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Evaluation of Agropomological Properties of Some Commercial Apple Cultivars in an Intensive Planting System in Karaj Climate

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ABSTRACT

Nowadays apple growers tend to use intensive planting systems and dwarfing rootstocks in order to increase yield and decrease production costs. A V-shape system represents an efficient and popular option to increase yield and fruit quality. Hence, this paper attempts to compare some vegetative, yield and fruit properties of five apple cultivars ('Golab-kohans', 'Fuji', 'Gala', 'Starking' and 'Delbar estival') grown at a horticultural research station in Karaj, Iran. The experimental apple cultivars were grafted onto an M.9 rootstock trained in a V system. All trees were planted in the winter of 2005 using drip irrigation. 'Golab-kohans' formed the highest trees (278.63 cm), trunk cross sectional area (7.31 cm^2), mean shoot length (100.58 cm) and pH (4.85). Also 'Delbar estival' had the highest yield (0.98 kg), yield efficiency (0.55 kg/cm^2), fruit weight (131.30 g), fruit length (5.91 cm), fruit diameter (6.72 cm) and L/D (0.87). In addition, 'Fuji' had the highest dry matter (21.71%) and fruit sunburn (56.92%). 'Golab-kohans' had the highest ash (0.66) and TSS (16.12) levels. 'Starking' had the highest fruit firmness (13.60 kg cm^{-2}) and titrable acid (0.73). Consistently, results revealed that among the investigated cultivars, 'Delbar estival' can be introduced as a productive cultivar for the V system in Karaj's climatic condition.

Keywords: dwarfing rootstocks, orchard training systems, V system, vegetative and reproductive characteristics

Abbreviations: L/D, fruit length to diameter ratio; **TA**, titrable acids; **TCSA**, trunk cross sectional area; **TSS**, total soluble solids

INTRODUCTION

At the time of 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 an intensive planting system has been carried out in different countries. Dwarfing rootstocks have become widely accepted by the industry as a tool for increasing orchard efficiency because they influence the size of the tree, yield and planting density per unit area (Barritt *et al*. 1995). 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 spray to the tree centre (Malavolta and Cross 2009). Over the last 30-40 years, several planting systems for apple orchards have been developed to attain high early yields and improved fruit quality (Ferre and Warrington 2003). Modern orchards planting systems are based on higher tree densities with 1000-6000 trees/ha (Robinson 2003). However, increasing planting density alone does not provide an efficient tool to increase yield and improve fruit quality, as planting density and yield are not linearly related and a threshold can be found beyond which a further increase in density may not result in greater yield (Corelli and Sansavini 1989; Weber 2001; Hampson *et al*. 2002). Indeed, with age, high-density orchards may pose serious problems for canopy management and ultimately compromise fruit quality (Jackson 1980; Corelli and Sansavini 1989; Sanasavini and Corelli-Grappadelli 1997; Hampson *et al*. 2002). The Gutingen V is a V-shaped system, with individual conic-shaped trees, that allows high tree densities within multiple rows (Ferree and Warrington 2003). Dwarfing rootstocks, such as M.9 and M.27, are used and trees are planted at 0.9 m in-row spacing and 3.5 m between rows. Over the last 25 years, V systems have been become increasingly popular and account for a significant portion of new fruit plantings in developed countries. The primary advantage of V systems is high yields per hectare due to precocity of the system (Hutton *et al*. 1987; Van Den 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 (Van Den Ende *et al*. 1987). V systems show better light interception than spherical or conic-shaped trees and improve light distribution within the canopy due to their two-dimensional light exposure (Robinson 2003). Early studies indicated that perhaps tree density, percent ground cover, canopy volume or tree surface area may be related to orchard productivity (Robinson and Lakso 1991). Furthermore, several studies on orchard productivity have shown a close correlation between fruit yield and seasonal leaf area (Barritt *et al*. 1995). Studies showed that there was a negative correlation between vegetative and reproductive behavior of two pear cultivars trained to a V-shaped system (Lo Bianco *et al*. 2007). Another study showed that there are significant differences in growth and productivity between local and overseas cultivars in apricot trained to a high density system (Strikic *et al*. 2007).

Thus our objective in this paper was to study the behavior of five apple cultivars grafted onto M.9 in a V system under Karaj's climate.

