield

MM106 Anacı Üzerine Aşılı Ara Anaç (M9) Uzunluğunun Bazı Elma Çeşitlerinde Yan Dal Oluşumu, Büyüme ve Verim Üzerine Etkileri

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ÖZET

Bu çalışmada 2003-2010 yılları arasında, MM106 anacı üzerinde 15 ve 30 cm uzunluğundaki M9 ara anacının Golden Delicious ve Granny Smith elma çeşitlerinde fidanın dallanması üzerine etkisi ile vegetatif büyüme ile toplam verim üzerine etkisi belirlenmiştir. Sonuçlar, ara anaç yüksekliğinin artması ile her iki çeşitte fidan ve ağaç gelişiminin önemli ölçüde azaldığını ancak yan dallanmanın arttığını göstermiştir. En uzun ağaç boyu Golden Delicious ve Granny Smith

çeşitlerinin kontrol grubunda sırasıyla 176.5 - 186.5 cm olarak, en kısa ağaç boyu ise aynı çeşitlerde 30 cm'lik ara anaç yüksekliğinde sırasıyla 147.5 cm ve 162.6 cm olarak ölçülmüştür. Kontrolde yan dal oluşumu meydana gelmezken, yan dal sayısı 30 cm'lik ara anaç yüksekliğinde 3.67 (Golden Delicious) ve 5.33 (Granny Smith) bulunmuştur. En yüksek toplam verim, 30 cm'lik ara anaç yüksekliğinden 21.77 kg ağaç⁻¹ (Golden Delicious) ve 19.18 kg ağaç⁻¹ (Granny Smith) elde edilmiştir. Sonuçlar, bodur M9 ara anaçının özellikle sürdürülebilir ve organik elma yetiştiriciliği sistemlerinde büyümeyi azaltıcı, dallanma ve erken meyveye yatmayı ise teşvik etme potansiyelinin bulunduğunu göstermektedir.

Anahtar Kelimeler: Bodur Ara anaç; Dallanma; Golden Delicious; Granny Smith; Ağaç büyüklüğü; Verim

1. Introduction

The goal of modern high-density orchard systems is to achieve high yield at early tree age and control vegetative growth. Thus, growers require dwarfed and well-branched maiden trees for planting in intensive orchards. Scions may be dwarfed by grafting onto dwarfing rootstocks (Webster 1995). However, dwarf rootstocks are poorly anchored and more sensitive to nutrient and water stress since they are shallow rooted. On the other hand, the use of vigorous rootstocks offers some advantages such as higher resistance against drought, longer performance and better anchorage in windy conditions. If planting at high densities on strong seedling rootstocks is desired then vigor reduction is required, and it can be achieved by grafting a dwarf interstem or interstock between the scion and the rootstock. Well-branched maiden tree is also key factor for an early crop and quick economic returns in the orchard. The number of lateral branches provides the opportunity to obtain good tree architecture. In addition, the height, location and the wide angle of laterals provide earlier and higher yields (Barrit 1992; Hrotko et al 1996; Yıldırım & Kankaya 2004). But, not all apple cultivars grown as one-year-old plant are suitable for the establishment of intensive orchards since they do not produce sylleptic shoots i.e. feathers (Bootsma & Baart 1990; Kviklys 2004, 2006). Many scientific studies confirm the effectiveness of interstock to control the vigor of apple trees, and in some cases to induce an early fruiting and to increase efficiency of productivity and fruit quality (Lord et al 1985; Loreti & Morini 1986; Webster 1995; Samad et al 1999; Vercammen et al 2007; Di Vaio et al 2009; Marcon Filho et al 2010).

However, so far there have been a few studies on the effects of interstock on sylleptic shoot formation in apple tree. Therefore, the objective of this study was to examine the effect of different interstock lengths on lateral branching, tree growth, early fruiting and yield in Golden Delicious and Granny Smith apple cultivars.

2. Material and Methods

The experiments were conducted in İspir Technical Vocational School at Ataturk University in İspir, Erzurum, Turkey between 2003 and 2010. Golden Delicious and Granny Smith apple cultivars grafted on M9 interstock/MM106 rootstock were used in the study. Interstocks were grafted on clonal rootstocks at 10 cm height from ground level at the end of summer 2003. Next summer scion woods were grafted on 15 or 30 cm long interstocks. In control (no interstock) the grafts were made only on MM106 rootstocks at 10 cm height from ground level in 2004. All grafted trees were planted in the early spring of 2005, at 4.0 x 3.0 m distances. The plants were fertilized by drip irrigation. Pest and weeds were controlled as needed.

