International Journal of Horticultural Science 2005, 11 (2): 23–27
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Growth and productivity of a young apple orchard at different spacing

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Summary: Planting of new high density apple orchards showed an increasing tendency over the last ten years. Growers use in those orchards mainly dwarfing or semi dwarfing rootstocks. The spacing for those orchards is recommended based on Dutch and German experiences; however, the optimization of orchard planting density as a key factor for successful orchard management should consider the local climate conditions. An experimental orchard was planted in 2000 to investigate the effect of spacing on three dwarfing rootstocks with two apple cultivars 'Jonica' and 'Gala Must'. We compared 8 planting densities (1270–3704 tree/ha) and two tree shapes (slender spindle and vertical axis). In this paper the data of the first five years' growth and bearing are presented. After 4 years, the decreasing tree densities caused reduced trunk cross sectional area. Tree density had a significant positive effect on cumulative yield per hectare. From the examined rootstocks, M.9 Burgmer 984 gave the smallest canopy for both cultivars. The trees on M.9 T.337 and on Jork 9 rootstocks have stronger growth. The light interception was measured under the canopy by AccuPAR (Decagon Devices Inc.'s).

Key words: apple, rootstocks, planting density, row distance, in-row spacing, efficiency, light interception

Introduction

Planting of new high density apple orchards showed an increasing tendency over the last ten years. Growers use in these orchards mainly dwarfing or semi dwarfing rootstocks. The spacing for these orchards is recommended based on Dutch and German experiences; however, the optimization of orchard planting density as a key factor for successful orchard management should consider the local climate conditions.

Opinions differ on the optimal tree density. For northern Europe, it seems that systems on M. 9 with densities between 3,000 and 6,000 are optimal for quality production (*Wertheim* et al., 2001). In Mika and Piskor's opinion, planting over 4,000 dwarf trees per hectare was uneconomical (*Mika & Piskor,* 1997). The optimum planting density is about 2,000 to 3,000 dwarf trees, but this may vary according to the cultivar and the growing conditions (*Mika* et al., 1997).

A successful high density orchard should start cropping early and give an annual production of high yields of high-quality fruit in an economically justified way (*Wertheim* et al., 2001). Numerous studies have shown the advantages of increasing tree density on early yields of apples (*Christensen,* 1979; *Wertheim* et al., 1986; *Meland* et al., 1997; *Gonda* et al., 2004).

Jackson (2003) emphasizes the importance of the local light climate. According to *Szász & Tőkei* (1997) the global irradiation intensity in Central Hungary is 25–30% higher than in Western Europe, which would allow higher leaf density in the same canopy dimensions or larger canopies, following *Jackson's* (2003) theory (*Hrotkó,* 2002). Despite of systematic planting density trials the adequate spacing to local conditions is difficult.

The objective of this study was to examine the effect different tree spacing on growth and productivity of a young Hungarian apple orcahrd planted in 2000. The orchard is now in bearing stage, this paper presents the growth and productivity results from the early years of the trial.

Material and method

An experimental orchard was established at the Corvinus University Budapest, Faculty of Horticultural Science, Department of Fruit Science, to investigate the optimal spacing on three dwarfing rootstocks (M.9 Burgmer 984, M.9 T337 and Jork 9) with cultivars 'Jonica' (Jonagold Schneica) and 'Gala Must' (Regal Prince). Trees were planted in 2000 spring at the spacing of 3.6×0.75, 3.6×1.0, 3.6×1.25 and 3.6×1.5 m as slender spindle, and to 4.5×1.0, 4.5×1.25, 4.5×1.5, and 4.5×1.75 m as vertical axis. There were four trees in one plot, and tree distance variation was done in five replicates.

We measured the trunk circumference, canopy sizes, quantity of inflorescences, crop weight/tree, weight of 50 fruits per tree, fruit colouration, size and light interception (%). Trees started to yield in the second year.

