

Investigation of Some Vegetative and Reproductive Characteristics of Five Apple Cultivars in 'Guttingen V' System

Ahmad Dadashpour*,

Department of Horticulture, University College of Agriculture & Natural Resources, University of Tehran, Karaj, Iran

Sasan Sadegh Hasani,

Department of Horticulture, University College of Agriculture & Natural Resources, University of Tehran, Karaj, Iran.

Seyed Fazel Mirahmadi,

Department of Horticulture, University College of Agriculture & Natural Resources, University of Tehran, Karaj, Iran.

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*Corresponding author's email: dadashpour@can.ut.ac.ir

Orchard intensification is motivated by the desire to produce fruit early in the life of the orchard to rapidly recover establishment costs. Intensification is possible using dwarfing rootstocks that control tree size, induce early cropping and produce large quantities of fruit compared to the amount of wood produced. Therefore, this study attempts to compare some yield and fruit properties of five apple cultivars grown in Karaj, Iran. The concerned apple cultivars were 'Golab-kohans', 'Fuji', 'Starking', 'Delbar estival' and 'Gala' that were grafted on M.9 rootstock which were trained in 'Guttingen V' system. All trees were planted in winter 2005. The trees were irrigated since the second year after planting as drip irrigation. Results showed that 'Golab-kohans' had the highest vegetative traits include TCSA (11.30 cm²), shoot growth (185.30 cm) and tree height (325.32 cm). Also 'Delbar estival' had the highest amount of yield / tree (6.2 kg), yield efficiency (1 kg/cm²) and fruit weight (147.52 g). 'Starking' owned the highest fruit firmness (15.27 kg/cm²), dry matter (32.86 %) and ash (0.82 %). In addition, 'Gala' had the most TSS (16.12), pH (4.02), fruit length (5.79 cm) and fruit diameter (6.68 cm). 'Fuji' had the greatest L/D (0.89), TA (0.74 %) and fruit sunburn (56.23 %).

Abstract

Keywords: Commercial apple cultivar, Intensive orchard system, Vegetative and reproductive characteristics,

INTRODUCTION

In the last 60 years, numerous planting systems for modern orchards have been developed. They all have the goals of high early yields, high sustained yields and superior fruit quality. The move to high planting densities has been driven primarily by the need for early production to pay back the primary investment cost and improve profitability. With most modern high density planting systems, a small but significant yield is expected during the second growing season of the orchard. The second reason for the change in orchard production systems has been the need to reduce tree size to facilitate management. Large trees are costly and hard to prune, spray and harvest. In addition, fruit color is often poor in the center of the canopy of large trees (Ferree and Warrington, 2003).

Small trees of uniform size are the aim for the future so that safer, more efficient spraying practices can be adopted. Trees must be trained and pruned to achieve a manageable uniform size, a balance between growth and regular yields, and to allow good penetration of light and its distribution to the tree centre (Malavolta and Croos, 2009). During planting a grower must make four key decisions about: a) the rootstock, b) the variety, c) the tree spacing and d) the training system. Research on apple trees using dwarf rootstocks in intensive planting systems has been carried out in different countries (Barritt *et al.*, 1995). The switch to smaller trees and higher tree planting densities has allowed significant improvements in fruit quality (Robinson, 2007). Modern orchards planting systems are based on higher tree densities with 1000-6000 tree/ha and some up to 10000 tree/ha (Robinson, 2003). Over the last 25 years, the V systems have become increasingly popular and account for a significant portion of new fruit plantings in developed countries. The first benefit of V systems is high yield/ha (Hutton *et al.*, 1987; Ende *et al.*, 1987; Robinson and Lakso, 1989; Robinson, 1992; Sosna and Czaplicka, 2008), high levels of light interception (Robinson and Lakso, 1991; Widmer, 2005) and improved fruit quality (Ende *et al.*, 1987). Fruit quality is a combination of appearance, flavor, texture and nutritional value. It is affected by pre-harvest factors such as climatic conditions and cultural methods (Licznar, 2006). Orchard trials with V-shaped canopies have shown to be highly productive and highly efficient at converting light energy into fruit (Ferree and Warrington, 2003). Previous study (Strikic *et al.*, 2007) showed that there are significant differences in growth and productivity between local and foreign cultivars in fruits trained to a high density system.

The aim of this study was to evaluation of some vegetative and reproductive traits of five apple cultivars grafted on M.9 in a 'Gutigen V' system that are more cultivated in Karaj climate.