The effects of interstock length were evaluated by measurements of sapling height (cm), stem diameter (5 cm from ground level, mm), branching height from ground level (cm), number of lateral shoot, shoot length (cm) and diameter (mm) in 2005, cumulative yield (kg tree⁻¹) in 2006-2010, and tree height (cm) and canopy diameter (cm) which was measured regarding projection of the widest ends of the tree branches in 2010. The experimental design was completely randomized

design with three replications which consisted of 6 trees in each. A total of 108 plants were used in the study. The data were analyzed by analysis of variance (ANOVA) using SPSS package program (Version 16.0. SPSS Inc., Chicago) and means were separated by Duncan's multiple range test.

3. Results and Discussion

The results showed that interstock length significantly affected branching, growth, early fruiting and yield parameters (Table 1). The interstock length of 30 cm significantly decreased sapling height in both cultivars ($p < 0.05$). The average stem diameter was between 9.7 mm and 10.6 mm in 30 cm length and in the control (no interstock) in Golden Delicious, respectively, while it was between 9.3 mm and 10.2 mm in 30 cm length and in the control in Granny Smith, respectively. The plant height of 5 year old plants were between 147.5 cm and 162.6 cm in 30 cm interstock length and between 176.5 cm and 186.5 cm in control in both cultivars. Similarly, the canopy diameter significantly decreased ($p < 0.001$) by both interstock lengths as compared with the control (Table 1). Significant differences were found between interstock lengths in Granny Smith while there was no significant difference in Golden Delicious. In general, dwarf interstock between scion and more vigorous rootstock decreased sapling and scion growth in both cultivars. These results are in agreement with previous reports by the others (Parry 1986; Richards et al 1986; Samad et al 1999; Wertheim & Webster 2005; Di Vaio et al 2009; Marcon Filho et al 2010). Researchers found that increased interstock length up to 30 cm resulted in smaller trees (Wertheim & Webster 2005). Growth reduction in both sapling and tree could be related to distribution of mineral and plant hormones in whole plant. Rozpara et al (1990), reported that the interstock could modify content of mineral nutrients in the plants. And the reduction of the vegetative growth in these plants could be caused especially by the reduction in potassium content. On the other hand, Richards et al (1986) and Li et al (2012) suggested that dwarf interstock

decreased the transport of plant hormones such as auxins, gibberellins and cytokinins in both rootstock and scion.

There was no branching in the control plants and in Granny Smith plants on 15 cm interstock length. Interstock length of 30 cm resulted in branching at 55.3 cm height in Granny Smith while 15 and 30 cm interstock lengths showed branching at 34.0 cm and 50.7 cm in Golden Delicious, respectively. The number of lateral shoots was significantly increased with 30 cm interstock length as compared to the control in both cultivars ($p < 0.01$). Lateral shoot number was 3.67 in Golden Delicious and 5.33 in Granny Smith at 30 cm interstock length, but none in the control (Table 1). Lateral shoot length and diameter were also significantly affected by interstock length in both cultivars, that 30 cm interstock length resulted 24.7 cm and 4.3 mm in Golden Delicious and in 17.5 cm and 3.4 mm in Granny Smith, respectively ($p < 0.001$).

The effect of interstock on branching is not well known, but could be explained by hormonal balance, especially in auxin and cytokinin in grafted trees. Wickson & Thimann (1958) and Sachs & Thimann (1967) reported that lateral branch development in fruit trees is under the control of a physiological system as named "apical dominance". Both auxin and cytokinin have important roles in apical dominance. The shoot tip and the newly developing leaves on the shoot produce auxin, which is transported in a polar manner down to the new actively growing shoot. This naturally produced auxin inhibits the development of lateral buds located below the active shoot tip. But auxin has no direct effect on lateral bud growth, since auxin not produced by shoot tips are not transported to lateral buds (Leyser 2003; Ongaro & Leyser 2008; Shimizu-Sato et al 2009). At the same time, cytokinin transported from roots and produced at shoot nodes act as bud growth promoters tending to stimulate cell division and growth activity in those newly formed lateral buds. Cytokinin, especially produced by shoot node, is directly transported to lateral buds and it increase at significant levels in growing lateral bud. Cytokinin produced at root