We calculated unit trunk cross sectional area (TCSA) in cm^2, trunk cross sectional area per hectare in m^2/ha, flower number per TCSA cm^2, cumulative yield in 2001–2003, in kg/tree, cumulative yield efficiency in 2001–2003 in kg per TCSA cm^2, ratio of first rate fruits in%, value equivalent yield in % (Σ ratio of first rate fruits in kg + ratio of second rate fruits in kg $\times$ 0.6 + ratio of third rate fruits in kg $\times$ 0.3), value equivalent yield/ area in%/m^2 and the light efficiency index [value equivalent yield (kg) / light interception (%)].

The light interception was measured under the canopy by AccuPAR (Decagon Devices Inc.'s).

Results

The increasing density reduced the trunk cross sectional area of 'Jonica' and 'Gala Must' trees with significant differences *(Figures 1, 2)*. In spite of this the larger tree number per hectare compensated the bearing surface: trunk cross sectional area per hectare increased with increasing density at both cultivars *(Figures 3, 4)*. The light interception (%) did not alter significantly with increasing density on 'Gala Must' trees, but showed similar, increasing tendency *(Figure 5)*, while 'Jonica' trees at highest densities showed significantly higher light interception *(Figure 6)* compared to 1852 trees/ha. During the first three bearing years, yields per hectare were positively correlated with tree density

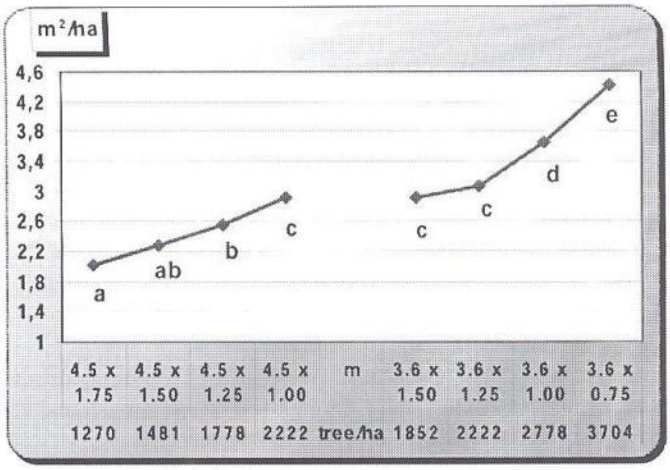

Figure 3 Effect of tree density on orchard bearing surface (TCSA m^2/ha) in 2003 (cv. 'Gala Must')

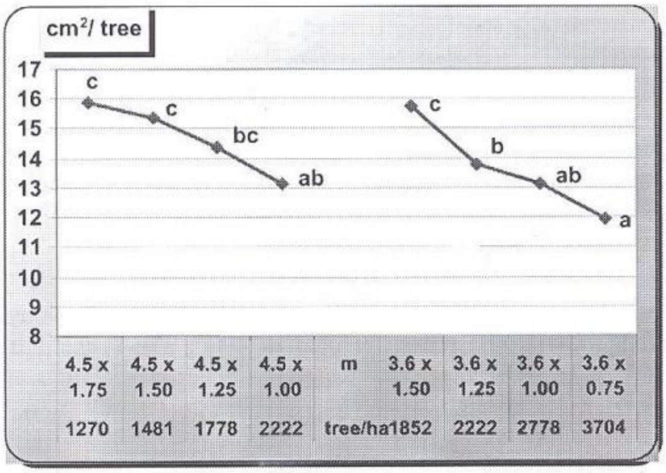

Figure 1 Effect of spacing on trunk growth of 'Gala Must' trees (TCSA cm^2) in 2003