MATERIALS AND METHODS

Plant Material and Experimental Design

The present study was conducted during 2006, 2007 and 2008 at the experimental field of the Horticultural Research Station of the University of Tehran, Karaj, Iran. The results of trials obtained in a 3-year-old apple trees 'Gutigen V' system include 5 cultivars: 'Golab-kohans', 'Fuji', 'Starking', 'Delbar estival' and 'Gala' grafted on dwarfing M.9 rootstock. The average annual maximum temperature of the region is 13.7 °C with an annual rainfall of 254 mm. Soil of the research station was clay-loam. The soil between the rows was mowed, and the strips in the row were fallowed with herbicides. Twenty representative trees in each replication were selected for sampling and data collection. The four replicates were arranged in a randomized completely block design (RCBD). The field and laboratory's data were analyzed using SAS software and the Duncan mean separation test.

Horticultural Traits

TCSA (20 cm above the graft union) was measured with a hand caliper at the end of the growing season in November and then converted to TCSA in cm². Moreover, shoot growth was

measured by average current season growth of 5 branches in each tree (cm). In addition, yield of tree was recorded at harvest time. Yield efficiency was measured as yield per tree divided to TCSA in November, as well.

Fruit Properties

Individual fruit length, diameter and length to diameter ratio (L/D) were measured on 5-fruit random samples from each tree. In fact, fruit length and fruit diameter were measured using a vernier caliper; fruit fresh weight was determined using a Mettler PC 8000 scale; fruit firmness was measured using a penetrometer (Instron Universal Machine, Model 1011). Total soluble solids (TSS) were measured with a Bausch and Lomb Abbe 3L refractometer; juice pH was measured using an Accumet pH meter 925 (Fisher Scientific pittsburgh, PA); dry matter content was determined from fresh and dry weight differences after drying at 70°C for 48 h. 1 g of dry matter was ashed in a Gaallankamp furnace at 550°C for 6 h. Titrable acids (TA) were determined using an Aminex HPX-87H column, run at 65°C and 4 mM sulphuric acid.

RESULTS AND DISCUSSIONS

Tree Height, TCSA and Shoot Growth

In the investigated cultivars, maximum tree height (325.32 cm), shoot growth (185.30 cm) and TCSA (11.30 cm²) were obtained in 'Golab-kohans' that means this cultivar was generally more vigorous than other trees which may be result of a higher degree of shading than other cultivars (Table 1). Short-term shade causes an enhanced retention of assimilates in vegetative sinks, reduction in carbohydrate availability to the fruitlets, limited fruit growth rates and eventually fruit shedding (Byers *et al.*, 1991; Kondo and Takahashi, 1987). In addition, Golab-kohans probably because of its early fruit harvest (the earliest harvested cultivar) had longer period for vegetative growing, resulted in more vegetative characteristics. Also this research implies that trees with the highest vegetative growth generally produce the lowest yield per tree, confirming previous study (Strikic *et al.*, 2007). Tree growth and development can be markedly influenced by both cultivar and rootstock (Hirst and ferree, 1995). Differences in TCSA indicate that rootstock controls the tree size (Dolp and Proebsting, 1989). In fact in this study the rootstock (M.9) has controlled the tree size of 'Delbar estival' more than other cultivars resulted to the lowest TCSA (6.15 cm²) and the greatest yield (6.20 kg) in 2008. Other study also found that scion and rootstock interaction influences the size and attributed rootstock (Hirst and ferree, 1995). Small TCSA produced by 'Delbar estival' may be a genetic trait transferred from the rootstock to the scion.

Yield Characteristics

The first production was obtained one year after planting, but this was relatively poor (data not shown). By the secondary year after planting, the greatest yield per tree (1.48 kg tree⁻¹) and yield efficiency (0.47 kg cm⁻²) were related to 'Delbar estival'. So, the yield ranging was 3.71-6.20 kg tree⁻¹ in 2008 (Table 2). This research showed that trees began to bearing in the second year, with yield increasing in the subsequent year. In fact, the 'V system/M.9' combination permitted early fruiting, confirming previous studies (Platon, 2007; Hampson *et al.*, 2002). In addition, the most TCSA and the lowest yield resulted in the lowest yield efficiency in 'Golab-kohans' (Fig.1a). Although it is assumed that trees on dwarf rootstocks have limited vegetative growth resulting to higher yield (Robinson, 2007) but may be differences between cultivars in this study (with a same rootstock) has been resulted from different morphological traits, according Barritt *et al.*, (1995).