MATERIALS AND METHODS

Plant material and experimental design

This study was conducted during 2006 and 2007 at the experimental field of the Horticultural Research Station of the University of Tehran, Karaj, Iran. Thus, this paper presents the results of trials carried out in a 2-year-old apple production V system with five

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apple cultivars (‘Golab-kohans’, ‘Fuji’, ‘Gala’, ‘Starking’ and ‘Delbar estival’) grafted onto an M.9 rootstock. The average annual maximum temperature of the region is 13.7°C with an annual rainfall of 254 mm. The soil at the station is classified as clay-loam. Trees were fertilized with soil applications of manure annually and were drip irrigated twice a week during the 2006 and 2007 growth seasons. The soil between the rows was mowed, and the strips in the rows were fallow with the help of a brand-spectrum by Roundup herbicide applied in accordance with standard commercial orchard procedures. Twenty representative trees within each replicate and for each season were selected for sampling and data collection. The four replicates from each cultivar were arranged in a randomized completely block design (RCBD). The data obtained from field measurements and laboratory observations were subjected to an analysis of variance using SAS software and the Duncan’s mean separation was applied at $P < 0.01$.

Vegetative growth indices

For calculating the trunk cross sectional area (TCSA), trunk circumference (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 trunk cross sectional area (TCSA) in cm^2. Moreover, shoot growth was measured by average current season growth of 5 branches in each tree (cm). Also, in order to measure the tree height, distance between graft union to end of highest branch in main trunk was recorded in cm. In addition, yield per tree was recorded at harvest in each tree.

Fruit properties

Individual fruit length, diameter and length to diameter ratio (L/D) were measured on 5 random fruit samples from each test tree. Fruit length and 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 & Lomb Abbe 3L refractometer; juice pH was measured using an Accument 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. Fruit sunburn percentage was measured by eye using the number of sunburned trees. 1 g of dry matter was ashed in a Gaallankamp furnace at 550°C for 6 h. Titrable acids were determined using an Aminex HPX-87H column, run at 65°C using 4 mM sulphuric acid as eluent.

RESULTS AND DISCUSSION

Tree height, TCSA and shoot growth

In the investigated cultivars, the greatest tree height (278.63 cm), shoot growth (100.58 cm) and TCSA (7.31 cm^2) were obtained in ‘Golab-kohans’ indicating that this cultivar was generally more vigorous than other trees, which may be the result of a higher degree of shading than other cultivars, confirming the findings of a previous study (Lobianco *et al.* 2007) (**Table 1**). Short-term shade at the fruit growth period causes an enhanced retention of assimilates in vegetative sinks, reduction in carbohydrate availability to the fruitlets, limited fruit growth rates and eventually fruit shedding (Schnider 1977; Kondo and Takahashi 1987; Lakso *et al.* 1989; Lakso and Corelli Grappadelli 1992). ‘Golab-kohans’ probably had longer period for vegetative growth, resulting in more vegetative characteristics because this cultivar is harvested earliest. Our research implies that trees with the highest vegetative growth generally produce the lowest yield per tree, confirming a 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 tree size (Dolp and Proebsting 1989). In fact, in this study the rootstock (M.9) controlled the tree size of ‘Delbar estival’ more than other cultivars, resulting in the lowest TCSA (3.14) and the greatest yield (1.48 kg). Previous studies also found an interaction between scion and rootstock: size and rootstock were the predominant factors controlling size (Hirst and Ferree 1995). ‘Delbar estival’ produced a small TCSA.

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 (0.55 kg cm^{-2}) were related to ‘Delbar estival’. The yield range was 0.29-1.48 kg $tree^{-1}$ (**Table 1**). ‘Golab-kohans’, ‘Fuji’, ‘Gala’, ‘Starking’ and ‘Delbar estival’ trees grafted onto M.9 began to bear fruit 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 (Hampson *et al.* 2002; Platon 2007). In addition, the highest TCSA and the lowest yield resulted in the lowest yield efficiency in ‘Golab-kohans’ (**Table 1**), although it is assumed that trees on dwarf rootstocks have limited vegetative growth resulting in higher yield (Robinson 2007). However, the differences between cultivars in this study (with the same rootstock) may have resulted from different morphological traits, confirming in a study by Barritt *et al.* (1995). Yield is linearly 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 (Robinson and Lakso 1989; Hampson *et al.* 2002; Robinson 2007). Elfving and Schechter (1993) reported that annual yields per tree for ‘Starkspur Supreme Delicious’ trees on nine dwarfing rootstocks were linearly related 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 fruits per tree.

Fruit weight, fruit length and diameter, and L/D

The highest fruit weight (131.30 g), fruit length (5.91 cm), fruit diameter (6.72 cm) and L/D (0.87) was recorded in ‘Delbar estival’, a good cultivar due to its visual appearance (**Table 2**). 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 to generally due to bigger fruit. ‘Delbar estival’ had the highest L/D (0.87), 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 (e.g. 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 (Matta 2001). 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’ (16.12) (**Table 2**) 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, 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). ‘Fuji’ had the highest dry matter (21.71%), thus it can be said this cultivar has the highest organic and mineral materials (**Table 2**). Total dry matter is

Table 1 Effect of cultivar on vegetative and reproductive parameters.