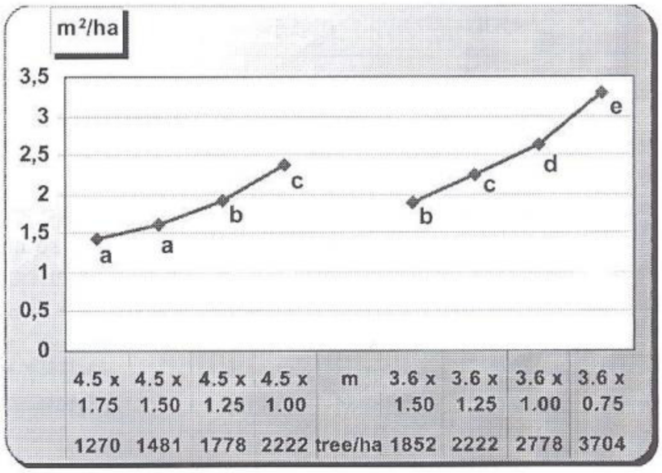

Figure 4 Effect of tree density on orchard bearing surface (TCSA m^2/ha) in 2003 (cv. 'Jonica')

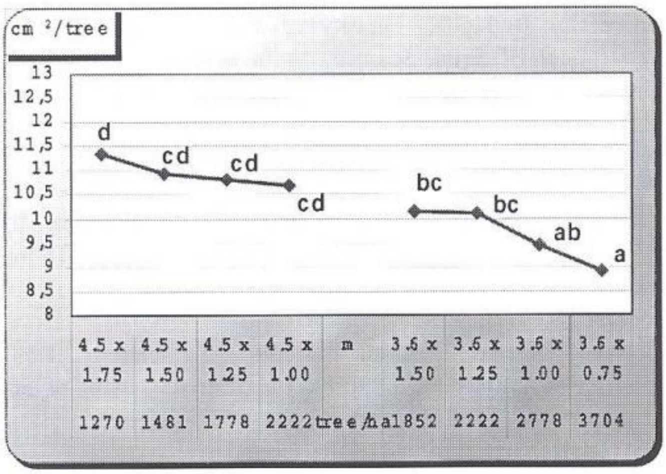

Figure 2 Effect of spacing on trunk growth of 'Jonica' trees (TCSA cm^2) in 2003

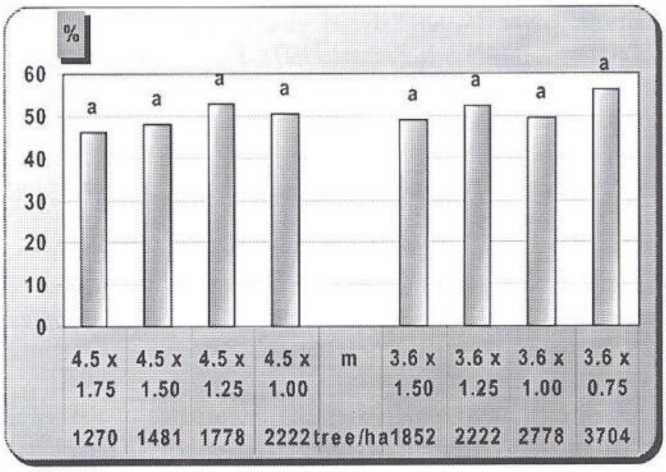

Figure 5 Effect of spacing on light interception (%) in 2004 (cv. 'Gala Must')

(Figures 7 and 8). Significant differences were found in the 'Gala Must' orchard between vertical axis trees planted at 2 m, 1.75 m and 1.5 m compared to slender spindle trees planted to 1m and 0.75 m. In 'Jonica' orchard considerable cumulative yield differences were found between vertical axis planted at 2 m and 1.75 m compared to slender spindle planted at 0.75 m.