Researches show that yield linearly is related to light interception (Robinson and Lakso, 1989; Robinson, 2007) but the best time for calculating the light interception is in the 4th or more

year (Hampson *et al.*, 2002). Elfving and Schechter (1993) reported that annual yields per tree for 'Starkspur Supreme Delicious' trees on nine dwarfing rootstocks were related linearly to the number of fruits per tree at harvest, independent of rootstock. They concluded that there is a linear relationship between yield and fruit count per tree and suggested that the sink strength of an apple crop is almost proportional to the number of fruit per tree.

According to the results, 'Delbar estival' trees represent a generally more efficient portion, at least in the early stages of orchard life, for apple cultivation using V-shape systems in Iran's climate conditions.

Fruit Weight, Fruit Length, Fruit Diameter and L/D

The maximum fruit weight (147.52 g) was recorded in 'Delbar estival'. The greatest fruit length (5.79 cm) and fruit diameter (6.68 cm) were shown in 'Gala'. The highest L/D (0.89) was recorded in 'Fuji', a good cultivar due to its visual appearance (Table 4). Although fruit number is assumed to be the most relevant component of yield (Derkacz and Norton, 2000), in this case greater yields in 'Delbar estival' trees are not due to a greater number of fruits (data not shown), but it is due to bigger fruits. 'Fuji' had the highest L/D (0.89), i.e., this cultivar has more marketable value than other cultivars although this characteristic is affected by both genetic and environmental factors. L/D (≥ 1) is a criteria for marketing in apple but fruits of this study had L/D < 1 , probably was due to warm nights in Karaj, resulting to insufficient cell elongation at night. Studies have shown that fruit size is smaller on the most dwarfing rootstock and large with the semi-vigorous and vigorous rootstocks such as M.27, M.26, and P.18 (Barritt *et al.*, 1995). The physiological mechanisms by which dwarfing rootstocks affect fruit characteristics can be due to the reduction in transport of nutrients and hormones, especially gibberellins across the scion/rootstock union. In this research the fruits of 'Delbar estival' were affected by the dwarf rootstock (M.9) less than other cultivars, because they resulted in the largest fruits.

TSS, Dry Matter, Firmness and Fruit Sunburn

The highest TSS content in 'Gala' (18) (Table 4) may be explained by differences in leaf area, as suggested by Hudina and Stamper (2002) or by a presumed higher degree of shading for other cultivars (Garriz *et al.*, 1996; Garriz *et al.*, 1998). High exposure of fruit and leaves to light may increase TSS in the fruit compared to fruit that has poor exposure to light (Tustin *et al.*, 1988). 'Starking' had the highest dry matter (32.86 %), thus it can be said this cultivar has the highest organic and mineral materials (Table 4). Total dry matter is related to total light interception (Palmer and Jackson 1974; Monteith, 1977). The highest fruit sunburn percentage (56.23 %) was shown in 'Fuji' due to latest harvesting (Table 4). 'Golab-kohans' and 'Delbar estival' had the lowest fruit sunburn (0%) resulting from an early fruit harvest. The highest (15.27 kg cm⁻²) and the lowest (8.89 kg cm⁻²) firmness were obtained in 'Starking' and 'Delbar estival', respectively (Table 3,4). Firm fruit in 'Starking' may be due to small fruit size, confirming a previous study (Drake *et al.*, 1988). In addition, difference in firmness may have resulted from genetic traits in each cultivar (King *et al.*, 2000).

TA, Ash and pH

The TA content differed among cultivars. In 'Fuji' the average of TA was 0.74, in 'Golab-kohans' 0.43, in 'Delbar estival' 0.37, in 'Gala' 0.35 and in 'Starking' 0.22 (Table 4). In fact, 'Fuji' fruits are the sourest. The greatest ash (0.82 %) was obtained in 'Starking' (Table 4), implying that this cultivar has good nutrition resulting in a higher nutritional value. In this study 'Gala' had the highest pH (4.02); the lowest pH was in 'Starking' (3.28) (Table 4) which may have resulted from morphological differences, confirming a previous study (Platon, 2007). In general, juice pH ranged from 3.39 to 3.99 for the rootstock/cultivar combination. These results

show that acidity generally varies with the cultivar, confirming previous study (Platon, 2007), that may have resulted from lower shading in 'Starking'. These results show that acidity generally varies with cultivar, confirming previous studies (Platon, 2007). According to the results, these cultivars represent a generally more efficient portion, at least in the early stages of orchard life, for apple cultivation using V-shape systems in Karaj's climatic conditions.