Cultivars	TCA (cm^2)	Shoot growth 2007 (cm)	Tree height 2007 (cm)	Yield 2007 (kg)	Yield efficiency 2007 (kg/cm^2)
'Fuji'	5.32 b	89.77 ab	259.25 ab	0.53 bc	0.11 c
'Golab-kohans'	7.31 a	100.58 a	278.63 a	0.29 c	0.04 c
'Delbar estival'	3.14 d	52.83 d	220.38 dc	1.48 a	0.55 a
'Gala'	4.78 bc	74.48 bc	242.19 bc	0.48 bc	0.12 c
'Starking'	4.12 dc	69.45 dc	208.56 d	0.93 b	0.32 b

Means separation by Duncan's multiple range test ($P < 0.01$).

Table 2 Effect of cultivar on fruit characteristics.

Cultivars	Firmness (kg/cm^2)	L/D	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit sunburn	TA (%)	TSS	pH	Ash	Dry Matter
'Fuji'	12.21 b	0.82 b	5.10 b	6.17 b	106.12 b	56.91 a	0.69 ab	15.24 b	3.55 c	0.64 a	21.70 a
'Golab-kohans'	9.49 c	0.84 b	4.76 c	5.58 c	70.72 d	0 c	0.44 c	10.75 d	4.85 a	0.42 b	14.75 e
'Delbar estival'	8.05 d	0.87 a	5.91 a	6.72 a	131.29 a	0 c	0.64 ab	12.43 c	3.34 d	0.34 b	16.07 d
'Gala'	12.42 b	0.84 b	5.16 b	6.13 b	102.01 b	43.92 b	0.57 b	16.12 a	3.68 b	0.65 a	20.28 b
'Starking'	13.60 a	0.79 c	4.62 c	5.72 c	85.71 c	33.83 b	0.72 a	12.23 c	3.60 c	0.40 b	18.08 c

Means separation by Duncan's multiple range test ($P < 0.01$).
L/D, length to diameter ratio; **TA**, titrable acids; **TSS**, total soluble solids.

related to total light interception (Palmer and Jackson 1974; Monteith 1977). The highest fruit sunburn percentage (56.92%) was shown in 'Fuji' due to latest harvesting (**Table 2**). 'Golab-kohans' had the lowest fruit sunburn (0%) resulting from an early fruit harvest. The highest (13.60 kg cm^{-2}) and the lowest (8.05 kg cm^{-2}) firmness were obtained in 'Starking' and 'Delbar estival', respectively (**Table 2**). 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 0.69, in 'Golab-kohans' 0.44, in 'Delbar estival' 0.64, in 'Gala' 0.57 and in 'Starking' 0.72 (**Table 2**). In fact, 'Starking' fruits are the sourest. The greatest ash (0.65%) was obtained in 'Gala' (**Table 2**), implying that this cultivar has good nutrition resulting in a higher nutritional value. In this study 'Golab-kohans' had the highest pH (4.85); the lowest pH was in 'Delbar estival' (3.34) (**Table 2**) 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 studies (Lo Bianco *et al.* 2007; Platon 2007), that may have resulted from lower shading in 'Starking'.

These results show that acidity generally varies with cultivar, confirming previous studies (Lo Bianco *et al.* 2007; Platon 2007). 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 Karaj's climatic condition.

REFERENCES

Barritt BH, Konishi AS, Dilley MA (1995) Intensive Orchard Management. Performance of three apple cultivars with 23 dwarfing rootstocks during 8 seasons in Washington. *Fruit Varieties Journal* **49**, 158-170

Corelli L, Sansavini S (1989) Light interception and photosynthesis related to planting density and canopy management in apple. *Acta Horticulturae* **243**, 159-174

Derkacz M, Norton D (2000) Effect of training systems and cultivars on selected yield components in pears. Proceedings of ISHS 8th International Pear Symposium, 4-9 September 2000, Ferrara-Bologna, Italy pp 189-199

Dolp CA, Proebsting EL (1989) Root confinement affect growth and physiology of sweet cherry and apple. *50th ASHS Annual Meeting*, Tulsa, Oklahoma, p 99 (Abstract)

Drake SR, Larsen FE, Fellman JK, Higgins SS (1988) Maturity, storage quality, carbohydrate, and mineral content of 'Gold spur' apples as influenced by rootstock. *Journal of the American Society for Horticultural Science* **116**, 261-264

Elfving DC, Schechter I (1993) Fruit count, fruit weight, and yield relationship in 'Delicious' apple tree on nine rootstocks. *HortScience* **28**, 793-795