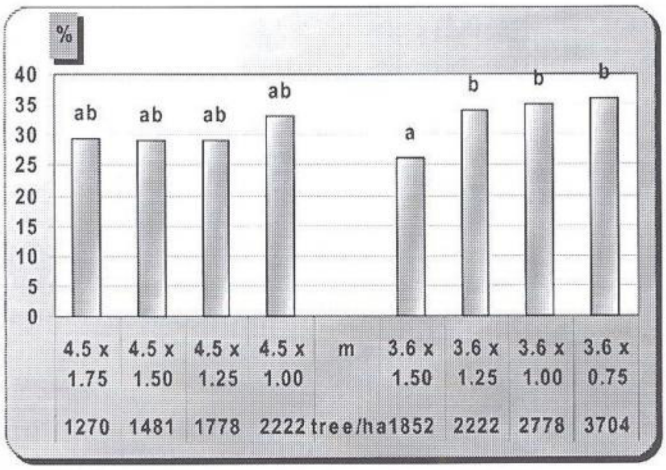

Figure 6 Effect of spacing on light interception (%) in 2004 (cv. 'Jonica')

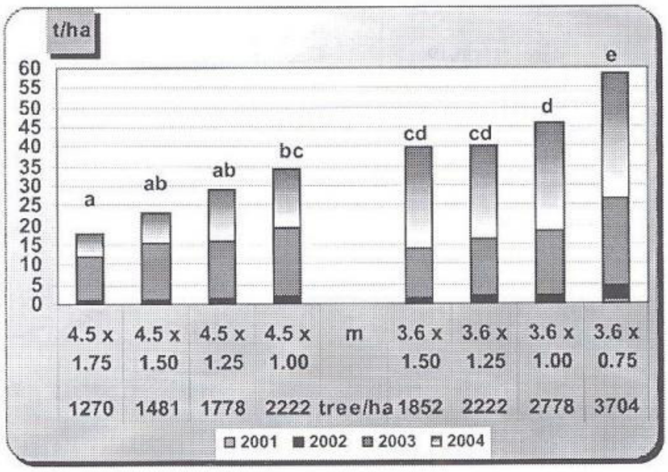

Figure 7 Cumulative yield of cv. 'Gala Must' at different spacings. 2001–2004 (t/ha)

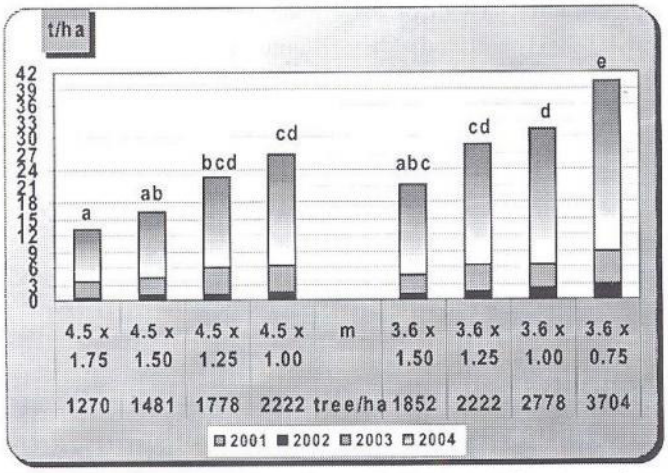

Figure 8 Cumulative yield of cv. 'Jonica' at different spacings. 2001–2004 (t/ha)

The value equivalent yield per area unit (m^2) in 2004 was significantly higher in the 'Gala Must' slender spindle orchard, than in the 'Gala Must' vertical axis orchard *(Figure 9)*, while in the orchard of 'Jonica' the value equivalent yield per area was lower only at 1.75 m in-row spacing compared to slender spindle planted at 1.25 m, 1 m and 0.75 m. The positive effect of increasing density on value equivalent yield efficiency is obvious *(Figure 10)*.

The light efficiency index of 'Gala Must' did not alter significantly within the vertical axis spacing variants, while in slender spindle, it decreased with increasing density *(Figure 11)*. The light efficiency index of 'Jonica' was only significantly different between 4.5×1.00 m and 3.6×1.5 m *(Figures 12)*.