Table 1- Effect of interstem length on branching, tree growth and yield of apple*Çizelge 1- Elmada ara anaç yüksekliğinin dallanma, büyüme ve verim üzerine etkisi*

Interstem length (cm)	Golden Delicious								
	Number of lateral shoot	Branching height (cm)	Sapling height (cm)	Stem diameter (mm)	Shoot length (cm)	Shoot diameter (mm)	Tree height (cm)	Canopy diameter (cm)	Cumulative yield (kg tree ⁻¹)
Control	-	-	106.7 a	10.6 a	-	-	176.5 a	154.9 a	11,38 c
15	0.67 b	34.0 b	108.0 a	10.4 a	10.7 b	2.3 b	156.4 b	110.4 b	16,58 b
30	3.67 a	50.7 a	95.3 b	9.7 b	24.7 a	4.3 a	147.5 b	107.3 b	21,77 a
LSD	2.3**	16.4***	7.96*	0.06*	4.16***	0.95**	13.86***	10.11***	2.21***
Interstem length (cm)	Granny Smith								
	Number of lateral shoot	Branching height (cm)	Sapling height (cm)	Stem diameter (mm)	Shoot length (cm)	Shoot diameter (mm)	Tree height (cm)	Canopy diameter (cm)	Cumulative yield (kg tree ⁻¹)
Control	-	-	107.3 ab	10.2	-	-	186.5 a	153.1 a	7,31 c
15	-	-	119.3 a	14.2	-	-	165.5 b	90.1 c	13,56 b
30	5.33	55.3	91.3 b	9.3	17.5	3.4	162.6 b	113.9 b	19,18 a
LSD	2.01	5.34	19.5***	NS	3.97	0.27	17.3***	16.0***	2.87***

NS, not significant, means separation within column by Duncan's multiple range test; *, P<0.05; **, P<0.01; ***, P<0.001

have less effect on sylleptic shoot formation than the ones produced by shoot node (Leyser 2003; Dun et al 2006; Ongaro & Leyser 2008; Shimizu-Sato et al 2009). Moreover, basipetally moving IAA (Indole-3-acetic acid) prevents cytokinin biosynthesis at the shoot node (Ongaro & Leyser 2008). It is evident that, as shoot growth proceeds, it is the dynamic interaction or balance between endogenous auxin (inhibitors) and cytokinin (promoters) that is thought to play the key role in controlling the fate of lateral buds. Furthermore, graft union can reduce transport of some substances such as hormone from rootstock to scion or vice versa (Wertheim & Webster 2005). Thus, IAA levels in interstock and rootstock trunk may be reduced, which may lead to more cytokinin production at nodes of interstock and rootstock trunk. Therefore, higher cytokinin could be synthesized at higher levels in longer trunk. Consequently, higher cytokinin amounts transported to scion may promote lateral bud growth. In fact, the number of lateral shoot increased by increased

interstock length in our study showing positive relationship.

The results showed that age of fruit bearing and cumulative yield significantly affected by interstock in both cultivars (P<0.001). The trees on interstocks having 15 and 30 cm interstock lengths started to bearing in 2007 but in 2008 in the control (Table 1). The cumulative yield in Golden Delicious and Granny Smith was higher at 30 cm interstock length (21.77 and 19.18 kg tree⁻¹, respectively) than 15 cm interstock length (16.58 and 13.56 kg tree⁻¹, respectively). The yield increase in Golden Delicious and Granny Smith was 91.3% and 162.5% at 30 cm interstock length as compared with the control (11.38 and 7.31 kg tree⁻¹, respectively). Early fruit production in double grafted trees might be resulted from the interaction between vegetative and reproductive growth. Interrelationship between vegetative and reproductive development in fruit trees is well known for a long time and reproductive growth was stimulated by reduced vegetative

growth (Faust 1989; Hartmann et al 1990; Miller & Tworokovski 2003). Our results showed that the increase in the length of interstock resulted in increment in the early fruit bearing and yield. The means reducing vegetative growth encourages dwarfing via photosynthetic effectiveness which is related to the nutrition uptake and phytohormon transportation. Thus, we believe that the effect of interstock length occurred due to nutrition and hormonal system.

4. Conclusions

The results suggest that interstock have a potential to induce branching, growth, early fruit bearing and yield in apples. In both cultivars, early fruit bearing, branching and cumulative yield significantly increased as interstock length increased. Thus, use of long interstock could be suggested for branching and early fruit bearing for especially in sustainable and organic fruit production systems.

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