Ferree DC, Warrington IJ (2003) *Apples: Botany, Production and Uses*, CABI Publishing, Wallingford, UK, 660 pp

Garriz PI, Alvarez HL, Alvarez AJ (1996) Influence of altered irradiance on fruits and leaves of mature pear trees. *Biologia Plantarum* **39**, 229-234

Garriz PI, Colavita GM, Alvarez HL (1998) Fruit and spur leaf growth and quality as influenced by low irradiance levels in pear. *Scientia Horticulturae* **77**, 195-205

Hampson CR, Quamm HA, Brownlee RT (2002) Canopy growth, yield, and fruit quality of Royal Gala apple trees grown for eight years in five tree training systems. *HortScience* **37**, 627-631

Hirst PM, Ferree DC (1995) Effect of rootstock and cultivar on the growth and precocity of young apple trees. *Journal of the American Society for Horticultural Science* **120**, 622-634

Hudina M, Stamper F (2002) Influence of leaf area on the suger and organic acids content in pear (*Pyrus communis*) fruits cultivar Williams. *Acta Horticulturae* **596**, 749-752

Hutton RJ, Mcfadyen LM, Lill WJ (1987) Relative productivity and yield efficiency of canning peach trees in three intensive growing systems. *HortScience* **22**, 552-560

Jackson JE (1980) Light interception and utilization by orchard systems. *Horticultural Reviews* **2**, 208-267

King GJ, Maliepaard C, Lynn JR, Alston FH, Durel CE, Evans KM, Griffon B, Laurens F, Manganaris AM, Schrevens E, Tartarini S, Verhaegh J (2000) Quantitative genetic analysis and comparison of physical and sensory descriptors relating to fruit flesh firmness in apple (*Malus pumila* Mill.). *Theoretical and Applied Genetics* **100**, 1074-1084

Kondo S, Takahashi Y (1987) Effects of high temperature in the nighttime and shading in the daytime on the early drop of apple fruit 'Starking Dilicious'. *Journal of the Japanese Society for Horticultural Science* **56**, 142-150

Malavolta C, Cross J (2009) Guidelines for integrated production of pome fruits. *IOBC/WPRS Bulletin* **47**, 1-13

Matta FB (2001) Performance of apple cultivar/rootstock combinations grown in Mississippi. *Journal of the Mississippi Academy of Sciences*. Available online: http://www.thefreelibrary.com/Performance+of+Apple+Cultivar%2FRootstock+Combinations+Grown+in...-a077378934

Monteith JL (1977) Climate and efficiency of crop production in Britain. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* **281**, 277-294

Palmer JW, Jackson JE (1974) Effects of tree population and variations in spacing within and between rows on Golden Delicious on M.9. *Report of the East Malling Research Station* **1973**, 66-68

Platon IV (2007) Preliminary results on planting system and density in apple. *Acta Horticulturae* **732**, 471-473

Robinson TL (1992) Performance of Y-shaped apple canopies at various angles in comparison with central leader trees. *Acta Horticulturae* **322**, 79-86

Robinson TL (2003) Apple-orchard planting systems. In: Ferree DC, Warrington IJ (Eds) *Apples*, CABI Publishing, Wallingford, UK, pp 345-407

Robinson TL, Lakso AN (1989) Light interception, yield and fruit quality of Empire and Delicious apple trees in four orchard systems. *Acta Horticulturae* **243**, 175-184

Robinson TL, Lakso AN (1991) Bases of yield and production efficiency in apple orchard systems. *Journal of the American Society for Horticultural Science* **116**, 188-194

Sosna I, Czaplicka M (2008) The influence of two training systems on growth and cropping of three pear cultivars. *Journal of Fruit and Ornamental Plant Research* **16**, 75-81

Strikic F, Radunic M, Rosin J (2007) Apricot growth and productivity in high density orchard. *Acta Horticulturae* **732**, 495-500

Tustin DS, Hirst PM, Warrington IJ (1988) Influence of orientation and position of fruiting laterals on canopy light penetration, yield, and fruit quality of 'Granny smith' apple. *Journal of the American Society for Horticultural Science* **113**, 693-699

Van Den Ende B, Chalmers DJ, Jeri PH (1987) Latest developments in training and management of fruit crops on Tatura trellis. *Journal of the American Society for Horticultural Science* **105**, 695-699

Weber MS (2001) Optimizing the tree density in apple orchards on dwarf rootstocks. *Acta Horticulturae* **557**, 229-234

Widmer A (2005) The development of Guttingen-V, Mikado and Drilling growing systems: An overview. *OBST-UND WEINBAU* **141**, 14-16