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Tables

Table 1. Vegetative traits in 5 apple cultivars trained as Guttingen V system in 2006-2008.

Cultivar	Trunk-cross sectional area			Shoot growth			Tree height		
	TCSA			(cm)			(cm)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Delbar estival	1.43 b	3.14 d	6.15 d	21.03 b	52.83 d	120.34 d	133.56 b	220.38 dc	300.24 c
Starking	1.89 a	4.12 dc	7.10 dc	22.60 b	69.45 c	141.71 c	97.680 bc	208.56 d	285.12 d
Gala	1.83 a	4.78 bc	7.56 bc	20.53 b	74.48 bc	165.31 bc	111.34 bc	242.19 b	312.25 b
Golab-kohans	2.14 a	7.30 a	11.30 a	24.03 a	100.58 a	185.30 a	94.560 c	271.63 a	325.32 a
Fuji	1.83 a	5.32 b	8.43 b	20.53 b	89.77 b	171.10 b	133.73 c	259.25 ab	320.45 ab

Table 2. Yield in 5 apple cultivars trained as Guttingen V system in 2006-2008.

Cultivar	Yield per tree			Yield Efficiency		
	(kg)			(kg/cm ²)		
	2006	2007	2008	2006	2007	2008
Delbar estival	-	1.48 a	6.2 a	-	0.47 a	1.00 a
Starking	-	0.92 b	5.2 b	-	0.22 b	0.73 ab
Gala	-	0.47 bc	4.56 bc	-	0.098 c	0.65 ab
Golab-kohans	-	0.28 c	3.71 c	-	0.03 c	0.32 c
Fuji	-	0.52 bc	4.80 bc	-	0.097 c	0.56 b

Table 3. Fruit properties in 5 apple cultivars trained as Guttingen V system in 2007.

Cultivar	Trait	Fruit Firmness (kg cm ⁻²)	Fruit Weight (g)	Fruit Diameter (cm)	Fruit Length (cm)	L/D	TSS	TA (%)	pH	Dry Matter (%)	Ash (%)	Fruit sunburn (%)
Delbar estival		10.47 b	131.29 a	6.72 a	5.91 a	0.87 a	13.43 c	0.64 ab	3.34 d	16.07 d	0.34 b	0.00 c
Starking		15.82 a	85.71 c	5.72 c	4.62 c	0.79 c	12.23 c	0.72 a	3.60 c	18.08 c	0.40 b	33.83 b
Gala		14.59 a	102.01 b	6.13 b	5.16 b	0.84 b	16.12 a	0.57 b	3.68 b	20.28 b	0.65 a	43.92 ab
Golab-kohans		10.48 b	70.72 d	5.58 c	4.76 c	0.84 b	10.75 d	0.44 c	4.85 a	14.75 e	0.42 b	0.00 c
Fuji		15.13 a	106.12 b	6.17 b	5.10 b	0.82 b	15.24 b	0.69 ab	3.55 c	21.70 a	0.64 a	56.91 a

Table 4. Fruit properties in 5 apple cultivars trained to Guttingen V system in 2008.

Cultivar	Trait	Fruit Firmness (kg cm ⁻²)	Fruit Weight (g)	Fruit Diameter (cm)	Fruit Length (cm)	L/D	TSS	TA (%)	pH	Dry Matter (%)	Ash (%)	Fruit sunburn (%)
Delbar estival		10.24 c	147.52 a	6.47 a	5.56 a	0.85 a	16.72 b	0.37 ab	3.66 c	10.51 b	0.63 ab	0.00 c
Starking		15.27 a	110.43 b	4.36 b	3.50 b	0.77 b	13.92 c	0.22 b	3.28 d	32.86 a	0.82 a	31.58 b
Gala		13.35 b	137.58 ab	6.68 a	5.79 a	0.86 a	18 a	0.35 ab	4.02 a	17.27 ab	0.67 ab	39.21 b
Golab-kohans		8.89 d	108.22 b	6.05 a	5.23 a	0.857 a	11.09 d	0.35 ab	3.65 c	32.63 a	0.45 b	0.00 c
Fuji		13.75 b	123.75 ab	6.14 a	5.35 a	0.89 a	14.16 c	0.74 a	3.80 b	20.80 ab	0.48 b	56.23 a