The trees on M.9 Burgmer 984 are less vigorous compared to those on M.9 T.337, and Jork 9 *(Tables 1 and 2)*. Cumulative yield per hectare was the highest on Jork 9 trees. The trees on Jork 9 were more productive than those on the two other rootstocks.

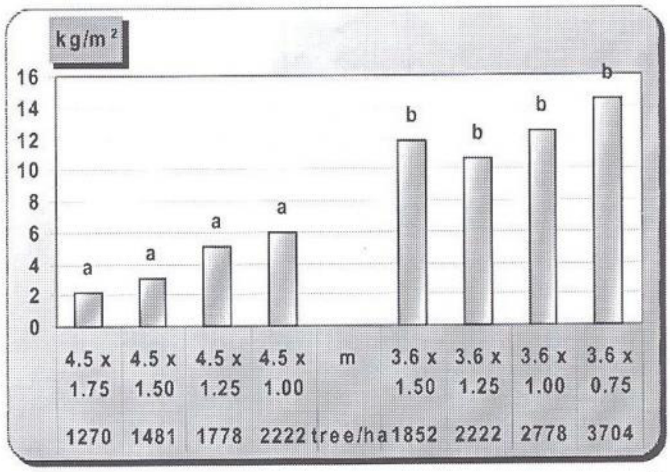

Figure 9 Effect of spacing on value equivalent yield per area (kg/m^2) of cv. 'Gala Must' in 2004

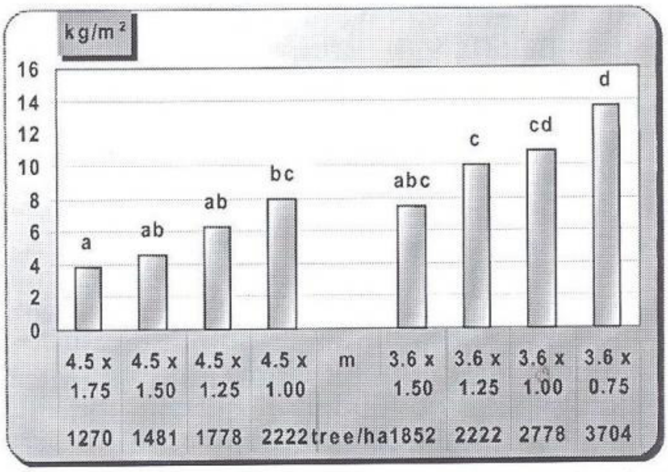

Figure 10 Effect of spacing on value equivalent yield per area (kg/m^2) of cv. 'Jonica' (kg/m^2) in 2004

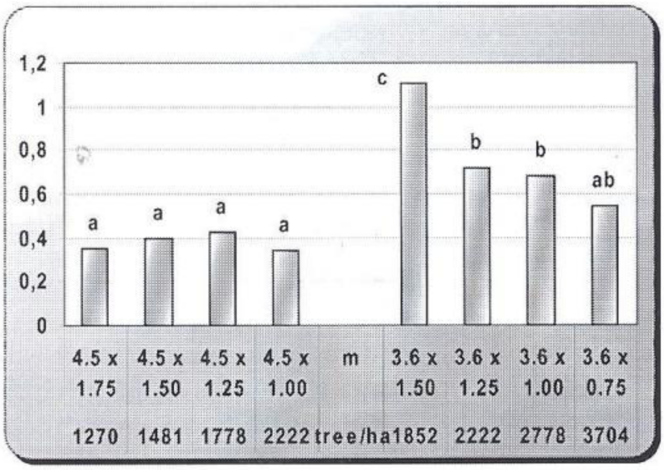

Figure 11 Effect of spacing on the light efficiency index [value equivalent yield (kg) / light interception (%)] of cv. 'Gala Must' in 2004

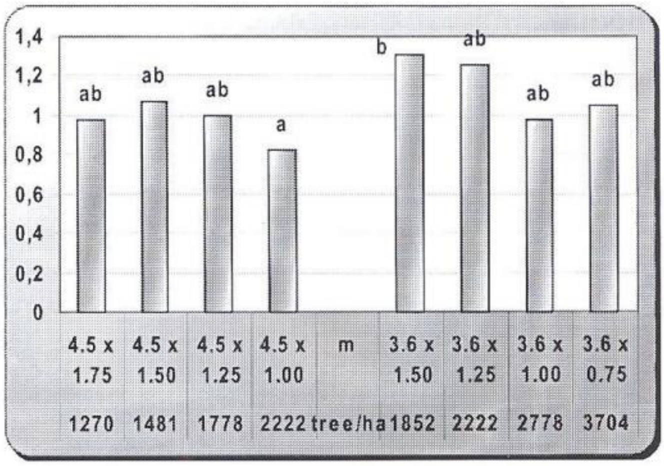

Figure 12 Effect of spacing on the light efficiency index [value equivalent yield (kg) / light interception (%)] of cv. 'Jonica' in 2004

Table 1. Tree size, flower density, yield and light interception of cv. 'Gala Must' on various rootstocks

Rootstocks	Trunk cross sectional area 2003 (cm^2)		Flower density 2004 (number/ TCSA cm^2)		Cumulative yield efficiency 2001–2004 (kg/TCSA cm^2)		Value equivalent yield efficiency 2004 (kg/ TCSA cm^2)		Light interception 2004) (%)	
Burgmer 984	9.7	a	49.7	a	0,833	a	2,44	A	26.6	a
Jork 9	10.5	b	67.2	b	1,347	c	4,19	C	34.5	b
M.9 T.337	10.7	b	52.4	a	1,136	b	3,03	b	32.4	b

Table 2. Tree size, flower density, yield and light interception of cv. 'Jonica' on various rootstocks

Rootstocks	Trunk cross sectional area 2003 (cm^2)		Flower density 2004 (number/ TCSA cm^2)		Cumulative yield efficiency 2001–2004 (kg/TCSA cm^2)		Value equivalent yield efficiency 2004 (kg/ TCSA cm^2)		Light interception 2004) (%)	
Burgmer 984	13.0	a	13.9	a	1,033	a	2,16	a	48.3	a
Jork 9	13.5	a	19.0	ab	1,368	b	2,75	b	50.2	a
M.9 T.337	15.1	b	21.4	b	1,174	a	2,45	ab	51.5	a

Discussion

The decreasing space caused reduced TCSA while the bearing surface (TCSA/ha) increased significantly, which is well known from the literature (*Christensen,* 1979; *Mika & Piskor,* 1997; *Mika* et al., 1997; *Hrotkó,* 2002).

This study confirmed also the positive relationship between tree density and early yield. The cumulative yield and the value equivalent yield / area increased significantly with decreasing space on bothe cultivars (*Wertheim* et al., 2001; *Mika & Piskor,* 1997; *Mika* et al., 1997). At the highest density, a yield of 30 t/ha was achieved in the fourth year, while for the lowest density, it did not exceed 10 t/ha. The vertical axis system did not reach the planned height and canopy dimensions yet, this should be considered also.

There is a slight increasing tendency in the light interception (%) with increasing planting densities, which indicates that by increasing densities within the canopy the light interception cannot be improved any more. This is in agreement with the findings of Jackson (2003), who showed a logarithmic growth of PAR-interception with increasing density (LAI) within the canopy volume.

The decreasing light efficiency index of slender spindle 'Gala Must' trees and the similar tendency of 'Jonica' indicates that within the investigated spacing domain the orchard and canopy density may turn into a decreasing efficiency during the further years. For this reason careful pruning is needed. Further investigation may reveal the relationships of light interception, canopy density, yield and fruit quality under local climate conditions.

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